Tina Tin · Daniela Liggett
Patrick T. Maher
Machiel Lamers *Editors*

Antarctic Futures

Human Engagement with the Antarctic Environment

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Foreword

Few environments are as compelling and as illustrative of the achievements of human endeavour as the Antarctic. It is an extraordinary place, and especially for humans to endure and to succeed. Global interest in the current centenary of many of the great scientific explorations has reaffirmed the significance of Antarctica in the human psyche. However, Antarctica also has another existential role.

The continent has long been considered an isolated wilderness, largely free of the impacts humanity has wrought on so much of the planet's surface. For the Southern Ocean this view is illusory, given the decimation of whale and seal populations in the previous century. But for the continent, with its sparse rocky environments and cap of ice, this wilderness view has long prevailed, and indeed taken on even greater significance as the world has changed.

The change has been extraordinary. Between 1959, when the Antarctic Treaty was signed, and today, the human population has more than doubled, growing from 3 billion to more than 7 billion. Gross Domestic Product has grown even faster, with per capita GDP rising as a result. That rise has been fuelled largely through our ingenuity as a species and the consumption of natural resources. The waste products are transformed and homogenised landscapes, an increase in the diversity and distribution of pollutants, declines in biodiversity, and enormous increases in greenhouse gases, most notably CO_2. The latter are leading to profound global changes in climate. They also mean that we are now starting to live outside the conditions under which we evolved as a species. And there is no end to the change in sight. Rather, we face the sobering prospect of a threshold shift that may increase the pace and impact of change.

Against such a backdrop, we might well take heart that Antarctica remains isolated and free of so much of our influence. But as this book so comprehensively and thoughtfully demonstrates, this view too is illusory. Antarctica is by no means free of human impact. Rather its environments continue to experience pollutant contamination, non-indigenous species have established, populations of several indigenous species are declining and systems are responding to ongoing climate change. Moreover, these impacts are growing and for the most part predicted to do so at an increasing pace. While governance arrangements in the form of the Antarctic Treaty System and its associated instruments are in place, these are facing challenges that are mounting both in extent and diversity. How the interactions between these challenges and the responses of the various actors in the Antarctic and elsewhere will play out into the future forms a novel and significant feature of this book.

The future scenarios raised by the authors are concerning. They suggest that whilst humanity values Antarctica and has a strong desire to protect its environments and biodiversity, without much change, current governance arrangements are unlikely to succeed in doing so. Similar messages are emerging from many other international environmental governance arrangements: we seem to have the will, but not the capability. The Antarctic Treaty System has in the past shown that desire can be matched by action. Thoughtful assessments such as the one presented in this book demonstrate how the Treaty System could lead the way again. Such leadership is essential if a liveable future for humanity is to be secured.

August 2012

Steven L. Chown
Monash University

Preface

The Antarctic continent and the Southern Ocean make up one tenth of the Earth's surface and remain some of the most pristine environments on Earth, with relatively few direct environmental impacts compared to the rest of the world. This is partly due to the region's remoteness and isolation, which meant that large-scale human activities did not take place here until the eighteenth century. However, it is also partly a result of the environmental safeguards that have been put in place to protect the region's environment and natural resources under the Antarctic Treaty System and other international agreements. Over the last few decades, human activities in the Antarctic region have been intensifying and diversifying rapidly. In the coming decades, increased accessibility, in part due to a changing climate and technological advances, is also likely to play a significant role. Increasing human activities place growing pressures on the Antarctic environment and can potentially leave behind significant environmental, social and political footprints with the level of cumulative impacts remaining largely unknown.

More than 50 years after the signing of the 1959 Antarctic Treaty, it is time to take stock and look ahead at the future challenges of Antarctic environmental management as well as to explore what needs to be done to maintain the relatively pristine character of the Antarctic environment.

This book is an outcome of the session '*Human Impacts in the Arctic and Antarctic*: *Regulatory and Management Implications*' that was held at the International Polar Year (2007–2009) Oslo Science Conference held in Oslo, Norway, from June 8 to 12, 2010. Contributors to the conference session were invited to explore all types of impacts of human activities and regional environmental change in the Polar Regions, with a special focus on highlighting the management priorities for the protection of the landscape (environment and people) of the Polar Regions in the face of increasing human activity.

A total of 27 talks and 21 posters were presented over 2 days, covering topics such as human–wildlife interactions, chemical contamination, whaling and polar tourism. Some speakers provided examples of where existing environmental management regimes were working, but also where they were not working. Two common themes emerged from the presentations focused on the Antarctic region: (i) the need for strategic planning in the management of human activities in the Antarctic along with the conservation of terrestrial as well as marine ecosystems; and (ii) the values of Antarctica that merit protection. A thematic cluster of the journal *Polar Research* (2012) brings together a collection of the presentations on both Arctic and Antarctic issues. This volume focuses on Antarctic environmental management and expands on the themes of strategic thinking and values that were raised during the conference.

Contributors to this volume were invited to build on their ongoing research to explore issues surrounding environmental impacts and management of human activities in the Antarctic, following a common theme of strategic thinking and future vision. Contributors were invited to consider future scenarios for the Antarctic environment, notably the Business-As-Usual scenario where the current trends of increasing human activities continue and no additional conservation action is taken and alternative future scenarios. They were also invited to examine strategic planning needs that would ensure continued conservation of the Antarctic environment.

This volume does not, by any means, represent a full consideration of the complex 'futures' that can be imagined for the Antarctic environment. The possible futures of the Antarctic environment are determined by multifaceted human–environment interactions. While acknowledging that global contexts will also have profound influences in shaping the future of the Antarctic environment, we have made the choice to focus our efforts in this volume on examining issues arising within the immediate Antarctic region, leaving a broad regional and global analysis as a future endeavour. As such, issues of global climate change, geopolitical relations and world economy will not be examined in detail but will be referred to in the discussions as appropriate.

Following an initial chapter by the editors, which outlines the Antarctic context, this volume is divided into four parts, each of which closes with a short summary:

Part I: Species and Ecosystems is broken down into five chapters that examine a breadth of Antarctic species and ecosystems that are afforded special protection status under the Antarctic Treaty System and other international agreements. With coverage from baleen whales to soil microbes, these chapters explore both marine and terrestrial contexts and also look back to the past, provide a baseline of today and offer an eye to the future.

Part II: Regional Case Studies looks at three Antarctic regions and examines their different environmental situations, management models and strategic planning needs. Each of these case studies is a microcosm from which lessons could be learned for other Antarctic locations, or scaled up and applied to the Antarctic as a whole.

Part III: Actors and Sectors gives room for actors engaged in different activities to voice their views on the future of the Antarctic environment. In these five chapters, representatives of environmental non-governmental organisations, governmental institutions involved in supporting scientific activities, as well as tourism and sustainability researchers discuss how Antarctica is used and valued by different actors and sectors, both now and in the future. They also explore how strategic thinking can contribute to reaching desirable futures for the Antarctic environment.

Part IV: Conclusions provides a synthesis of the preceding chapters, following a narrative of possible futures and strategic planning actions necessary for the continued conservation of the Antarctic environment.

The human species interacts (or engages) with the multiple components of the Antarctic environment at different times and locations, through various means, driven by diverse motivations resulting in a variety of outcomes. The scope of human engagement with the Antarctic environment includes human activities; it includes governance scenarios; it includes non-human species and the environment where human activities take place; and the impacts that human activities have on them; but perhaps above all it includes the values we embrace as humans. How we choose to value the ice, the rock, the springtail, the silence, the wilderness and the 'goal' of a pristine place for science, for economic reasons, for idealistic aspirations or for future generations, influences what we do. In conclusion, we hope that this book will raise questions related to these points and start a dialogue that is both strategic and timely.

Acknowledgments

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Acronyms

ACAP	Agreement on the Conservation of Albatrosses and Petrels
AEON	Antarctic Environmental Officers Network
ASOC	Antarctic and Southern Ocean Coalition
ASMA	Antarctic Specially Managed Area
ASPA	Antarctic Specially Protected Area
ATCM	Antarctic Treaty Consultative Meeting
ATCP	Antarctic Treaty Consultative Party
ATS	Antarctic Treaty System
BAS	British Antarctic Survey
CAML	Census of Antarctic Marine Life
CBD	Convention on Biological Diversity
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CCAS	Convention for the Conservation of Antarctic Seals
CEMP	CCAMLR Ecosystem Monitoring Programme
CEP	Committee for Environmental Protection (established under the Madrid Protocol)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMP	Conservation Management Plan
CMS	Convention on Migratory Species
COMNAP	Council of Managers of National Antarctic Programs
CRAMRA	Convention on the Regulation of Antarctic Mineral Resource Activities
DROMLAN	Drønning Maud Land Air Network
EEZ	Exclusive Economic Zones
EIA	Environmental Impact Assessment
EMS	Environmental Management System
ENGO	Environmental Non-Governmental Organization

GPS	Global Positioning System
IAATO	International Association of Antarctica Tour Operators
ICJ	International Court of Justice
ICRW	International Convention for the Regulation of Whaling
IGY	International Geophysical Year
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
ISO	International Organization for Standardization
IUCN	International Union for the Conservation of Nature
IUU	Illegal, Unreported and Unregulated (in relation to fishing)
IWC	International Whaling Commission
LAC	Limits of Acceptable Change
MA	Millennium Ecosystem Assessment
Madrid Protocol	Synonymous with the following terms: the Protocol, the Environmental Protocol, PEPAT (the Protocol on Environmental Protection to the Antarctic Treaty)
MARPOL	International Convention for the Prevention of Pollution from Ships
MSY	Maximum Sustainable Yield
NAP	National Antarctic Program
NGO	Non-Governmental Organization
NSF	National Science Foundation
PAHs	Polycyclic Aromatic Hydrocarbons
PBDE	Polybrominated Diphenylether
PCB	Polychlorinated Biphenyls
SCAR	Scientific Committee on Antarctic Research
SEA	Strategic Environmental Assessment
SOS	Southern Ocean Sanctuary
SSAG-SCAR	Social Sciences Action Group of the Scientific Committee on Antarctic Research
SSMU	Small-Scale Management Unit
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
UAV	Unmanned Autonomous Vehicle
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USAP	United States Antarctic Program (part of the NSF)

Chapter 1
Setting the Scene: Human Activities, Environmental Impacts and Governance Arrangements in Antarctica

Tina Tin, Machiel Lamers, Daniela Liggett, Patrick T. Maher and Kevin A. Hughes

Abstract The scope and intensity of human activity in the Antarctic region has changed considerably over the past 100 years, resulting in significant modifications to the Antarctic environment and its ecosystems, and to the institutional arrangements governing human activities. Since the nineteenth century, Antarctica has seen periods of heavy resource exploitation followed more latterly by swells of governmental scientific research programmes which have, in turn, led to a plethora of international agreements. By the end of the twentieth century, commercial tourism was also firmly established. Development in human engagement with the Antarctic environment has been accompanied by changes in human values, technologies and ways of thinking. This chapter sets the scene for the entire volume by providing a historical background on human activities, their management and their implications, which other chapters

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build upon. The purpose of this chapter is not to explore the full breadth of human activities, environmental impacts and governance arrangements in Antarctica. Rather, it aims to provide a contextual framework that can be used to anchor together the diverse subjects treated in the subsequent chapters.

Keywords Human activities • Environmental impacts • Governance

1.1 Introduction

Over the past few centuries, the scope and intensity of human contact with the Antarctic region has changed considerably, and this has had cascading effects on Antarctic ecosystems as well as on the institutional arrangements governing human activities. Marine living resource extraction began in late eighteenth century and continues today. Governmental scientific research programmes became the primary human activity in the Antarctic from the mid twentieth century onwards, and commercial tourism was established firmly by the end of that century. The need to manage human activities in the Antarctic led to the establishment and expansion of the Antarctic Treaty System (ATS), which started as an international agreement aimed at circumventing conflicts arising from sovereignty issues whilst allowing for peaceful activities such as scientific research to take place. It has since evolved into a set of complex institutional arrangements, with one of its primary foci being the protection of the Antarctic environment. There are many studies and reviews on Antarctic geopolitics, history, governance, human activities and environmental impacts (e.g. Hansom and Gordon 1998; Bargagli 2005; Knox 2007; Sánchez 2007; Koch 1992; Dodds 1997; Riffenburgh 2006; Child 1988; Hemmings et al. 2012; Chaturvedi 1996; McGonigal 2008; Berkman 2002; Bauer 2001; Maher et al. 2011; Stonehouse and Snyder 2010). The purpose of this chapter is neither to reproduce this extensive body of knowledge nor to explore the full breadth of human activities, environmental impacts and governance arrangements in Antarctica. Rather, this chapter aims at providing a judicious selection of the relevant information that imparts the context necessary for the remaining chapters in this volume.

1.2 Human Activities: A Brief History, Current Status and Trends

Humans have claimed to have ventured southward into the Southern Ocean and the islands therein since the sixteenth century. Cook's second expedition (1772–1775) effectively delimited the extent of Antarctica. Following Cook's sightings of huge populations of fur seals, sealers were drawn to the peri-Antarctic islands in the late eighteenth century (Mill 1905). Sealing activities were initially concentrated at South Georgia, then spread to other islands as fur seal populations were systematically reduced to levels that were no longer economically worth harvesting (Bonner and Laws 1964; Headland 2009; Trathan and Reid 2009). After the mid-1820s, sealers expanded their harvests of elephant seals for blubber (Laws 1994). This activity continued into the twentieth century, before whaling took over as the primary commercial venture in the Antarctic.

Antarctic whaling began in the late nineteenth century and reached an industrial scale with the establishment of the first shore-based whaling station at Grytviken on South Georgia in 1904. The venture was so lucrative that new shore stations and floating factory ships were soon introduced throughout the South Georgia, South Shetland, South Orkney and Kerguelen Islands (Tønnessen and Johnsen 1982; Hart 2006). The Southern Ocean quickly became the global center of whaling, supplying half the world's annual catch (Knox 2007). Whaling expanded into the Ross Sea, along the edge of the pack ice and further into the open sea. During the peak whaling season of 1930–1931, 41 factory ships and six shore stations caught 40,000 whales and produced more than 3 million barrels of oil (Headland 2009). As whale stocks declined, the International Whaling Commission (IWC) put in place a global moratorium on commercial whaling which led to the end of commercial whaling in the Southern Ocean in 1987 (Leaper and Miller 2011). Since then, Japan has been the only nation to continue whaling activities in the region. Approximately 10,000 whales, mostly minke, have been caught between 1987 and 2008 in the Southern Ocean under the IWC's special scientific permit (IWC 2012).

Despite the decline of commercial sealing and whaling, the exploitation of Antarctica's marine living resources continued to be a major human activity in the Antarctic throughout the twentieth and into the twenty-first century. Large-scale exploitation of finfish began in 1969/1970 in the south-west Atlantic around South Georgia, then expanded into the Indian Ocean around the Kerguelen Islands and reached the coastline of the Antarctic continent in the late 1970s. The commercial exploitation of Antarctic krill commenced in the 1970s in the South Atlantic and currently represents, in terms of tonnage, the largest fishery in the Southern Ocean. The possibility of large-scale harvesting of this keystone species triggered the signing of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) in 1981 (Miller 2002). However, most fish stocks had already been overexploited before CCAMLR came into force in 1982 (Kock 1994). Since then, fishing activities in the Southern Ocean have been the subject to internationally agreed management measures, including the setting of total allowable catches, spatial and seasonal restrictions and measures aimed at the reduction of by-catch (Constable et al. 2000; Miller 2013), although there remains a significant and, difficult to quantify challenge from illegal, unreported and unregulated (IUU) fisheries. In the 1980s, deepwater longlining was introduced in fin fisheries, enabling exploitation of the larger and older fish found in areas inaccessible to trawlers. Longlining became the principal fishing method for Patagonian toothfish and a lucrative commercial venture which triggered substantial IUU fishing activities. IUU catches were at their peak in the Atlantic sector during the second half of the 1990s and have since decreased and moved into the Indian Ocean sector and the Ross Sea (Miller 2004; CCAMLR 2011).

Whilst whalers were the first to build significant infrastructure on the peri-Antarctic islands, explorers built the first huts on the continent to serve as bases for moving into the interior. During the 'Heroic Age', the period roughly between 1895 and 1915, parties from different nations engaged in the geographical exploration and scientific study of Antarctica. Huts were built in Victoria Land (e.g. Cape Adare by Borchgrevink in 1898), the Antarctic Peninsula (e.g. Hope Bay by Nordenskjöld in 1902) and East Antarctica (e.g. Commonwealth Bay by Mawson in 1912), where personnel overwintered and conducted scientific observations. From these early bases, some expeditions attempted to reach the geographical South Pole. The parties of Amundsen and Scott reached the South Pole in the 1911/1912 austral summer (Headland 2009), whereas the Shirase party did not (Dagnall and Shibata 2011). Whilst some of the well-publicised exploration and rescue expeditions had little scientific substance, some of them set the foundation for scientific investigations in the fields of geology, meteorology and zoology in Antarctica (Fogg 1992).

Between the two World Wars, the use of aircraft and aerial photography greatly increased the knowledge of the Antarctic coastline and parts of the continental interior. During and after the Second World War, the number of regular annual national expeditions to the Antarctic increased as the continent's geopolitical and strategic importance came to the forefront (Klotz 1990). Human presence on the Antarctic continent expanded significantly during the 1957/1958 International Geophysical Year (IGY). New stations were built in new areas, including Terre Adélie (France's Charcot station), Drønning Maud Land (Norway's Norske Stasjon) and on the polar plateau (USA's Amundsen-Scott station and the Soviet Union's Vostok station) to support international cooperative research programmes undertaken by 12 countries in the Antarctic during the IGY. A total of 54 research stations operated in Antarctica and the peri-Antarctic islands during the winter of 1957 (Headland 2009). Based on historical data (Headland 2009), current operational data from the Council of Managers of National Antarctic Programs (COMNAP 2012) and the Antarctic Treaty Secretariat (ATS 2012), approximately 240 research stations, refuges and camps have been constructed to date within the Antarctic Treaty area. Approximately 190 of these facilities are actively in use, providing simultaneous accommodation for approximately 5,400 people in the summer and 1,100 people in the winter (see Figs. 1.1, 1.2; COMNAP 2012; ATS 2012).

Technological advances are allowing stations and research activities to reach further into remote parts of Antarctica. New stations are built in previously unoccupied areas (e.g. the Chinese Kunlun station at Dome A and the Belgian Princess Elisabeth station at Sør Rondane). Deep ice cores have been drilled down to bedrock level at multiple locations on the polar plateau (Motoyama 2007; Jouzel et al. 1989). Lake Vostok, lying below nearly 4,000 m of glacial ice was penetrated for the first time in 2012 (Russian Federation 2012), and plans are underway to sample water from Lake Ellsworth in the coming Antarctic seasons (United Kingdom 2011). Field parties are travelling to increasingly remote areas, such as the icesheet over the Gamburtsev Mountains (Bo et al. 2009), and areas not previously visited by humans are becoming a diminishing resource (Hughes et al. 2011a).

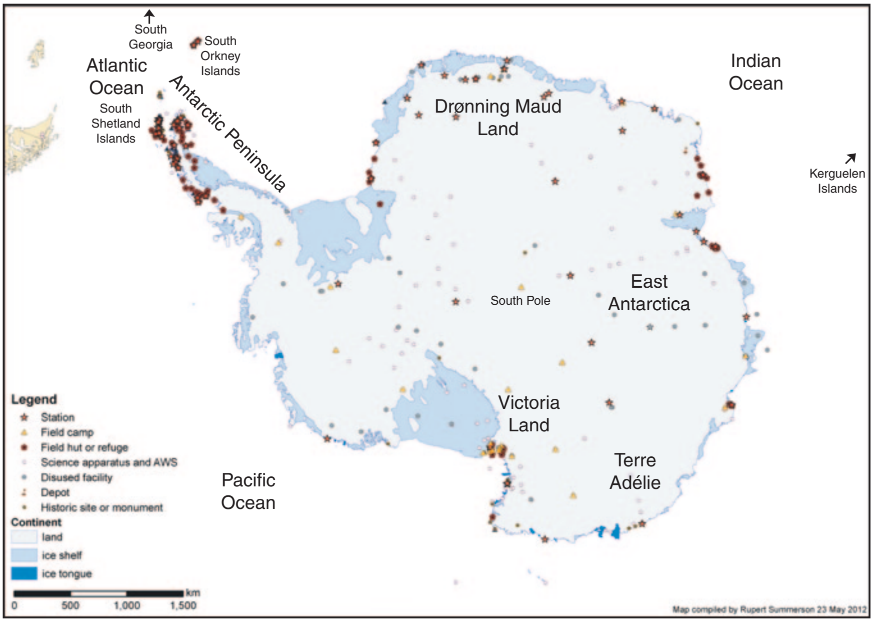

Fig. 1.1 Locations of stations (active and disused), refuges, camps, science apparatus, historic sites and land-based tourism facilities based on the following data sources: Headland (2009), COMNAP (2012), ATS (2012) and subsequent links to websites of National Antarctic Programs, IAATO (2012), University of Wisconsin-Madison (2012), Adventure Network International (www.adventure-network.com), SCAR Antarctic Digital Database (http://www.add.scar.org:8080/add/). This is not a complete list of infrastructure that can be found on the ground in Antarctica. Created by Rupert Summerson

Commercial tourism is another major addition to the suite of human activities in Antarctica. Regular Antarctic tourism started in the late 1960s, when the first commercial tourist cruises to Antarctica in small ships carrying between 50 and 120 paying passengers were organised (Stonehouse and Snyder 2010). Larger ships, carrying between 400 and 500 passengers, occupied an increasing proportion of the expanding market in the 1990s. The start of the twenty-first century saw the arrival of large cruise liners, carrying between 800 and 3,000 passengers (Lamers et al. 2008). The majority of Antarctic tourism continues to be ship-based with more than 90 % of all tourists visiting Antarctica on cruise vessels (Bertram 2007). In the last two decades, tourist numbers have grown exponentially, from a few thousand to a peak of around 45,000 in the 2007/2008 season (see Fig. 1.3) (Crosbie and Splettstoesser 2011). Global recession and the declining number of the mid- and large-size vessels (over 200 passengers) operating in the Antarctic have dampened tourist numbers to Antarctica since. However, demand to visit Antarctica is expected to continue and growth is projected to pick up again in the coming years (IAATO 2011; Jabour 2013). Travelling along with the tourists are the approximately 10,000–20,000 service staff and crew members (see Fig. 1.4). Between 2000

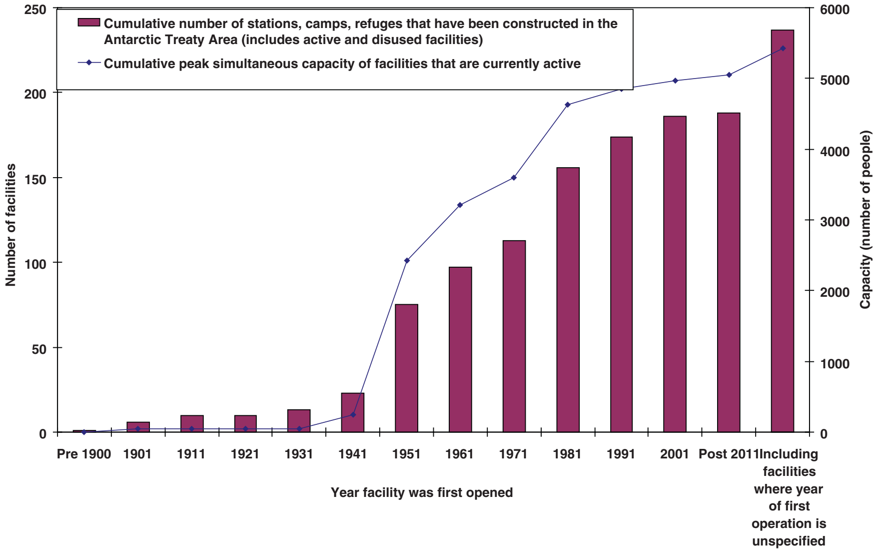

Fig. 1.2 Cumulative number of stations, camps and refuges constructed in the Antarctic Treaty Area [includes active and disused infrastructure; based on historical data (Headland 2009) and operational data (COMNAP 2012; ATS 2012)]. Cumulative peak simultaneous capacity of stations, camps and refuges that are currently active (data: COMNAP 2012; ATS 2012). Numbers shown in figure probably represent lower-bound estimates as capacity data is not available for all facilities and each location with multiple facilities is only counted once

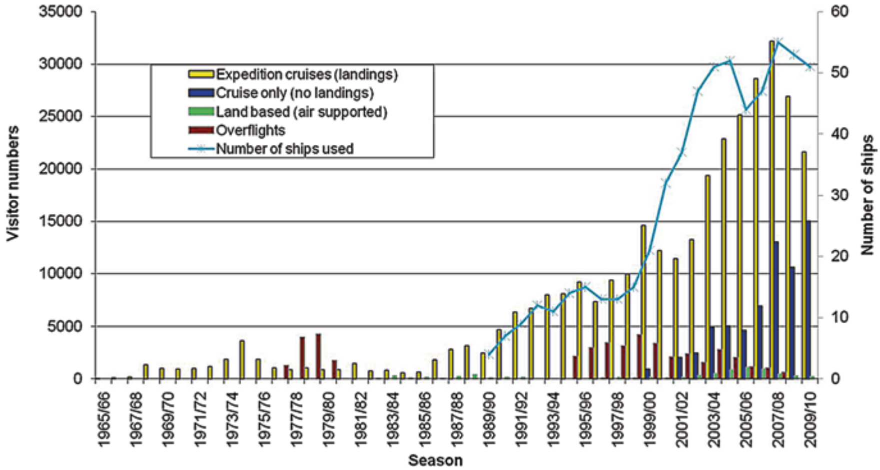

Fig. 1.3 Antarctic tourism development—Estimated number of Antarctic tourists between 1965/1966 and 2010/2011 based on historical records published by Enzenbacher (1993), Headland (2005) and Reich (1980) and incorporating data provided by IAATO (2012). After Liggett and Engelbertz (2013)

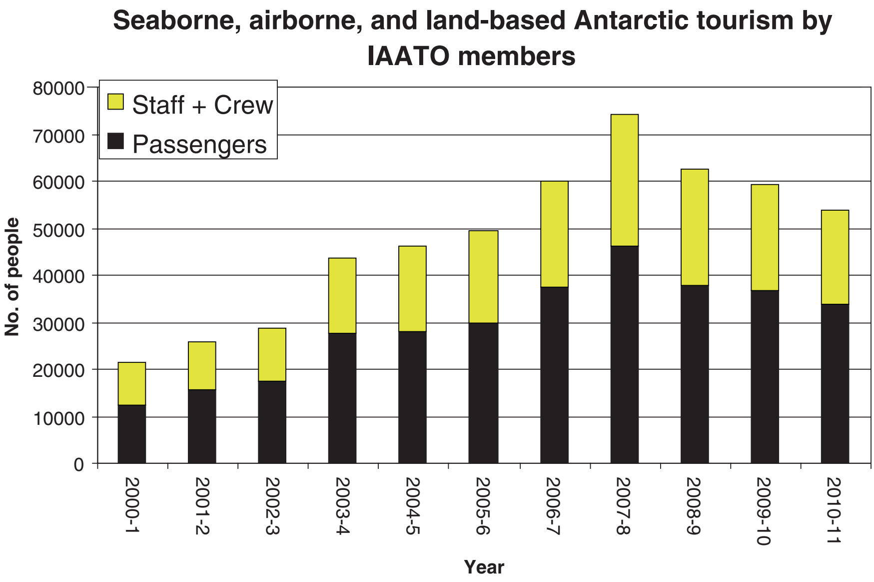

Fig. 1.4 Number of passengers, staff and crew travelling to Antarctica on seaborne, airborne and land-based commercial tour operations with IAATO member companies. *Data source* IAATO (2012)

and 2010, the tourism industry has brought a total of between 20,000 and 70,000 people to Antarctica annually, and it is the type of human activity that brings in the largest number of people to the region. Antarctic tourism is also diversifying, which means that tourists now have access to a greater range of destinations (e.g. the Antarctic Peninsula, the Ross Sea continental destinations) and can participate in a more diverse selection of activities (e.g. kayaking, mountain climbing and scuba diving) than ever before (Lamers and Gelter 2010). Some land-based tourism infrastructure already exists (ASOC 2009, 2011) in the form of tourist accommodation supported by a national operator on King George Island, and the Antarctic Logistics Expeditions camp and support facility at Union Glacier (formerly at Patriot Hills) in the Ellsworth Mountains. The expansion of permanent land-based infrastructure for tourism is considered a feasible future development (Bastmeijer et al. 2008), although at this point it is not envisioned to happen in the near future (Liggett 2009).

1.3 Environmental Impacts

In a remote region like Antarctica, environmental impacts may arise as a consequence of human activities, but may also remain undetected or undetectable because of lack of monitoring, lack of knowledge of baseline conditions or concurrent natural phenomena that mask the effects of human activities. As a result, some impacts of some human activities are relatively well studied, whilst others remain unidentified, undescribed or unmeasured.

Once an impact is identified, described or predicted, an evaluation process to assess the significance of the impact can be undertaken. This is an inherently subjective process (ATS 2005) that depends on social constructs defining which changes in the state of the biophysical environment brought about by human interference are deemed acceptable or unacceptable in the light of society's shared perspectives (Sloep and Van Dam-Mieras 1995). This human dimension of environmental impacts creates a complex mix of societal interests and values around environmental problems, which affects decision-making processes on the scientific/political benefits and financial/environmental costs of human activity—debates that are not restricted to the Antarctic region.

The following sections provide an overview of the types of environmental impacts arising from human activities in the Antarctic. The focus will be on the relationship between human activity and the environment (e.g. the reaction of penguins to overflying helicopters), not on differentiating between motivations behind human action (e.g. tourist flight, science logistics flight) or on evaluating the significance of the impact (e.g. will the scientific value of the research coming from the use of a new research station outweigh the impacts that construction activities have had on the surrounding penguin colonies?).

1.3.1 Exploitation of Marine Living Resources

Whaling is estimated to have reduced the large whale species—blue, humpback, fin—to between 2.5 and 6 % of their initial levels (Kock and Shimadzu 1994). Fin, sei and minke whales were particularly heavily exploited, and it is estimated that most species are still at small fractions of their assumed former abundance (Leaper and Childerhouse 2013). Since the end of sealing activities, Antarctic fur seal populations have increased to an estimated population of over four million, possibly exceeding pre-harvesting levels (SCAR 2006) whilst some populations of elephant seals have continued to decline (e.g. Ainley and Blight 2008; McMahon et al. 2005). The recovering fur seal populations are now leading to serious negative changes in previously unoccupied and fragile terrestrial habitats especially in the Antarctic Peninsula region (Smith 1988; Favero-Longo et al. 2011), an example of a secondary consequence of the earlier uncontrolled human exploitation of the marine environment. Published studies continue to demonstrate little recovery of many of the finfish stocks that were exploited prior to CCAMLR management whilst some modern fisheries regulated under CCAMLR have remained productive (Ainley and Blight 2008).

Direct and indirect impacts on non-target species, and cumulative impacts arising from the removal of large amounts of biomass from the Southern Ocean ecosystem (and in some cases its transfer to the terrestrial ecosystem; Convey and Lebouvier 2009), are not well understood. The removal of whales, and to a certain extent seals, is hypothesised to have led to a krill surplus, which suggests a greater availability of food for other species released by the reduced number of large krill predators (Mori and Butterworth 2006). Long-line fishing has led to significant seabird by-catch. At its height in the late 1990s, albatross mortalities from legal and IUU fisheries were unsustainable for the populations involved. Fishing practises promoted in response by CCAMLR have helped to reduce by-catch from legal fisheries significantly (Miller 2004; Croxall and Nicol 2004). The exploitation of toothfish from the Ross Sea is said to have caused a reduction in the resident population of killer whales (Ainley et al. 2009).

1.3.2 Building and Living in Antarctica

The construction and utilisation of infrastructure in the Antarctic results in environmental impacts that are difficult to reverse. The impacts of fuel and chemical spills around stations built by early twentieth century explorers are still detectable in the soil in and around historic huts today (Blanchette et al. 2004). Built around the same time, whaling stations have led to localised pollution of the near-shore marine environment through the discharge of whale refuse and fuel oil. After the end of whaling activities, these stations were simply abandoned, many hazardous wastes remained on site and fuel and oil leaks continued sporadically (e.g. Platt and Mackie 1979; Cripps and Priddle 1991).

The construction of modern research stations began in the 1950s (see Fig. 1.2) and has often impacted the surrounding habitat (Woehler et al. 2013; Parker 1972; Benninghoff and Bonner 1985). The resulting environmental impacts include the loss of nesting habitat during construction activities (Micol and Jouventin 2001; Woehler 2006), entanglement of Adélie penguins in construction materials (Woehler 1990), reduction in breeding activity of Wilson's storm petrels (Peter et al. 2008) and physical disturbance to soils and destruction of vegetation (e.g. Chen and Blume 1997; ASOC 2004). Amongst the most widespread contaminants around research stations are trace metals and Polycyclic Aromatic Hydrocarbons (PAHs) from combustion processes and fuel and oil spills (Bargagli 2005). In the late 1990s, contaminated soil and waste from abandoned waste disposal sites and fuel spills was estimated to be of the order of 1–10 million m^3 (Snape et al. 2001). Contaminants associated with synthetic chemicals are likely to persist for tens or hundreds of years (Kennicutt et al. 2010). Waste and contaminants left on the polar plateau will remain in the ice for thousands of years (Bargagli 2005).

1.3.3 Travelling to and Within Antarctica

Fossil fuel is the main energy source used for transportation to and within the Antarctic and for living in Antarctica. The overall amount of fuel consumed is small on a global scale but, considering the small number of users, the consumption of fuel and subsequent emission of greenhouse gases per person is large

(Eijgelaar et al. 2010; Amelung and Lamers 2007). For example, including the distance travelled between home countries and Antarctica, it has been estimated that the average two-week tourist trip to Antarctica results in five tonnes or more of carbon dioxide (CO_2) emissions per passenger (Farreny et al. 2011). This is more than the 4.2 tonne-per-person average of annual global CO_2 emissions from the combustion of fossil fuels (IEA 2011).

Shipping is a dominant contributor to atmospheric pollution over much of the world's oceans (Corbett and Fishbeck 1997). Sulphur dioxide emissions from Antarctic shipping activities in the 2004/2005 season were estimated to be ten times greater than those originating from power generation at research stations (Graf et al. 2010). Light, noise, visual and physical interaction with wildlife can disturb some species, leading even to death or colony desertion in extreme cases (de Villiers 2008; Tin et al. 2009). Deployment and retrieval of ship anchors can damage benthic marine habitats (Australia 2009). Ballast water and hull fouling are considered likely to be significant vectors for the introduction of non-native species into the Antarctic region (SCAR 2007; Lück 2010).

The most significant fuel spills in Antarctica have been caused by shipwrecks, collisions or accidents during bunker fuel transfer (Bargagli 2005). The largest oil spill in Antarctica involved the sinking of the *Bahia Paraiso* near to Anvers Island, during which 600,000 litres of diesel fuel were released into the ocean in 1989. Hydrocarbon contaminants are also found commonly where aircraft and vehicles are stored, used or refuelled (Aislabie et al. 2004; Kennicutt et al. 2010). Fossil fuel remains the main energy source at Antarctic stations and field camps, although renewable energy and energy efficiency applications are being deployed increasingly (Tin et al. 2010; Sánchez and Njaastad 2013).

Aircraft and vehicles are commonly used throughout Antarctica. Noise and the physical presence of aircraft and vehicles can disturb wildlife, with wildlife responses ranging from habituation, to insignificant or minor behavioural changes, increases in heart rate, temporary nest desertion, multiple nest desertion events, mass panic and death (de Villiers 2008; Hughes et al. 2008; Otley 2005). Tractor trains may travel over large distances (>1,000 km) to re-supply inland research stations. They cause unavoidable, though transient, physical disturbances to the snow and ice surface and alter the wilderness value of the area as snow surfaces are groomed, unstable snow bridges over crevasses are collapsed (sometimes with explosives) and exposed crevasses are filled with snow harvested from the surrounding area (NSF 2004).

Increasing travel to and within Antarctica, together with rapid regional climate change, is increasing the likelihood of the transfer and establishment of non-native species in the Antarctic (Frenot et al. 2005; Chown et al. 2012; Hughes et al. 2013). Seeds and assemblages of known invasive and non-native species have been found on food, personal clothing, cargo and ships travelling to and within the Antarctic (e.g. Hughes et al. 2011b; Lee and Chown 2009a, b). Transport and dissemination of microorganisms is considered an inevitable consequence of human presence in the Antarctic which may have substantial impacts upon existing Antarctic microbial communities (Cowan et al. 2011).

1.3.4 Visiting and Working in Antarctica

Wildlife populations near research stations generally receive frequent visits from station staff and scientists, both for scientific and recreational purposes (Braun et al. 2013). Tourists frequently visit concentrations of wildlife at different locations for relatively short period of time. The consequences of human interactions with wildlife are often cumulative in nature and may only become apparent over the long term (e.g. Cobley and Shears 1999; Trathan et al. 2008). Certain species and sub-populations may habituate to particular human activities (Pfeiffer and Peter 2004; Holmes et al. 2006). Uncontrolled visitation of people might also result in littering in and near wildlife colonies (Molenaar 2005), modifications of historical sites (Roura 2010) and removal of natural or historic artefacts. Walking and driving on Antarctic soils and vegetation disturb the ground surface and can lead to soil compaction, vegetation damage, alteration of the soil community and other impacts. Tracks are often created near research stations, wildlife colonies and historical sites. Studies generally conclude that even a minimum human presence is sufficient to generate measurable changes, and recovery from these types of disturbance may take decades (e.g. Tejedo et al. 2013; Ayres et al. 2008). Different types of scientific activities give rise to a range of different environmental impacts. In general, equipment, including radiosondes, data buoys and loggers might be left behind, and machinery can be lost in the ocean (Aronson et al. 2011). Petroleum-based drill fluid is detectable in the ice sheet for tens of thousands of years after ice cores have been retrieved (e.g. Frezzotti et al. 2004; RAE AARI 2010). Penetration of subglacial lakes carries the risk of microbial contamination of pristine lake ecosystems (Wingham et al. 2006; SCAR 2011a; Siegert et al. 2012). Handling of, or surgical operations on, animals can lead to physical injury or mortality of the animal or modifications to the foraging performance (e.g. Ropert-Coudert et al. 2007; Jackson and Wilson 2002).

As more people travel to the Antarctic to visit and work, the human footprint in the Antarctic expands, and unvisited areas become increasingly rare (Hughes et al. 2011a). There are fewer areas in which Antarctica's original endemic biodiversity can be studied in confidence of a lack of contamination, and fewer pristine areas that can be used as control sites for future comparative analyses of the impacts and consequences of the anthropogenic impacts (Cowan et al. 2011). At the same time, the Antarctic wilderness, often considered as one of the world's last great wildernesses, is under the pressure of being fragmented, eroded and diminished (Tin et al. 2008).

1.4 Environmental Governance

The main impacts of human activities on the Antarctic environment are connected to shifts in environmental regulations, and distinct epochs related to certain environmental protection measures can be identified. The following section introduces key pieces of international environmental legislation as well as non-binding and self-regulatory systems established to manage human activities and its associated impacts in Antarctica. A summary of regulatory measures related to the conservation of the Antarctic environment and its biota is provided by Table 1.1.

1.4.1 Antarctic Treaty System

The first piece of international legislation specifically concerning Antarctica and applying to the area south of 60°S Lat. was the Antarctic Treaty, which was signed in 1959 and entered into force in 1961. The Treaty currently has 29 consultative parties (i.e. participating in consensus-based decision making) and 21 non-consultative parties (i.e. not participating in decision making), in total representing around 65 % of the Earth's human population. The Treaty prohibits military activity, nuclear explosions and the disposal of radioactive waste material, whilst promoting international cooperation in scientific investigation in Antarctica and recommending signatory nations to take measures for the 'preservation and conservation of living resources in Antarctica' [Article IX, para 1 (f)]. Treaty parties meet annually at Antarctic Treaty Consultative Meetings (ATCMs) to discuss the implementation of the agreements that are in force and to consider the requirements for additional regulatory measures in view of new developments.

The Antarctic Treaty has expanded into the Antarctic Treaty System (ATS), which includes other legal instruments designed specifically for the protection of the Antarctic environment. These include the 1964 Agreed Measures for the Conservation of Antarctic Flora and Fauna and the 1972 Convention for the Conservation of Antarctic Seals (CCAS). Much of the former has been subsumed into the 1991 Protocol on Environmental Protection to the Antarctic Treaty (also known as the Madrid or Environmental Protocol), which came into force in 1998. In addition, the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) established a commission to manage Southern Ocean fisheries adopting a precautionary and ecosystem-based approach.

By acceding to the Madrid Protocol, parties agree to designate Antarctica 'as a natural reserve, devoted to peace and science' [Article 2—Objective and designation]. The environmental principles derived from this include: 'The protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area'. [Article 3(1)]. The Madrid Protocol requires human activities to be planned so as to avoid adverse impacts on the environment and harmful interference on flora and fauna.

The Protocol is implemented through its six annexes. Annex I Environmental Impact Assessment (EIA) states that all activities within the Treaty Area should be subject to an EIA prior to the conduct of the activity. Annex II contains articles concerned with the conservation of Antarctic fauna and flora. It prohibits the

Table 1.1 Antarctic Treaty System and international legislation concerning conservation of biota within the Antarctic region

Legislation	Legislation signatory nations		Details
	Antarctic Treaty Consultative Parties (total:29)	Antarctic Treaty Non-consultative Parties (total:21)	
Antarctic Treaty System Legislation			
Antarctic Treaty (signed 1959, entered into force 1961)	29	21	Article XI, 1(f): Treaty parties must formulate measures regarding 'preservation and conservation of living resources in Antarctica'
Conservation of Antarctic Flora and Fauna (signed 1964, entered into force 1982)	–	–	The Convention has largely been superseded by the legislation within the Protocol on Environmental Protection to the Antarctic Treaty (see below)
Convention for the Conservation of Antarctic Seals (CCAS) (signed 1972, entered into force 1982)	15	2 (Canada, Pakistan)	Commercial sealing no longer takes place within the Antarctic Treaty Area. However, the SCAR Group of Specialists on Antarctic Seals continues to monitor the capture or killing of seals for scientific purposes
Conservation of Antarctic Marine Living Resources (CCAMLR) (signed 1980, entered into force 1982)	28 (not Czech Republic, Ecuador)	3 (Canada, Greece, Pakistan)	Convention established a commission to manage the marine living resources within the CCAMLR area, which lies mainly south of the Antarctic Convergence (or Polar Front). It has also been signed by four non Antarctic Treaty signatory nations and the European Union

(continued)

Table 1.1 (continued)

Legislation	Legislation signatory nations		Details
	Antarctic Treaty Consultative Parties (total:29)	Antarctic Treaty Non-consultative Parties (total:21)	
Protocol on Environmental Protection to the Antarctic Treaty (signed 1991, entered into force 1998)	29	6 (Belarus, Canada, Czech Republic, Greece, Monaco, Pakistan, Romania)	(Annex I) Environmental Impact Assessment (Annex II) Conservation of Antarctic Fauna and Flora (Annex III) Waste Disposal and Waste Management (Annex IV) Prevention of Marine Pollution (Annex V) Area Protection and Management. Including Management Plans for Antarctic Specially Protected Areas (ASPAs) and Antarctic Specially Managed Areas (ASMAs) (Annex VI) Liability Arising From Environmental Emergencies
Other International Legislation			
International Whaling Commission: The International Convention for the Regulation of Whaling (signed 1946, entered into force 1948)	28 (not Ukraine)	12 (Austria, Colombia, Denmark, Estonia, Greece, Hungary, Monaco, Portugal, Romania, Slovak Republic, Switzerland)	The purpose of the Convention is to provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry. Under the convention, commercial whaling is not permitted in the majority of the Southern Ocean, including the Antarctic Treaty Area
Convention on the Conservation of Migratory Species of Wild Animals (CMS). Agreement on the Conservation of Albatrosses and Petrels (ACAP) (signed 2001, entered into force 2004)	13	0	ACAP aims to prevent migratory bird population decline through the implementation of an Action Plan comprising research, monitoring and conservation measures such as reduction of incidental mortality in fisheries and maintenance of habitats

deliberate introduction of non-native species[1] and requires the application for special permits before native flora or fauna can be killed or removed from Antarctica. Annex III addresses waste disposal and management. It puts an end to the practise of open incineration and requires the removal of solid non-combustible wastes and abandoned work sites. Annex IV focuses on the prevention of marine pollution and prohibits the disposal of garbage and chemicals at sea in the Treaty Area. It further requires that ships discharge their macerated food wastes, sewage and sewage sludge at least 12 nautical miles from land or ice shelf. Annex V is concerned with area protection and management. An area of Antarctica may be designated an Antarctic Specially Protected Area (ASPA) to protect outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or ongoing or planned scientific research. Antarctic Specially Managed Areas (ASMAs) may also be designated in places where activities are conducted, or may be conducted in the future, to assist in the planning and coordination of activities, to avoid possible conflicts, improve cooperation between Treaty parties or to minimise environmental impacts. A total of 73 ASPAs and 7 ASMAs have been designated to date (ATS 2013a). Annex III is concerned with liability following an environmental incident. If an activity led to an accidental event resulting in significant harmful impact on the Antarctic environment, Annex VI would require the operators of the activity to take action to respond immediately and minimise the environmental impacts. Signed in 2005, Annex VI is pending ratification from all Treaty parties before it will enter into force.

The Madrid Protocol also established the Committee for Environmental Protection (CEP) as an expert advisory body that meets annually to provide advice and formulate recommendations to the ATCM in connection with the implementation of the Environmental Protocol. Since its establishment in 1998, the CEP's workload has increased significantly, and the majority of the legally binding measures agreed at ATCMs have been related to the CEP's work (Orheim et al. 2011; Sánchez and McIvor 2007).

1.4.2 Other International Legislation

The 1946 International Convention for the Regulation of Whaling was the first piece of legislation to protect any aspect of Antarctic ecosystems. It placed a global moratorium on commercial whaling in 1982 (which came into force in 1986), and, in 1994, it established the Southern Ocean Whale Sanctuary, in the area roughly south of 40°S. The conservation measures of the 2001 Agreement on the Conservation of Albatrosses and Petrels (ACAP), especially those concerning fishing practises and protecting bird habitats, are also applicable to the Antarctic region. ACAP aims to prevent the decline of migratory bird populations and is a

[1] Except in accordance with a permit or for food.

daughter agreement of the Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention).

A number of other international environmental agreements of global or regional scope are also relevant to at least parts of the Antarctic region (Bastmeijer 2003). These include the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the 1992 UN Framework Convention on Climate Change (UNFCCC) and the environmental stipulations on shipping of the International Maritime Organisations (IMO) (Molenaar 2005). Antarctic Treaty parties have previously agreed on the importance of ensuring proper co-ordination with these global environmental agreements and have identified that the primary responsibility for ensuring such co-ordination lies with those Antarctic Treaty parties that are parties to the other agreements (ATCPs 1994). In reality, the degree of co-ordination with other international agreements varies, and is particularly sensitive to sovereignty issues and the prerogatives of the ATS (Guyomard 2010).

1.4.3 Non-binding Guidelines and Codes of Conduct

A wide range of non-binding guidelines and codes of conduct have been developed to aid with management of different human activities or specific locations. The CEP has developed a range of guidelines for Treaty parties to reduce human impact upon Antarctica's ecosystems, such as the Guidelines for the Operation of Aircraft Near Concentrations of Birds in Antarctica (ATCPs 2004). However, many of the guidelines on the practical implementation of Treaty legislation have been developed by individual nations and applied only to their own operations or a limited number of other parties' operations. As a result, standards of environmental practice are not consistent across the national operations within the Treaty area.

The Scientific Committee on Antarctic Research (SCAR 2009; SCAR 2011a, b) has developed codes of conduct for the use of animals for scientific purposes and for land-based scientific field research, as well as guidelines for the exploration of sub-glacial aquatic environments. Codes of conduct have also been developed as part of the management plans of Antarctic Specially Managed Areas (ASMAs), for example in the cases of the McMurdo Dry Valleys and Deception Island (Pertierra et al. 2013).

The regulation and management of tourism activities rely heavily on the development of general industry and site-specific guidelines created by the International Association of Antarctica Tour Operators (IAATO) (Maher 2008). These are created partly in consultation with the Treaty parties. General industry guidelines include visitor codes of conduct (IAATO 2008), restrictions to the number of passengers allowed ashore at any one time (IAATO 2009), minimum approach distances for wildlife (see Maher 2008) and quarantine guidelines to reduce the risks of introduction of disease and non-native species (IAATO 2007). Furthermore, site-specific guidelines have now been adopted by the ATCM as non-binding resolutions for 37 of the most visited locations in the Antarctic to manage biophysical impacts (ATS 2013b).

1.5 Conclusions

Human activities in the Antarctic region have changed considerably over the last two centuries. They have had, and continue to have, profound impacts on Antarctica's ecosystems, from the withdrawal of biomass, harmful emissions to soil, sea and atmosphere and disturbance of wildlife, vegetation and soil. Over time, a complex set of binding and non-binding institutional arrangements have been developed that govern human activities, including environmental impacts, in Antarctica in ways that have become increasingly focused on protecting Antarctica's ecosystems and its intrinsic values. From this brief historical overview a range of questions arise regarding future human engagement with the Antarctic environment. Will the recent trend towards environmental protection through the current governance arrangements prevail in the future, or will we see a trend towards intensified resource exploitation, or will hybrids of governance/exploitation develop in different regions or for different ecosystems? How will the different human activities in Antarctica develop in the future and what will be the implications for Antarctica's ecosystems, environment and natural values? What does the future hold for areas that are already intensively used, or for areas that are presently still relatively little visited? It is these questions and the debates surrounding them that the remainder of this volume seeks to address.

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References

Ainley, D. G., & Blight, L. K. (2008). Ecological repercussions of historical fish extraction from the southern ocean. *Fish and Fisheries, 10*, 13–38.

Ainley, D. G., Ballard, G., & Olmastroni, S. (2009). An apparent decrease in the prevalence of 'Ross Sea Killer Whales' in the Southern Ross Sea. *Aquatic Mammals, 35*(3), 335–347.

Aislabie, J. M., Balks, M. R., Foght, J. M., & Waterhouse, E. J. (2004). Hydrocarbon spills on Antarctic soils: Effects and management. *Environmental Science and Technology, 38*(5), 1265–1274.

Amelung, B., & Lamers, M. (2007). Estimating the greenhouse gas emissions from Antarctic tourism. *Tourism in the Marine Environment, 4*(2), 121–133.

Aronson, R. B., Thatje, S., McClintock, J. B., & Hughes, K. A. (2011). Anthropogenic impacts on marine ecosystems in Antarctica. *Annals of the New York Academy of Sciences, 1223*, 82–107.

ASOC. (2004). *Environmental reports of Fildes Peninsula, 1988–1997: Benchmarks for environmental management*. Washington, D.C.: Antarctic and Southern Ocean Coalition.

ASOC. (2009). *Tourism and land-based facilities in Antarctica*. Information Paper 23 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA. April 6–17, 2009.

ASOC. (2011). *Land-based tourism in Antarctica*. Information Paper 87 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina. June 20–July 1, 2011.

ATCPs. (1994). Final report of the XVIII Antarctic Treaty Consultative Meeting, Kyoto, Japan. April 11–22, 1994 (para 55).

ATCPs. (2004). *Guidelines for the operation of aircraft near concentrations of Birds in* Antarctica. ATCM Resolution (2) 2004. Final report of XXVII Antarctic Treaty Consultative Meeting, Capetown, South Africa, May 24–June 4, 2004.

ATS. (2005). *ATCM guidelines for environmental impact assessment* in Antarctica. ATCM Resolution (4) 2005. Final report of XXVIII Antarctic Treaty Consultative Meeting, Stockholm, Sweden. June 6–17, 2005. Buenos Aires, Argentina: Antarctic Treaty Secretariat.

ATS. (2012). *Information exchange*. Permanent information. Retrieved from: http://www.ats.aq/devAS/ie_permanent.aspx?lang=e.

ATS. (2013a). *Antarctic protected areas database*. Retrieved from: http://www.ats.aq/devPH/apa/ep_protected.aspx?lang=e.

ATS. (2013b). *Site guidelines for visitors*. Retrieved from: http://www.ats.aq/e/ats_other_siteguidelines.htm.

Australia. (2009). *Environmental aspects of Antarctic ship-borne tourism*. Working Paper 8 presented at Antarctic Treaty Meeting of Experts on ship-borne tourism, Wellington, New Zealand, December 9–11, 2009.

Ayres, E., Nkem, J. N., Wall, D. H., Adams, B. J., Barrett, J. E., Bross, E. J., et al. (2008). Effects of human trampling on populations of Soil Fauna in the McMurdo Dry Valleys Antarctica. *Conservation Biology, 22*(6), 1544–1551.

Bargagli, R. (2005). *Antarctic ecosystems: Environmental contamination, climate change, and human impact*. Berlin, Germany: Springer.

Bastmeijer, K. (2003). *The Antarctic Environmental protocol and its domestic legal implementation*. The Hague, the Netherlands: Kluwer Law International.

Bastmeijer, K., Lamers, M., & Harcha, J. (2008). Permanent land-based facilities for tourism in Antarctica: The need for regulation. *Review of European Community and International Environmental Law (RECIEL), 17*(1), 84–99.

Bauer, T. G. (2001). *Tourism in the Antarctic: opportunities, constraints and future prospects*. New York, USA: Haworth Hospitality Press.

Benninghoff, W. S., & Bonner, W. N. (1985). *Man's impact on the Antarctic environment*. Cambridge, UK: SCAR.

Berkman, P. A. (2002). *Science into policy: Global lessons from Antarctica*. San Diego, USA: Academic Press.

Bertram, E. (2007). Antarctic ship-borne tourism: An expanding industry. In J. M. Snyder & B. Stonehouse (Eds.), *Prospects for polar tourism* (pp. 149–169). Wallingford, UK: CABI.

Blanchette, R. A., Held, B. W., Jurgens, J. A., Aislabie, J., Duncan, S., & Farrell, R. L. (2004). Environmental pollutants from the Scott and Shackleton expeditions during the 'Heroic Age' of Antarctic exploration. *Polar Record, 40*(213), 143–151.

Bo, S., Siegert, M. J., Mudd, S. M., Sugden, D., Fujita, S., Xiangbin, C., et al. (2009). The Gamburtsev mountains and the origin and early evolution of the Antarctic Ice Sheet. *Nature, 459*, 690–693.

Bonner, W. N., & Laws, R. M. (1964). Seals and sealing. In R. Priestley, R. Adie, & G. D. Q. Robin (Eds.), *Antarctic research* (pp. 163–190). London, UK: Butterworths.

Braun, C., Fritz, H., Mustafa, O., Nordt, A., Pfeiffer, S., & Peter H.-U. (2013). Environmental assessment and management challenges of the Fildes Peninsula region. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

CCAMLR, Commission for the Conservation of Antarctic Marine Living Resources. (2011). Statistical Bulletin, Vol. 23 (Database Version). Retrived from www.ccamlr.org. (accessed 15.05.11).

Chaturvedi, S. (1996). *The polar regions: A political geography*. Chichester, UK: Wiley.

Chen, J., & Blume, H.-P. (1997). Impact of human activities on the terrestrial ecosystem of Antarctica: A review. *Polarforschung, 65*, 83–92.

Child, J. (1988). *Antarctica and South American Geopolitics: Frozen Lebensraum*. New York: Praeger.

Chown, S. L., Huiskes, A. H. L., Gremmen, N. J. M., Lee, J. E., Terauds, A., Crosbie, K., et al. (2012). Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. *Proceedings of the National Academy of Sciences of the USA, 109*, 4938–4943.

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 Biology, 21*, 355–360.

COMNAP. (2012). *Main Antarctic facilities operated by National Antarctic Programs in the Antarctic Treaty Area (South of 60º latitude South)*. Retrieved from: https://www.comnap.aq/Members/Shared%20Documents/Antarctic_Facilities_List_3Feb2012.xls (accessed 14.02.12).

Constable, A. J., de la Mare, W. K., Agnew, D. J., Everson, I., & Miller, D. G. M. (2000). Managing fisheries to conserve the Antarctic marine ecosystem: Practical implementation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). *ICES Journal of Marine Science, 57*, 778–791.

Convey, P., & Lebouvier, M. (2009). Environmental change and human impacts on terrestrial ecosystems of the sub-Antarctic islands between their discovery and the mid-twentieth century. *Papers and Proceedings of the Royal Society of Tasmania, 143*(1), 33–44.

Corbett, J. J., & Fischbeck, P. (1997). Emissions from ships. *Science, 278*, 823–824.

Cowan, D. A., Chown, S. L., Convey, P., Tuffin, M., Hughes, K. A., Pointing, S., et al. (2011). Non-indigenous microorganisms in the Antarctic: Assessing the risks. *Trends in Microbiology, 19*, 540–548.

Cripps, G. C., & Priddle, J. (1991). Hydrocarbons in the Antarctic marine environment. *Antarctic Science, 3*, 233–250.

Crosbie, K., & Splettstoesser, J. (2011). Antarctic tourism introduction. In P. T. Maher, E. J. Stewart, & M. Lück (Eds.), *Polar tourism: Human, environmental and governance dimensions* (pp. 105–120). Elmsford, NY: Cognizant Communications Corp.

Croxall, J. P., & Nicol, S. (2004). Management of Southern Ocean Fisheries: Global forces and future sustainability. *Antarctic Science, 16*(4), 569–584.

Dagnall, L., & Shibata, H. (2011). *Translation of the Japanese South Polar Expedition 1910–1912: A record of Antarctica*. Eccles, UK: Erskine Press.

de Villiers, M. S. (2008). Revi*ew of recent research into the effects of human disturbance on wildlife in the Antarctic and sub-Antarctic region*. Appendix I to Working Paper 12 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine. June 2–13, 2008.

Dodds, K. (1997). *Geopolitics in Antarctica: Views from the Southern Oceanic Rim*. Chichester, UK: Wiley.

Eijgelaar, E., Thaper, C., & Peeters, P. (2010). Antarctic cruise tourism: The paradoxes of ambassadorship, 'Last chance tourism' and greenhouse gas emissions. *Journal of Sustainable Tourism, 18*, 337–354.

Enzenbacher, D. J. (1993). Tourists in Antarctica: numbers and trends. *Tourism Management, 14*(2), 143–146.

Farreny, R., Oliver-Solà, J., Lamers, M., Amelung, B., Gabarrell, X., Rieradevall, J., et al. (2011). Carbon dioxide emissions of Antarctic tourism. *Antarctic Science, 23*, 556–566.

Favero-Longo, S. E., Cannone, N., Worland, M. R., Convey, P., Piervittori, R., & Guglielmin, M. (2011). Changes in lichen diversity and community structure with fur seal population increase on Signy Island, South Orkney Islands. *Antarctic Science, 23*(1), 65–77.

Fogg, G. E. (1992). *A history of Antarctic science*. Cambridge, UK: Cambridge University Press.

Frenot, Y., Chown, S. L., Whinam, J., Selkirk, P. M., Convey, P., Skotnicki, M., et al. (2005). Biological invasions in the Antarctic: Extent, impacts and implications. *Biological Reviews, 80*, 45–72.

Frezzotti, M., Giuliani, P., & Torcini, S. (2004). *Talos Dome Ice Core Project (TALDICE): Initial Environmental Evaluation for recovering a deep ice core at Talos Dome, East Antarctica*. Rome, Italy: Consortium for the implementation of the National Programme of Antarctica Research ENEA CR Casaccia.

Graf, H., Shirsat, S., Oppenheimer, C., Jarvis, M., Podzun, R., & Jacob, D. (2010). Continental scale Antarctic deposition of sulphur and black carbon from anthropogenic and volcanic sources. *Atmospheric Chemistry and Physics, 10*, 2457–2465.

Guyomard, A.-I. (2010). *La protection de l'environnement en Antarctique—Droit international et droit comparé*. Thèse de Doctorat Droit des Espaces. Centre de Droit Maritime et Océanique CDMO. Faculté de Droit et des Sciences Politiques, Nantes, France.

Hansom, J. D., & Gordon, J. E. (1998). *Antarctic environments and resources: Geographical perspective*. Harlow, UK: Addison Wesley Longman.

Hart, I. B. (2006). *Whaling in the Falkland Islands Dependencies* (Vols. 1904–1931). Pequena Press: Newton St. Margarets, UK.

Headland, R. K. (2005). *Chronological list of Antarctic expeditions and related historical events*. Cambridge, UK: Cambridge University Press.

Headland, R. K. (2009). *A chronology of Antarctic exploration: a synopsis of events and activities from the earliest times until the International Polar Years, 2007–09*. London, UK: Quaritch.

Hemmings, A. D., Rothwell, D. R. & Scott, K. N. (Eds.). (2012). *Antarctic Security in the Twenty-First Century: Legal and Policy Perspectives*. Abingdon, UK: Routledge.

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 Biology, 29*(5), 399–412.

Hughes, K. A., Waluda, C. M., Stone, R. E., Ridout, M. S., & Shears, J. R. (2008). Short-term responses of king penguins Aptenodytes patagonicus to helicopter disturbance at South Georgia. *Polar Biology, 31*, 1521–1530.

Hughes, K. A., Fretwell, P., Rae, J., Holmes, K., Fleming, A., et al. (2011a). Untouched Antarctica: mapping a finite and diminishing environmental resource. *Antarctic Science, 23*(6), 537–548.

Hughes, K. A., Lee, J. E., Tsujimoto, M., Imura, S., Bergstrom, D. M., Lebouvier, M., et al. (2011b). Food for thought: Risks of non-native species transfer to Antarctic with fresh produce. *Biological Conservation, 144*, 1682–1689.

Hughes, K. A., Convey, P., & Huiskes, A. H. L. (2013). Global movement and homogenisation of biota: challenges to the environmental management of Antarctica? In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

IAATO. (2007). *Report of the International Association of Antarctica Tour Operations 2006–2007*. Information Paper 134 presented at XXX Antarctic Treaty Consultative Meeting, New Delhi, April 30–May 11, 2007.

IAATO. (2008). *Update on the Antarctic Peninsula landing site use and site guidelines*. Information Paper 82 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine, June 2–13, 2008.

IAATO. (2009). *Report of the International Association of Antarctica Tour Operators 2008–2009*. Information Paper 33 rev. 1 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, April 6–17, 2009.

IAATO. (2011). *IAATO overview of Antarctic tourism. 2010–2011 Antarctic season and preliminary estimates for 2011–2012 Antarctic season*. Information paper 106 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, June 20–July 1, 2011.

IAATO. (2012). *Tourism statistics*. Retrieved from http://iaato.org/tourism-statistics;jsessionid=9517B89DB019BF5BAA9163EEA1B0264F.

IEA. (2011). *CO2 emissions from fuel combustion* (2011th ed.). Paris, France: International Energy Agency.

IWC. (2012) *Catches taken: Under scientific permit special permit catches since 1985*. Retrieved from http://www.iwcoffice.org/conservation/table_permit.htm, (accessed: 15.05.11).

Jabour, J. (2013). Strategic management and regulation of Antarctic tourism. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

Jackson, S., & Wilson, R. P. (2002). The potential costs of flipper-bands to penguins. *Functional Ecology, 16*(1), 141–148.

Jouzel, J., Raisbeck, G., Benoist, J. P., Yiou, F., Lorius, C., Raynaud, D., et al. (1989). A comparison of deep Antarctic ice cores and their implications for climate between 65,000 and 15,000 years ago. *Quaternary Research, 31*(2), 135–150.

Kennicutt, M. C. II, Klein, A. G., Montagna, P., Sweet, S. T., Wade, T. L., Palmer, T. A., et al. (2010). Temporal and spatial patterns of anthropogenic disturbance at McMurdo station Antarctica. *Environmental Research Letters, 5*(03), 4010. doi:10.1088/1748-9326/5/3/034010.

Klotz, F. G. (1990). *America on the ice: Antarctic policy issues*. Washington, D.C., USA: National Defense University Press.

Knox, G. A. (2007). *Biology of the Southern Ocean*. Boca Raton, USA: CRC Press.

Koch, K.-H. (1992). *Antarctic fish and fisheries*. Cambridge, UK: Cambridge University Press.

Kock, K.-H. (1994). Fishing and conservation in southern waters. *Polar Record, 30*, 3–22.

Kock, K.-H., & Shimadzu, Y. (1994). Trophic relationships and trends in population size and reproductive parameters in Antarctic high-level predators. In S. Z. El-Sayed (Ed.), *Southern Ocean Ecology, The BIOMASS Perspective* (pp. 287–312). Cambridge, UK: Cambridge University Press.

Lamers, M., & Gelter, H. (2010). Diversification of Antarctic tourism: The case of a scuba diving expedition. *Polar Record, 48*(3), 280–290.

Lamers, M., Haase, D., & Amelung, B. (2008). Facing the elements: Analysing trends in Antarctic tourism. *Tourism Review, 63*(1), 15–27.

Laws, R. M. (1994). History and present status of Southern elephant seal populations. In B. J. Le Boeuf & R. M. Laws (Eds.), *Elephant seals: Population ecology, behavior, and physiology* (pp. 50–66). Berkeley, CA, USA: University of California Press.

Leaper, R., & Childerhouse, S. (2013). Present and future conservation management of Antarctic baleen whales. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

Leaper, R., & Miller, C. (2011). Management of Antarctic baleen whales amid past exploitation, current problems, emerging threats and complex marine ecosystems. *Antarctic Science, 23*(6), 503–529.

Lee, J. E., & Chown, S. L. (2009a). Quantifying the propagule pressure associated with the construction of an Antarctic research station. *Antarctic Science, 21*, 471–475.

Lee, J. E., & Chown, S. L. (2009b). Temporal development of hull fouling assemblages on an Antarctic supply vessel. *Marine Ecology Progress Series, 386*, 97–105.

Liggett, D. H. (2009). *Tourism in the Antarctic: Modi Operandi and regulatory effectiveness*. Saarbrücken, Germany: VDM Verlag.

Liggett, D. H., & Engelbertz, S. (2013). Values and political decision-making: The case of Antarctic tourism. *Proceedings of 3rd Conference of the International Polar Tourism Research Network*, Nain, Canada. April 17–21, 2012.

Lück, M. (2010). Environmental impacts of polar cruises. In M. Lück, P. T. Maher, & E. J. Stewart (Eds.), *Cruise tourism in polar regions: Promoting environmental and social sustainability?* (pp. 109–131). London, UK: Earthscan.

Maher, P. T. (2008). Wildlife and tourism in Antarctica: A unique resource and regime for management. In J. Higham & M. Lück (Eds.), *Marine wildlife and tourism management: Insights from the natural and social sciences* (pp. 294–318). Oxford: CABI.

Maher, P. T., Stewart, E. J., & Lück, M. (Eds.). (2011). *Polar tourism: Human, environmental and governance dimensions*. Elmsford, NY: Cognizant Communications Corp.

McGonigal, D. (2008). *Antarctica: Secrets of the southern continent*. Richmond Hill, Canada: Firefly.

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. *Mammal Review, 35*(1), 82–100.

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

Mill, H. R. (1905). *The Siege of the South Pole*. London, UK: Alston Rivers.

Miller, D. G. M. (2002). Antarctic Krill and ecosystem management—From Seattle to Siena. *CCAMLR Science, 9*, 175–212.

Miller, D. G. M. (2004). Patagonian toothfish: The storm gathers. In Fish Piracy- Combating Illegal (Ed.), *Unreported and unregulated fishing* (pp. 105–145). Paris, France: Organisation for Economic Co-operation and Development.

Miller, D.G.M. (2013). Antarctic marine living resources – 'the future is not what it used to be'. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), Antarctic futures: Human engagement with the Antarctic environment. Dordrecht, Netherlands: Springer.

Molenaar, E. J. (2005). Sea-Borne tourism in Antarctica: Avenues for further intergovernmental regulation. *International Journal for Marine and Coastal Law, 20*(2), 247–295.

Mori, M., & Butterworth, D. S. (2006). A first step towards modelling the krill–predator dynamics of the Antarctic ecosystem. *CCAMLR Science, 13*, 217–277.

Motoyama, H. (2007). The second deep ice coring project at Dome Fuji, Antarctica. *Scientific Drilling, 5*, 41–43.

NSF. (2004). *Development and implementation of surface traverse capabilities in Antarctica. Comprehensive Environmental Evaluation*. Arlington, VA, USA: National Science Foundation.

Orheim, O., Press, A., & Gilbert, N. (2011). Managing the Antarctic environment: The evolving role of the committee for environmental protection. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: science, Antarctica, and the governance of international spaces* (pp. 209–221). Washington, D.C., USA: Smithsonian Institution Scholarly Press.

Otley, H. (2005). Nature-based tourism: Experiences at the Volunteer Point penguin colony in the Falkland Islands. *Marine Ornithology, 33*, 181–187.

Parker, B. C. (Ed.). (1972). *Proceedings of the colloquium on conservation problems in Antarctica*. Held on September 10–12, 1971. Blacksburg, VA. Lawrence, KS, USA: Allen Press.

Pertierra, L. R., Tejedo, P., & Benayas, J. (2013). Looking into the future of Deception Island: Current status, drivers of change and policy alternatives. In T. Tin, D. Liggett, P. T Maher & M. Lamers (Eds.), *Antarctic futures: human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

Peter, H.-U., Buesser, C., Mustafa, O., & Pfeiffer, S. (2008). *Risk assessment for the Fildes Peninsula and Ardley Island, and development of management plans for their designation as Specially Protected or Specially Managed Areas*. Dessau, Germany: German Environmental Agency. Retrieved from http://www.umweltdaten.de/publikationen/fpdf-l/3478.pdf.

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

Platt, H. M., & Mackie, P. R. (1979). Analysis of aliphatic and aromatic hydrocarbons in Antarctic marine sediment layers. *Nature, 280*, 576–578.

RAE AARI. (2010). *Water sampling of the subglacial Lake Vostok. Final Comprehensive Environmental Evaluation*. St. Petersburg, Russia: Russian Antarctic Expedition Arctic and Antarctic Research Institute.

Reich, R. J. (1980). The development of Antarctic tourism. *Polar Record, 20*(126), 203–214.

Riffenburgh, B. (Ed.). (2006). *Encyclopedia of the Antarctic*. New York, NY, USA: Routledge.

Ropert-Coudert, Y., Wilson, R. P., Yoda, K., & Kato, A. (2007). Assessing performance constraints in penguins with externally-attached devices. *Marine Ecology Progress Series, 333*, 281–289.

Roura, R. M. (2010). Cultural heritage tourism in Antarctica and Svalbard: Patterns, impacts, and policies. In M. Hall & J. Saarinen (Eds.), *Tourism and change in the Polar Regions: Climate, environment and experiences* (pp. 180–203). London, UK: Routledge.

Russian Federation (2012). *Results of Russian activity for penetrating subglacial Lake Vostok in the seasons 2011–12*. Information Paper 74 presented at XXXV Antarctic Treaty Consultative Meeting, Hobart, Australia, June 11–20, 2012.

Sánchez, R. A. (2007). *Antártida: Introducción a un continente remoto*. Buenos Aires, Argentina: Editorial Albatros.

Sánchez, R. A., & McIvor, E. (2007). The Antarctic committee for environmental protection: Past, present, and future. *Polar Record, 43*(226), 239–246.

Sánchez, R. A., & Njaastad, B. (2013). Future challenges in environmental management of National Antarctic Programs. In T Tin, D Liggett, P. T Maher & M Lamers (Eds.), Antarctic futures: Human engagement with the Antarctic environment. Dordrecht, Netherlands: Springer.

SCAR. (2006). *Proposal to de-list Antarctic fur seals as specially protected species*. Working Paper 39 presented at XXIX Antarctic Treaty Consultative Meeting, Edinburgh, UK. June 12–23, 2006.

SCAR. (2007). *Hull fouling as a source of marine invasion in the Antarctic*. Information Paper 37 presented at XXX Antarctic Treaty Consultative Meeting, Delhi, India, April 30–May 11, 2007.

SCAR. (2009). *SCAR's environmental code of conduct for terrestrial scientific field research in Antarctica*. Information Paper 4 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, April 6–17, 2009.

SCAR. (2011a). *SCAR'S code of conduct for the exploration and research of subglacial aquatic environments*. Information Paper 33 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, June 20–July 1, 2011.

SCAR. (2011b). *SCAR'S code of conduct for the use of animals for scientific purposes in Antarctica*. Information Paper 53 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, June 20–July 1, 2011.

Siegert, M. J., Clarke, R. J., Mowlem, M., Ross, N., Hill, C. S., Tait, A., et al. (2012). Clean access, measurement, and sampling of Ellsworth Subglacial Lake: a method for exploring deep Antarctic subglacial lake environments. *Reviews of Geophysics, 50*(1), RG1003, 40. doi:10.1029/2011RG000361.

Sloep, P. B., & Van Dam-Mieras, M. C. E. (1995). Science on Environmental Problems. In P. Glasbergen & A. Blowers (Eds.), *Environmental policy in an international context. Part 1: Perspectives*. London, UK: Arnold.

Smith, R. I. L. (1988). Destruction of Antarctic terrestrial ecosystems by a rapidly increasing fur seal population. *Biological Conservation, 45*(1), 55–72.

Snape, I., Stark, J. S., Cole, C. M., Gore, D. G., Duquesne, S., & Riddle, M. J. (2001). Management and remediation of contaminated sites at Casey Station Antarctica. *Polar Record, 37*(202), 199–214.

Stonehouse, B., & Snyder, J. M. (2010). *Polar Tourism—An environmental perspective*. Bristol, UK: Channel View Publications.

Tejedo, P., Pertierra, L. R., & Benayas, J. (2013). Trampling the Antarctic: Consequences of human traffic on Antarctic soils. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

Tin, T., Hemmings, A. D., & Roura, R. M. (2008). Pressures on the wilderness values of the Antarctic continent. *International Journal of Wilderness, 14*(3), 7–12.

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., et al. (2009). Impacts of local human activities on the Antarctic environment. *Antarctic Science, 21*, 3–33.

Tin, T., Sovacool, B. K., Blake, D., Magill, P., El Naggar, S., Lidstrom, S., et al. (2010). Energy efficiency and renewable energy under extreme conditions: Case studies from Antarctica. *Renewable Energy, 35*(8), 1715–1723.

Tønnessen, J. N., & Johnsen, A. O. (1982). *The history of modern whaling*. London, UK: C. Hurst & Co.

Trathan, P. N., & Reid, K. (2009). Exploitation of the marine ecosystem in the sub-Antarctic: Historical impacts and current consequences. *Papers and Proceedings of the Royal Society of Tasmania, 143*(1), 9–14.

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. *Biological Conservation, 141*, 3019–3028.

United Kingdom. (2011). *Proposed exploration of subglacial Lake Ellsworth Antarctica*. Draft Comprehensive Environmental Evaluation. Retrieved from http://www.antarctica.ac.uk/about_antarctica/geography/environment/eia/subglacial_lake_ellsworth_cee.pdf.

University of Wisconsin-Madison. (2012). *Antarctic meteorological research center and automatic weather stations project*. Retrieved from: http://amrc.ssec.wisc.edu/.

Wingham, D. J., Siegert, M. J., Shepherd, A., & Muire, A. S. (2006). Rapid discharge connects Antarctic subglacial lakes. *Nature, 440*, 1033–1036.

Woehler, E. J. (1990). Two records of seabird entanglement at Casey, Antarctica. *Marine Ornithology, 18*, 72–73.

Woehler, E. J. (2006). Status and conservation of the seabirds of Heard Island and the McDonald Islands. In K. Green & E. J. Woehler (Eds.), *Heard Island, Southern Ocean Sentinel* (pp. 128–165). Chipping Norton, Australia: Surrey Beatty and Sons.

Woehler, E. J., Ainley, D. & Jabour, J. (2013). Human impacts to Antarctic wildlife: Predictions and speculations for 2060. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

Part I
Species and Ecosystems

Chapter 2
Human Impacts to Antarctic Wildlife: Predictions and Speculations for 2060

Eric J. Woehler, David Ainley and Julia Jabour

Abstract Four broad categories of human activities that presently threaten Antarctic wildlife in the Antarctic were identified: (1) tourism and non-governmental activities, (2) scientific research, (3) commercial fisheries and (4) whaling. Two further broad categories of threats that originate from multiple forms of human activities are: (1) shipping-related impacts and (2) the introduction of non-native species or disease-causing agents. These threats are not mutually exclusive, and there are various interactions and synergies present amongst them. We have not incorporated climate change into the assessment of each of these, but briefly assess the hierarchical contribution of climate change to other threats. We confidently expect an expansion of virtually all anthropogenic activities in the Antarctic (primarily tourism, research and fisheries) in the next 50 years. The threats will also increase in their complex synergies and interactions, giving further increasing urgency to adopting a more precautionary approach to managing human activities in the Antarctic. We present predictions for 2060 and list suggested proactive management and conservation strategies to address the predicted threats to Antarctic wildlife and their environment.

Keywords Antarctica • Conservation • Cumulative impacts • Threats • Wildlife

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2.1 Introduction

With no native human population in the Antarctic or on the peri-Antarctic islands, resident wildlife have evolved in the absence of human hunters, the pressures arising from habitat modification and the predation from domesticated vertebrates that are all common throughout the rest of the world. In this chapter, we aim to predict and speculate on potential direct impacts of human activities to Antarctic wildlife in 2060, based on our understanding of current impacts, and with a continuation of Business-As-Usual in the spectrum of existing anthropogenic activities; we do not examine the direct effects of climate change, but note its potential synergistic and hierarchical role with other impacts.

Our focus is on the areas south of the Antarctic Polar Front. We confine our discussions to those species for which contemporary data permit assessment of current and future threats and impacts, i.e. vertebrate species (seabirds, marine mammals and finfish), and include one invertebrate species for which there is a substantial commercial fishery, Antarctic krill (*Euphausia superba*).

2.2 Methodology, Qualifiers and Challenges

Our contemporary state of knowledge regarding human impacts on wildlife is based on three decades of studies on relatively few species that have generated widely disparate results (see de Villiers 2008, for a detailed review and list of the extensive literature). Predictions about threats and their impacts 50 years into the future, therefore, are substantially qualified. If researchers had been asked to undertake similar predictions in 1961—coincident with the Antarctic Treaty coming into force—for 2010, they would have been unlikely to predict the development of commercial tourism, the extent of research stations and the complexity of the associated and obligatory infrastructures, the scale of commercial krill and finfish fisheries, and the impacts from global warming.

The dramatic developments in technology and engineering since 1961 will be negligible compared to those advances that will occur in the next 50 years, so we may confidently predict unpredictable situations and circumstances that are beyond our current understanding or even our capacity to foresee. Clearly, lack of such foresight provides both a challenge to making predictions and an opportunity to speculate beyond what may appear likely today. To address the constraints, we incorporate results from reviews of human impacts to wildlife with observed and predicted trends in various human activities in the Antarctic and (where relevant, on the peri-Antarctic islands).

Our assessments are based on the available information in numerous wildlife impact studies (de Villiers 2008, lists well over 100 studies). Herein, we review studies on the efficacy of current Antarctic environmental regimes, examine trends of various human activities and draw upon our (EW: 32, DGA: 43 and JJ: 20) years of collective experience working in the fields of Antarctic and Subantarctic biology.

Since the 1980s, researchers have investigated the scale, duration and intensity of impacts to wildlife associated with human activities in the South Polar Region. A high number of studies examined physiological and behavioural responses by seabirds and seals in reaction to a range of human activities. Notable milestones include Benninghoff and Bonner (1985), Fraser and Trivelpiece (1994, seabird researchers), Kennicutt (1996, science and operations), Hofman and Jatko (2000, cumulative impacts from commercial tourism activities), United Nations Environment Programme (2002, persistent toxic chemicals) and Kerry and Riddle (2009, disease). Recent comprehensive reviews include de Villiers (2008), Tin et al. (2009) and Aronson et al. (2011). It is important to note that virtually all of the research on human disturbance has been limited to vertebrates, typically penguins (particularly Adélie penguins *Pygoscelis adeliae*) and seals at their breeding or haul-out sites. A greater range of species comprising procellarids, skuas and cormorants has recently been studied (de Villiers 2008), but little research has been undertaken on other taxa.

Headland (2009) provides a detailed listing of human activities in the Antarctic from the earliest records to the International Polar Year 2007–2009. Statistics in the public domain are available from the International Association of Antarctica Tour Operators (IAATO, commercial tourism since 1992), Commission for the Conservation of Marine Living Resources (CCAMLR: commercial fishing since 1970), and Council of Managers of National Antarctic Programs (COMNAP: infrastructure currently in use by National Antarctic Programs); see also Summerson and Riddle (2000).

A recent assessment of the functioning of the Committee for Environmental Protection (CEP) established under the Protocol on Environmental Protection to the Antarctic Treaty (also known as the Madrid Protocol) by Orheim et al. (2011) was complemented by that of Grant et al. (2012). Bastmeijer and Roura (2008) undertook a systematic examination of the strengths and weaknesses of the coverage and application of the Protocol's Annex I concerning Environmental Impact Assessments (EIAs). Hemmings and Kriwoken (2010) examined the limitations in coverage, compliance and effectiveness of high-level Antarctic Environmental Impact Assessments (EIAs), while Roura and Hemmings (2011) and Marsden (2011) each argued for Strategic Environmental Assessments. Annex II of the Protocol, dealing with the conservation of Antarctic flora and fauna was revised in 2009 but has yet to enter into force. Hughes and Convey (2010) examined the current practices to prevent the transfer and introduction of non-indigenous species to the Antarctic. Goldsworthy and Hemmings (2009) reviewed the efficacy of Annex V dealing with area protection and management. One weakness identified by them, that of the need to add Marine Protected Areas (MPAs) to the Antarctic Specially Protected Area (ASPA) network has seen some recent developments. A strategic overview of national, regional (i.e. Antarctic Treaty System, ATS) and global law touching on the Antarctic environment is provided by Hemmings (2011a).

We describe the intensities of a wide range of current anthropogenic activities that impact on Antarctic wildlife, and summarise the current efforts to minimise them. Based on current trends and impacts, we present predictions for 2060 and suggest proactive management and conservation strategies to address the predicted threats to Antarctic wildlife. While we are confident that all anthropogenic activities in the Antarctic will expand in the next 50 years, we are equally confident that the conservation and management of the Antarctic environment and the values of the people responsible for the task will also vary and evolve in the decades to come. As a result, some of our suggestions for conservation strategies may lose their relevance. We are also confident that climate change, globalisation and other global phenomena will have increasing effects on the Antarctic. In addition, in this chapter, we do not attempt to make value judgments of the significance of impacts or whether the benefits of an activity outweigh its impact. While a discussion of global influences on Antarctic wildlife deserves a more in-depth treatment than we can afford in this chapter, we dedicate Sect. 2.4.1 for a discussion of the synergies that climate change is likely to have with the threats associated with human activities taking place in Antarctica.

In this chapter, we adopt the term 'threat' to identify anthropogenic activities that may adversely affect the distribution and abundance of a taxon between the present and 2060. This includes activities that can cause a significant decrease or loss in the quality and quantity of required habitat, disrupt ecosystem services and functions, or result in a significant decrease in population sizes (e.g. by affecting breeding success and/or survival).

2.3 Contemporary Impacts to Antarctic Wildlife from Human Activities: Management and Gaps

Based on information from wildlife impact studies, we identify four broad categories of human activities that presently threaten Antarctic wildlife and two broad categories of threats that originate from multiple forms of human activities in the Antarctic. In no particular order or ranking, they are:

1. Tourism and non-governmental activities

Began in the 1960s and increasing significantly in the last two decades, commercial tourism now brings the highest number of people to the region. During the 2010/2011 season, just under 34,000 paying tourists travelled to Antarctica; more than 95 % of them travelled on cruise ships. About 40 % of the tourists stayed on-board their ship or aircraft during the entire voyage. Over 18,000 cruise ship passengers landed and visited tourist sites on the Antarctic Peninsula (IAATO 2012a). In general, the majority of tourist visits take place on the Antarctic Peninsula and adjacent localities, primarily between October and March, but all areas of the Antarctic Continent and many peri-Antarctic islands are visited and some sites are visited at other times of the year (Jabour 2009).

Travelling with the paying passengers are also approximately 10–20,000 staff and crew members (Tin et al. 2013), with a typical guide to tourist ratio of 1:20 while onshore, although this may vary amongst operators (IAATO 2012b).

Primary destinations are wildlife concentrations (seabird colonies and seal haul-outs), with multiple groups of tourists walking to the vicinity of the animals. The arrival of several cruise ships at the same site on the same day is possible at frequently visited sites, although under industry (IAATO 2012b) and site-specific guidelines (ATS 2012a), this practice is discouraged. However, no such guidelines or rules exist for private, independent expeditions to Antarctica. These are possibly of greater concern because of the lack of controls on their activities (Murray and Jabour 2004; Sandelson 2011).

Possible impacts of tourism on wildlife include disturbance of animals as a result of frequent visit on foot, introduction of diseases and non-native species and disturbance and pollution linked to ship and aircraft operations (e.g. Hofman and Jatko 2000; Stewart et al. 2005; de Villiers 2008; Australia 2009). However, little coordinated long-term monitoring and research exists, available data are at least partly contradictory (de Villiers 2008) and consequently our current understanding on long-term population effects and comparison to disturbances caused by intra- and inter-species interactions are minimal. Tourism activities are diversifying and the development of permanent, tourism-dedicated land-based infrastructure has been considered, although it is not supported by the Antarctic Treaty Consultative Parties (Bastmeijer 2007; Bastmeijer et al. 2008; IAATO 2008).

2. Scientific research activities, including infrastructure construction, support operations and logistics

Scientific research efforts and the construction of permanent research stations accelerated during and following the International Geophysical Year in 1957/58 (Tin et al. 2013). According to the Council of Managers of National Antarctic Programs (COMNAP 2012a), there are currently approximately 100 active research facilities (all-year and summer stations, field camps and refuges) in the Antarctic Treaty area.

Station footprints encompass a wide range of facilities and evidence of their use (e.g. runways, fuel storage and roads/tracks and exhaust from diesel power stations). Most stations are built on ice-free areas, in many cases occupying areas previously used for nesting and moulting seabirds, and for pupping and moulting by fur seals and seals. All stations combined, it is estimated that there is a maximum simultaneous accommodation capacity for 5,000 people during summer (October to March) and 1,000 during winter (cf Jabour 2009). Stations built since the Madrid Protocol came into force will have had some form of a national EIA undertaken for their construction and operation (see http://www.ats.aq/devAS/ep_eia_list.aspx?lang=e for all such assessments in the public domain). These assessments determine the scale and intensity of any environmental impacts, including those on local wildlife in the proximity of the station.

Stations have typically served as foci for local and regional research activities, acting as logistic hubs for fieldwork farther into the Antarctic wilderness. Almost all stations have a highly localised impact on their immediate environment, especially before the entry into force of the Madrid Protocol (Bargagli 2008). Since then, the footprints of some stations have stabilised while others have expanded or intensified (e.g. Peter et al. 2008; Kennicutt et al. 2010; Chwedorzewska and Korczak 2010; Klein et al. 2013). Joint facilities are rare, despite the seeming benefits in reducing human footprint (Hemmings 2011b). As noted, field research activities will also make use of temporary or permanent field camps away from stations. Data on the locations and use of field camps or the environmental guidelines that are applied to their operations are sparse and not regularly updated.

Fuel spills are one of the most widespread sources of contamination near research stations and refuelling areas (Bargagli 2008). Sewage discharged from stations is in most cases only lightly treated. High levels of polybrominated diphenylether (PBDE) have been found in fish living near a sewage outlet (Hale et al. 2008). Untreated sewage and other discharges from stations may introduce potential for disease transfer to environment (Barbosa and Palacios 2009; Kerry and Riddle 2009; Grimaldi et al. 2010; Hughes et al. 2013). Toxins such as asbestos and polychlorinated biphenyls (PCBs) are being released from decaying infrastructure and disused waste dumps with unknown impacts on wildlife and ecosystems (Tin et al. 2009). Construction has damaged breeding and roosting habitats (e.g. Wilson et al. 1990; Micol and Jouventin 2001; Woehler 2006; Braun et al. 2013).

Wildlife living in proximity to stations may become disturbed by interactions with humans while others have developed some habituation. Use of ships, zodiacs, aircrafts and other machinery can disturb wildlife (de Villiers 2008 and references therein). Research activities that involve banding, tagging, instrument attachment or handling of animals (primarily seabirds and seals) may stress the animals, though in most cases, relatively few individuals are involved and population-level effects have not been documented (Tin et al. 2009 and references therein).

Marine acoustic research and underwater construction activities can generate underwater noise at levels that disturb marine mammals, adversely affect hearing of diving seabirds (Cooper 1982; Woehler 2004), disturb birds foraging near breeding sites, and disperse prey in water, potentially reducing foraging efficiency.

3. Commercial fisheries

(a) Regulated fisheries and general fisheries impacts

Extensive fisheries were once present on the insular shelves of peri-Antarctic islands and the northern Antarctic Peninsula, but after overfishing destroyed many stocks, these were shut down (Koch 1992). Now only limited to small finfish fisheries for Patagonian toothfish (*Dissostichus eleginoides*) and mackerel ice fish (*Champsocephalus gunnari*) that remain in those areas, replaced to some degree by a burgeoning Antarctic krill (*Euphausia superba*) fishery centered in the Scotia Sea region. New ‘exploratory’ fish–fish fisheries for Antarctic toothfish (*D. mawsoni*) have begun to operate increasingly farther south, extending into the Ross Sea and elsewhere along the continental slope (CCAMLR 2010). Fishery operations occur year-round, depending on area closures, target species and sea ice presence and conditions. The total reported catches for 2010/11 were 179,131 tonnes of krill, 11,254 tonnes of toothfish and 11 tonnes of icefish within the CCAMLR area (CCAMLR 2011a). Improper fisheries management is a major challenge to the Antarctic marine ecosystem’s integrity (Miller 2013).

Bycatch species comprise seabirds, Antarctic rock cods, macrourid fish, skates and rays, sponges, corals and other benthic invertebrates. The most direct impacts have arisen from harm to the seabed by long lines, in some cases scraping clean several sea mounts, and over-fishing, with corresponding alteration of food webs. Depleted fish stocks have failed to recover even after 20 years of no fishing (Marschoff et al. 2012). CCAMLR practices a form of ecosystem based management for species it views as 'forage', e.g. krill, and employs an Ecosystem Monitoring Programme (also known as CEMP) to help inform management (Constable et al. 2000). However, CCAMLR resorts to a single-species maximum sustainable yield (MSY) strategy for finfish, which it views as 'predatory', but with no monitoring programme in place (Constable et al. 2000). CCAMLR introduced Conservation Measures to protect shallow habitats (<550 m) from long-lines and trawls in 2008 and restricted fishing in areas of high concentration of what it calls, 'vulnerable marine ecosystem' species (corals etc.) in 2009, 30 years after the Convention came into force. Therefore, further damage to what is left should be minimal hereafter. Recovery of damaged stocks is at best uncertain.

Drawing on results elsewhere (e.g. Baum and Worm 2009), effects on top predators from fishing may come from competition for and reduced availability of preferred prey species, and altered ecosystem structure and functions, with concomitant cascading effects of reduced top predator species as seen in bank and reef ecosystems (Ainley et al. 2012). Almost all krill fishing occurs where land-based and marine-based predators forage or used to forage (ASOC 2010). Thus, while the overall take of krill may be relatively low from a Southern Ocean stock-size perspective, the spatial and temporal concentration in these important predator foraging areas can have disproportionately high effects, competing with predators for prey at critical periods during the year. Fishing operations are a key source of plastic debris in the Southern Ocean (Ivar do Sul et al. 2011). Loss and discard of fishing gear results in marine debris that can entangle wildlife (e.g. Ainley 1990; Auman et al. 2004; Hofmeyr et al. 2006). Shipping operations can also disturb wildlife nearby (see item 5).

(b) Illegal, unreported and unregulated (IUU) fisheries

IUU fisheries do not comply with established conservation measures, greatly exacerbating the general impacts arising from fishing operations described above. IUU fisheries operate throughout the Southern Ocean and extend northward into subantarctic and temperate waters. By the early 2000s, the total IUU catch for Patagonian toothfish was estimated to be at least double the legal catch, and exceeded the aggregate global limit recommended for regulated fisheries in all CCAMLR waters (Tin et al. 2009). Through CCAMLR's efforts, IUU fishing has decreased in recent years. In 2009/2010, total IUU catches were estimated to be just over 10 % of total reported catch. However, IUU operations also appear to have shifted southwards and in some areas, catches were estimated to be up to 10 times that of reported legal catches. There is concern that CCAMLR appears to be unable to control further IUU fishing in the Southern Ocean (CCAMLR 2011c).

4. Whaling

The International Whaling Commission (IWC) established a global moratorium on commercial whaling in 1986 and the Southern Ocean Whale Sanctuary in 1994. Between 1987 and 2009, Japanese vessels took over 9000 minke (*Balaenoptera bonaerensis*) and 14 fin (*B. physalus*) whales in the Southern Ocean Whale Sanctuary under scientific 'Special Permits', despite widespread criticism of the validity of the science being used as justification (Gales et al. 2005; Clapham et al. 2007). All sampled animals have been killed.

The direct effect of past commercial whaling and sealing has had major impacts to the Southern Ocean ecosystem, including impacts on ecosystem productivity (e.g. increasing ocean productivity by recycling iron, Nicol et al. 2010) and cascading effects on food webs (Emslie and Patterson 2007; Baum and Worm 2009). Recovery of fur seals (*Arctocephalus* spp.) and humpback whales (*Megaptera novaeangliae*) is having complex effects on trophically competing species, obscuring other effects from climate change (Ainley et al. 2010a; Trivelpiece et al. 2011; Trathan et al. 2012). While current Special Permit whaling removes a relatively low number of whales, its concentration along continental shelf-breaks along just one-third of the Antarctic circumference amplifies the ecological impact.

Recent proposals to increase the take to 1,000 minke whales per year, in conjunction with an expansion to take humpback whales, has been met with intense public outcry and vigilante action, causing even governments to voice opposition (McCurry 2012; Rothwell 2012). Other than hesitance to take humpback whales, the whalers have not responded. In addition, uncertainties exist as to the future of the global moratorium on commercial whaling and Special Permit whaling, which is the subject of a case currently before the International Court of Justice (ICJ 2012).

We have also identified two broad types of threats to wildlife that arise from multiple activity types:

5. Shipping-related impacts

Ships are used extensively by tourism operators, fishing operations and National Antarctic Programs to access and to work in the Antarctic and surrounding waters. Fuel spills from ships that run aground or sink can have severe and long-lasting impacts on marine wildlife (e.g. Eppley and Rubega 1989, 1990; Kennicutt and Sweet 1992; van den Brink and de Ruiter-Dijkman 1997; Ruoppolo et al. 2012). Bird strikes with vessels and ship collisions with cetaceans can cause injury and mortality (Black 2005; van Waerebeek et al. 2007). Ships' hulls, ballast water and sea chests are the primary means of introducing non-native marine organisms (Lee and Chown 2007, 2009).

Anti-fouling toxins applied on ship hulls may have adverse effects on marine species and ecosystems that are as yet unknown for the Southern Ocean. Ship traffic creates underwater noise that is likely to be audible to animals under the sea surface. The severity of impacts is related to the species concerned, the timing of the shipping activity relative to the breeding season of the species, and the distance from wildlife concentrations (de Villiers 2008).

Fishing vessels are the primary source of marine plastic debris within the Antarctic region. Fishing materials are generally not biodegradable and consequently are present in the ocean year-round and may persist for decades, leading to mortality and morbidity of relatively low numbers of seals and birds from ingestion and entanglement (Ainley 1990; Auman et al. 2004; Ivar do Sul et al. 2011). Marine debris can also serve as substrate for the transfer and introduction of non-native organisms that have the potential to alter ecosystem structure (Barnes and Fraser 2003; Gregory 2009).

6. Introduction of non-native species or disease-causing agents

While it is unlikely that unintentional introduction would lead to establishment of non-native vertebrates in the Antarctic because of the harsh climate (but see Headland 2012), the transport and dissemination of micro-organisms is an inevitable consequence of human presence in the Antarctic (Cowan et al. 2011). Visitors' clothing and personal belongings, vehicles, aircraft and ship holds, imported food, cargo and building materials are all viable pathways of transportation of non-native plant propagules (Hughes and Convey 2012 and references therein). Untreated sewage and other discharges from stations and ships may introduce pathogens to which native species have never been exposed and have developed no immunity (Smith and Riddle 2009). Researchers who come in contact with wildlife may carry and transfer disease-causing agents (Grimaldi et al. 2010).

It is important to note that these threats are not mutually exclusive, and there are various interactions and synergies present amongst them. We have not incorporated climate change into the assessment of each of these, and confine our predictions and discussions regarding this issue to Sect. 2.4.1.

Current terrestrial threats to Antarctic wildlife are largely confined to the ice-free areas around the periphery of Antarctica, which represent approximately 0.3 % of the surface area of the continent (Tin et al. 2009). Impacts also largely occur during the summer months, October to March, inclusive. The breeding seasons for most seabirds (excluding king *Aptenodytes patagonicus* and emperor penguins *A. forsteri*) and marine mammals that breed ashore coincide with the peak in human activities, human visitor numbers and associated logistic support efforts. The logistical support from research and supply vessels is largely confined to the summer months, being dependent on the break-up of the winter sea-ice before most vessels can approach the Antarctic continent. Thus, any adverse effects associated with vessels (bird strikes or noise, for example) are confined to the summer months.

Table 2.1 summarises some of the current management and conservation strategies that seek to minimise or mitigate these six selected threats. In the following Sects. 2.3.1–2.3.6, we describe current trends and our predictions for 2060 based on a Business-As-Usual scenario. Finally, a number of proactive management and conservation strategies are listed to address, minimise or prevent our 2060 predictions.

Table 2.1 Selected strategies in place in 2012 aimed at managing impacts of human activities on Antarctic wildlife

Activity	Selected 2012 strategies aimed at managing impacts on Antarctic wildlife
Tourism and non-governmental activities	• Madrid Protocol applies • Largely self-regulated by IAATO members through expedition leader instructions, Guidelines for wildlife watching, special activity guidelines, etc. (IAATO 2012c) • ATCM site guidelines for visitors for the 35 most-visited sites in the Antarctic Peninsula (ATS 2012a) • ATCM resolutions on tourism that recommend guide-to-passenger ratio, maximum ship capacity, etc. (ATS 2012b) • Varying and contradictory wildlife approach distances implemented by IAATO and various National Antarctic Programs (de Villiers 2008) • Protected Area network protects some wildlife values (New Zealand 2005, 2009) • Aircraft operation guidelines (Harris 2006)
Scientific research	• Madrid Protocol applies. Specifically: – Annex I requires EIAs prepared before all activities – Annex II requires special permits for research involving the killing, collection, capture, handling and tagging of birds and mammals – Annex III details requirements for waste and sewage disposal at field camps and research stations and clean-up of old and abandoned disposal sites – Annex IV prohibits the discharge of oil, chemicals and garbage into the marine environment – Protected area network, including marine reserves established under Annex V protect some wildlife values – Annex VI details liability arising from environmental emergencies (not yet ratified) • Scientific Committee on Antarctic Research (SCAR 2009, 2011a, b) non-mandatory codes of conduct for animal research, terrestrial field research and exploration of sub-glacial lake environments • Council of Managers of National Antarctic Programs (COMNAP 2012b) guidelines, manuals and handbooks that share best practices on energy, fuel and waste management, establishment of protected areas, etc • Practices vary amongst National Antarctic Programs, e.g. in quarantine and biosecurity protocols, sewage treatment, deployment of renewable energy and energy efficiency applications and oil spill response plans (e.g. Hughes and Convey 2010; Gröndhal et al. 2008; Shears et al. 2007; Tin et al. 2010)

(continued)

Table 2.1 (continued)

Activity	Selected 2012 strategies aimed at managing impacts on Antarctic wildlife
Commercial fisheries	• CCAMLR entered into force in 1982 to manage fisheries south of the Antarctic polar front. Science is a key component that underlies decision making that is aimed at ecosystem-based management, taking into account the precautionary approach. Conservation measures have included mesh size regulation, fisheries closures, bottom trawl and gillnet prohibition, longline prohibition in waters <550 m, and bycatch limits for some elasmobranches and vulnerable benthic invertebrates (e.g. Constable et al. 2000; CCAMLR Performance Review Panel 2008; Miller 2011) • Since 1985, CEMP monitors effects of krill fishery on land-breeding seals and seabirds. Other than some degree of spatial limits to catch, the data have not yet been used to adjust catch levels to avoid effects on krill-dependent or associated species, nor does it include monitoring of ecosystem effects by non-krill fisheries (CCAMLR Performance Review Panel 2008) • Seabird bycatch mitigation measures first introduced in 1992, result in significant decrease of seabird bycatch where enforced for regulated longline fisheries (Melvin and Baker 2006). Development or implementation of several international policies to reduce seabird bycatch, e.g. FAO's International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries, CCAMLR's *Ad-hoc* Working Group on Incidental Mortality Associated with Fishing (WG-IMAF) and Agreement on the Conservation of Albatrosses and Petrels' (ACAP) Seabird Bycatch Working Group • Establishment of first MPA in Southern Ocean, though applicability to fishery management appears to be minimal (CCAMLR 2009) • Effort to reduce bycatch in IUU fisheries progressing but with much further work needed (CCAMLR 2011c) • Other than unverified 'precautionary' measures, limited effort ensures that fisheries do not collectively have adverse population and ecosystem effects (Ainley and Brooks 2012) • Improved monitoring of IUU imports and exports through catch documentation schemes, and FAO's IPOA-IUU provides diplomatic and legal measures to diminish IUU fishing (Tuck et al. 2003)

(continued)

Table 2.1 (continued)

Activity	Selected 2012 strategies aimed at managing impacts on Antarctic wildlife
Shipping	• Annex IV of the Madrid Protocol prohibits discharge of oil, chemicals and garbage into the marine environment
	• International Convention for the Prevention of Pollution from Ships (MARPOL) applies and regulates atmospheric emissions, garbage and sewage discharges. August 2011 amendment prohibits use of heavy and intermediate fuel oils in Antarctic waters (Ruoppolo et al. 2012)
	• IMO member states adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments in 2004 (not yet in force)
	• COMNAP oil spill response plans and shipping guidelines (COMNAP 2012b)
	• Guidelines for reducing bird strikes on vessels (IAATO 2010)
	• Incomplete reporting of accumulation, ingestion and entanglement data required by CCAMLR. *Ad-hoc* reporting by tour operators, scientists and station personnel
	• CCAMLR has developed an education programme to encourage fishermen not to discard damaged fishing gear and other potentially harmful materials at sea. IAATO likewise has taken steps to ensure that tourists do not discard potentially hazardous materials at sea or on land in the Treaty Area (IAATO 2012c)
	• IMO efforts underway to increase safety of ships but so far do not apply to fishing vessels (ASOC 2011b)
Whaling	• Diplomatic pressure at meetings of the International Whaling Commission
	• Legal action in International Court of Justice by Australia (ICJ 2012)
	• Efforts by environmental groups to raise public awareness of whaling, subsidies involved and health hazards related to eating whale meat, and to intercept whaling vessels in the Southern Ocean to prevent operations (Roeschke 2009; WWF and Whales and Dolphins Conservation Society 2009)
Non-native species or disease-causing agents	• Annex II of Madrid Protocol prohibits deliberate imports of non-native species and requires imported poultry products to be inspected for evidence of diseases
	• CEP Non-native species manual provides information and non-mandatory guidelines on prevention, monitoring and response (CEP 2011)
	• Implementation of quarantine and biosecurity measures varies amongst countries and operations (e.g. IAATO 2012c; Grimaldi et al. 2010; Kerry and Riddle 2009)
	• Some development of disease response strategies and practical measures to diminish risk of spreading diseases amongst Antarctic wildlife with little adoption or implementation (Kerry and Riddle 2009)

2.3.1 Tourism and Non-governmental Activities

2.3.1.1 Current Trends and Impacts Predicted for 2060

Commercial tourism has been increasing in spatial and temporal extent over the last three decades, with a concomitant increasing spectrum of activities, increasing number of wildlife species exposed to, and potentially disturbed by tourism activities. Since 2008, the number of tourists travelling to Antarctica decreased as a result of the global financial crisis. In 2009, IAATO projected that the increase would resume. Nonetheless, there was still a 30 % decrease in tourist numbers between the 2008/2009 and 2010/2011 seasons (IAATO 2012a).

There have been few programmes of comprehensive and long-term research and monitoring of environmental impacts of Antarctic tourism (e.g. Naveen 1996; Lynch et al. 2010). In the face of this lack of conclusive evidence, some Antarctic Treaty parties are not willing to take precautionary action to minimise tourism impacts, nor are they investing the requisite resources in monitoring programmes that could provide these fundamental scientific data necessary to inform management decisions (ASOC 2011a).

Based on current trends, we conservatively project that there will be 120,000–160,000 visitors to Antarctica annually by 2060. This projection may appear high, but it is barely twice the peak of visitors to the Antarctic before the most recent financial crisis. A recovery to double the previous peak over the next 50 years is realistic in light of the previous growth in Antarctic tourism. We also forecast that there will be an increasing number of vessels. Large vessels may have an advantage as a result of economy of scale as costs of compliance with international law increase (Jabour 2013). However, the ban on the use of heavy fuel oils by ships transiting the Antarctic area is likely to reduce the number of very large (500 + passengers) vessels.

We further expect that there will be increased numbers of tourist flights to more areas over greater periods of each year and not primarily confined to summer months, as is the current situation. It is possible that land-based tourism will also develop, leading to increased permanent infrastructure, with concomitant increase in risk of pollution and damage to wildlife habitat (Bastmeijer et al. 2008). In general, we project there to be an increasing range and spectrum of human activities that would increase the potential for disease and other species' introductions due to rapid transit of tourists and their gear from elsewhere on the planet (e.g. Curry et al. 2002; Frenot et al. 2005; Bergstrom et al. 2006 and references therein; Frenot et al. 2008).

2.3.1.2 Management Needs for 2060

Many suggestions on how to manage Antarctic tourism have been proposed (e.g. Hemmings and Roura 2003; Bastmeijer and Roura 2004; Liggett et al. 2010; Jabour 2013). In our opinion, in order that commercial tourism activities do not result in harmful interference on Antarctic wildlife and ecosystems, it would be necessary to manage tourism proactively, and to a greater extent than currently. There needs to be more active involvement by the Antarctic Treaty Consultative Parties in the regulation of the tourism industry, starting with the development of a strategic vision on tourism in Antarctica (sensu Amelung and Lamers 2006). Greater constraints need to be established to reduce the number of sites visited, the number of visitors ashore and the ratio of tourists to guides ashore. At all wildlife sites, site-specific and species-specific guidelines for visitors need to be adopted, implemented and enforced. Resources need to be made available in order that the impacts of all aspects of commercial tourism can be assessed objectively and independently.

The Madrid Protocol requires that EIAs are undertaken before the start of any activity, and that cumulative impacts (temporal and spatial) and other ongoing and future activities (including research) need to be incorporated into management considerations. This requirement needs to be implemented. Where it is not possible to predict cumulative impacts a priori with reliability, monitoring programmes need to be established in order to detect impacts in time and space so that remedial action can be taken (Hofman and Jatko 2000). Until scientifically valid and independent data are available, tourism activities need to be managed with a precautionary approach, e.g. by increasing minimum approach distances to wildlife from 5 to 20 m to allow for the current uncertainty. Tighter biosecurity protocols need to be adopted, implemented and legally enforced (see Sect. 2.3.6). In addition, regional zonation with specified inviolate (i.e. no-research, no-tourism, no-entry) sites needs to be used to protect wildlife and other environmental values (e.g. wilderness and aesthetic: Summerson and Riddle 2000).

2.3.2 Scientific Research and Associated Logistics

2.3.2.1 Current Trends and Impacts Predicted for 2060

The Madrid Protocol entered into force in 1998 and has significantly reduced the environmental impacts of scientific research and the activities of National Antarctic Programs (e.g. Bargagli 2008; Kerry and Riddle 2009). More than a decade later, gaps in its implementation still remain—e.g. no EIA appears to have prevented or modified any proposed activity (Hemmings and Kriwoken 2010), only a few abandoned sites have been cleaned up, with only a few of them involving the full remediation of contaminated soils and sediments (Tin et al. 2009) and there is a general lack of compliance at some locations (e.g. Peter et al. 2008; Braun et al. 2012). Concomitant with these gaps in implementation, has been the increasing human presence in the Antarctic.

Following current trends, we forecast that there will be increasing numbers of year-round and summer stations, researchers and support staff, support vessels and flights and all forms of vehicular traffic and subsequently, increasing volumes of fuel consumption and storage requirements. These will all contribute to greater spatial footprints of research stations and activities, increased local pollution and disturbance from station and operations and greater realised and potential disturbance to wildlife, assuming that no additional steps are taken to minimise their effects. There will also be associated deterioration of the wilderness values of areas close to these stations.

Chemical contamination from past decades is likely to continue to adversely affect the environment. We expect an increased potential for disease and other species introductions due to the rapid transit of researchers and their field equipment and personal gear (Frenot et al. 2005, 2008; Bergstrom et al. 2006 and references therein; Grimaldi et al. 2010). National Antarctic operations may be subject to future budget cuts, which could lead to varying reductions in construction and logistics activities, however, a wide range of effects (comprising reductions in scientific research, logistics, environmental management or construction and new facilities) remain possible (Sánchez and Njaastad 2013).

2.3.2.2 Management Needs for 2060

Many suggestions have been proposed on how to improve the implementation and compliance to the Madrid Protocol (e.g. Hemmings and Roura 2003; Bastmeijer and Roura 2008; Tin et al. 2009; Roura and Hemmings 2011). In our opinion, to minimise the potential that scientific research and its supporting logistics will result in harmful interference on Antarctic wildlife and ecosystems, it would be necessary that all aspects of station activities and operations are managed proactively, with a greater integration of the impacts from commercial tourism activities (where present) to more appropriately assess cumulative impacts over time and space of all human activities in an area, past, present and future. This would ensure that impact assessments address cumulative impacts (temporal and spatial) and include commercial tourism activities where relevant in order that the EIA process can work effectively as a gatekeeper. As Hemmings and Roura (2003) noted, 'Impact assessments should identify any uncertainties and assumptions concerning possible temporal and spatial impacts, and describe the research or monitoring that will be done to resolve the uncertainties and validate the assumptions. If other activities are occurring or likely to occur where they could have additive effects, the impact assessment should reference those activities and describe the research and monitoring that will be done to be able to distinguish those effects from the effects of the activity for which the impact assessment was done'. A standardised understanding and measurement of stations 'footprint' would assist in impact assessments and management implications.

Objective assessments of the threats and cumulative impacts to Antarctic wildlife from all aspects of research programmes must be more fully incorporated into research protocols, and station and local protected area(s) management plans. Additional long-term population studies to assess long-term trends and to distinguish the effects of climate change, fisheries, tourism and other activities in the Southern Ocean should be established to complement existing decadal-scale seabird and seal studies. Such long-term studies could contribute to regional zoning for wildlife and other values, with some high-conservation value sites off-limits to all visits from both research and tourism. Remotely sensed data could be used to facilitate monitoring of wildlife populations inside these restricted areas.

The Antarctic Treaty Consultative Parties conduct site and compliance inspections in accordance with Article VII of the Treaty and Article 14 of the Madrid Protocol (Sánchez and Njaastad 2013). A recent preliminary evaluation of the value of these inspections in fostering protection of Antarctic values has found that while the number and scope of inspections was adequate, the process was fundamentally flawed without a mechanism for applying sanctions for poor environmental compliance (Jabour 2012a). The so-called 'no-blame policy' may be ideal diplomatically for keeping the peace amongst parties, but it is unhelpful environmentally. To make a real difference to environmental protection, this approach must change.

More countries should investigate the potential for greater use of renewable energy sources. Examples include hydroelectric power at Grytviken, South Georgia (Morrison 2006), wind turbines at Mawson Station (Australian Antarctic Division 2011), McMurdo-Scott Base (Antarctica New Zealand 2011) and at various field sites (Tin et al. 2010; Sánchez and Njaastad 2013). Wind energy will reduce the volume of fuels required for station operations and may reduce the likelihood of fuel spills, but must be considered in the light of potential for bird-strikes. It would be very useful to obtain objective risk assessment information for future clean-up and remediation programmes that is specifically relevant to the Antarctic environment (Tin et al. 2009). Because the Madrid Protocol allows that clean up efforts only take place if in doing so, they do not create, 'greater adverse environmental impact' [Annex III, Article 1.5(b)], it will not be possible to remediate all past and current waste disposal and abandoned work sites.

2.3.3 Commercial Fisheries

2.3.3.1 Current Trends and Impacts Predicted for 2060

Longline fishing effort has increased markedly in the Southern Ocean during the last 20 years. The average effort between 2000 and 2009 is more than 300 % that of the previous decade (CCAMLR 2011b, 2012). There has been a dramatic increase in the mean depth of the fish catch which has recently stabilised, clearly reflecting the collapse and the implementation of fisheries restrictions for some shallower water fishes in the late 1980s, and increased landings of the deep-water toothfish (*Dissostichus* spp) during late 1980s (Morato et al. 2006; Ainley et al. 2012).

The krill catch has remained relatively stable for 17 years until 2009, at which time it nearly doubled (Nicol et al. 2012). While CCAMLR's efforts have reduced

IUU catches markedly since the early 2000s, IUU operations continue to evolve despite CCAMLR's controls. IUU operations are moving farther south, fishing in areas where little or no regulated fishing occurs. Gillnets are used and the extent of by-catch of fish and seabirds and the impact on benthos are unknown (SC-CAMLR 2010a).

We forecast that regulated fisheries will continue to expand, although rising fuel costs may reduce some fishing effort (Pauly et al. 2003; Fabri and Gascón 2008). IUU fishing will not be eradicated. Combined IUU and regulated fisheries will be unsustainable for long-lived demersal species, resulting in some current target species being unable to remain commercially viable (Briggs 2011). Long-term viability of many seabird species and some killer whale ecotypes may be jeopardised (Tuck et al. 2003; Guinet and Tixier 2011). Novel species, e.g. myctophids or silverfish (*Pleuragramma antarcticum*), are likely to be targeted or subjected to increased fishing pressure as currently targeted species and populations are overfished, protected or become economically unviable.

The krill fishery is likely to expand as more efficient krill fishing technology and more lucrative krill products are developed (Nicol et al. 2012). If the krill fishery does expand substantially beyond its present level, we forecast that there will be more general and substantial population and ecosystem effects on its predator and associated species. These effects are likely to be exacerbated by the effects of climate change (Atkinson et al. 2008; Kawaguchi et al. 2009, 2011) and the recovery of depleted whales (Ainley et al. 2010a; Leaper and Miller 2011; Trivelpiece et al. 2011). Recovery of depleted fish stocks is likely to be slow (Marschoff et al. 2012), especially in the face of a rapidly changing Southern Ocean, and at best will attain levels well below pre-exploitation levels. Benthic communities, once populated by 1,000-year old organisms, but destroyed by long-lines will not fully recover. Food webs and ecosystem structure will remain altered.

2.3.3.2 Management Needs for 2060

First and foremost, the broad consensus amongst fishery biologists and managers is that spatial management of fisheries, e.g. the designation of ecologically meaningful MPAs, is required for effective management of live-capture marine fisheries (Fosså and Skjodal 2009; Clark 2009; Kompas et al. 2009; Longhurst 2010). While CCAMLR currently is absorbed in designating a network of MPAs in the Southern Ocean, thus in keeping to Article IX 2(g) in its charter, it remains to be seen how many will actually be useful in fishery management rather than protecting areas where industry has no interest.

In our opinion, more robust and fishery-independent data needs to be incorporated into fishery models, and used to verify model assumptions and catch rates that are considered as precautionary. Until the validity of the data, models and assumptions used to estimate sustainable catch levels can be confirmed, quotas for target and bycatch species need to be more conservative. CCAMLR's CEMP needs to be expanded to include research and monitoring that are capable of detecting and providing feedback to manage the toothfish and other finfish fisheries. The current CEMP effort which focuses on krill needs to be maintained and expanded to concentrate on areas that are smaller than the current regional harvesting units in order to better assess and minimise effects on krill-dependent predators.

CCAMLR allows a 50 % reduction in spawning biomass of so-called 'predatory' species (e.g. toothfish) and 25 % reduction in the case of forage species (e.g. krill; cf Constable et al. 2000; Croxall and Nicol 2004). While the 25 % rule, which includes ecosystem monitoring through CEMP and spatial management of take, is consistent with the Precautionary Principle (Constable 2011), CCAMLR's admitted application of the single-species MSY principle (cf Constable et al. 2000; Longhurst 2010) was not what was originally envisioned in the founding principles of CCAMLR and cannot be construed in any way as 'rational use' (Ainley et al. 2012; Ainley and Brooks 2012). Efforts should be coordinated at the global scale, providing for the development and implementation of best management practices to further reduce seabird bycatch (Melvin and Baker 2006).

2.3.4 Whaling

2.3.4.1 Current Trends and Impacts Predicted for 2060

Japanese scientific whaling in the Southern Ocean has decreased in recent years partly due to non-governmental organisation activities that have drawn the attention of governments. Some whale populations are increasing rapidly, e.g. humpback whales (*Megaptera novaeangliae*), others remain far below population levels before industrial whaling of the 1900s, e.g. blue (*B. musculus*) and fin whales, others may be decreasing (e.g. Antarctic minke whales), and insufficient data exist to assess other species, e.g. sei *B. borealis* whales) (IWC 2012).

Changes in attitudes towards whaling and eating whale meat may combine with increasing fuel costs and compliance costs for vessels going into Antarctic waters to end government-subsidised whaling in the Southern Ocean (Hoek 2010). While full recovery of whale populations is doubtful in the face of climate change, any increase in whale populations will continue to result in alteration of food web dynamics (Ainley et al. 2010a; Trivelpiece et al. 2011; Trathan et al. 2012). Only large MPAs, that prohibit fishing and whaling, will reveal the recovery potential. However, uncertainties exist as to the future of the global moratorium on whaling activities, and on the form of regulations of any future commercial whaling (Leaper and Childerhouse 2013).

2.3.4.2 Management Needs for 2060

In order to allow for recovery of whale populations to the extent that climate change allows, large MPAs need to be designated and the existing global moratorium on commercial whaling needs to continue. Non-complying nations need to be convinced to comply with the moratorium. The Southern Ocean Sanctuary needs to be universally adopted and recognised. Management needs for the future will hinge to a great degree on the decision of the International Court of Justice (ICJ 2012). If the ICJ finds that Japanese Special Permit whaling is in fact commercial whaling, a whole regime change will occur. But it is noted that this will involve the International Convention for the Regulation and Whaling and the IWC, neither of which are Antarctic-specific.

2.3.5 Shipping-Related Impacts

2.3.5.1 Current Trends and Impacts Predicted for 2060

With the expected increase of tourism, fishing and National Antarctic Program activities, we forecast shipping activities to increase correspondingly. As the amount of marine traffic increases, there will be increased discharges of sewage, sewage sludge, grey-water and ground food wastes, increased undersea noise and higher likelihood of shipping accidents, fuel spills and ship strikes on marine mammals (e.g. Ruoppolo et al. 2012). Worldwide, the quantity of persistent debris in the marine environment is increasing. In the Southern Ocean, increasing marine traffic, especially IUU fishing vessels, in combination with greater quantities of waste produced and transported from north of the Antarctic Polar Front, from population centers in the Southern Hemisphere are likely to increase the quantity of persistent marine debris.

2.3.5.2 Management Needs for 2060

The International Maritime Organisation (IMO) is presently developing a mandatory polar shipping code that needs to be adopted and implemented. This Code must include fishing vessels, which are currently excluded in IMO deliberations. Ideally the Code needs to ensure that only properly equipped ice-class vessels should enter into Antarctic Treaty waters and that the disposal of operational wastes from vessels are regulated under more stringent requirements than at present (ASOC 2011b). However, the Code is likely to employ a new ship classification system to rate the ability of any ship to operate safely in a range of different ice conditions. In tandem, an up-to-date map of conditions—zoned according to the prevailing ice regime—will be required. Progress is slow on both of these developments. The Code will not prevent any vessel from entering Antarctic waters. It will only prescribe areas of safe operation. As enforcement of IMO conventions is a flag state responsibility, implementation will rely heavily on support from ship insurers and classification societies (Jabour 2012b).

The EIA process, as stipulated under the Madrid Protocol, needs to recognise the potential and actual impacts of undersea noise on marine mammals. Undersea noise, while on its own may be a relatively minor threat to wildlife, will interact synergistically with other concurrent threats, such as climate change and alterations in ecosystem structure, and contribute to significant cumulative impacts. Currently, basic data are lacking on the marine acoustic environment of the Southern Ocean and research needs to be initiated in the Southern Ocean into acoustics and marine mammals if a sound scientific basis is to underpin any future management of ocean noise (SCAR 2006).

More scientific data and continued monitoring are also needed to better document the rates and levels of wildlife entanglement and ingestion of marine debris, and the accumulation rates of marine debris on Antarctic shores. Improved education, and where possible, promulgation of regulations and monitoring programmes, can also contribute towards reducing sources of marine debris from vessels and from population centers in the Southern Hemisphere. Section 2.3.6 further discusses the need for sound biosecurity and quarantine measures to reduce the risk of introduction of non-native species.

In general, MPAs can be created to protect biologically sensitive species, communities and areas from the impact of shipping activities. IMO's polar shipping code may assist here, with regulations proscribing shipping activities in areas of high ice concentration, corresponding with areas of high productivity. Furthermore, in the event that migration routes of marine mammals vulnerable to ship strikes can be charted, additional safety regulations could be imposed on ship operators to reduce pressure during times of heavy traffic.

2.3.6 Introduction of Non-native Species or Disease-Causing Agents

2.3.6.1 Current Trends and Impacts Predicted for 2060

There are currently relatively few established introduced species on the Antarctic, none of which are vertebrates (Headland 2012; Frenot et al. 2005). On peri-Antarctic islands, however, introduced rodents and cats have led to predation of native birds, and the number of species introduced has been found to be related (amongst other things) to the number of human visitors to the site (Johnstone 1985; Chown et al. 1998; Jones et al. 2008; Jones and Ryan 2010; Headland 2012).

Introduced species have the potential to alter breeding habitat of native species (Bell and Dieterich 2010). Seabirds and seals will be the most likely taxa to face threats from any introductions to the Antarctic, due largely to their proximity to stations, their close relationships with species elsewhere and from their prevalence in numbers and biomass. Local cases of unusual disease-associated die-offs of wildlife have been observed. Most events have unknown origins, but human activities have been implicated in some instances, although to date there has been no evidence of any direct human-mediated pathogen introduction (Kerry and Riddle 2009).

Greater human presence, in combination with more amenable conditions, will increase the probability of introductions (Hughes et al. 2013). Increased mobility within Antarctica will also increase the potential for inadvertent transfer of native biota from one part of Antarctica elsewhere where they are alien (Frenot et al. 2005; Hughes and Convey 2010). Warming associated with climate change will increase the likelihood of establishment and expansion of non-native species (Turner et al. 2009a; Grimaldi et al. 2010) and the possibility of mutation of disease-causing agents currently present in Antarctic flora and fauna to more virulent forms. Increased use of aircraft to bring people to Antarctica will exacerbate the potential threat of introductions, including infectious disease-causing agents. It is likely that a greater range of species and areas will be impacted as longer periods of milder conditions and greater extents of ice-free areas with greater inter-connectivity (Cook et al. 2010) become available for colonisation and establishment.

2.3.6.2 Management Needs for 2060

Existing quarantine and biosecurity measures, both inward and outward for all human visitors and equipment to the Antarctic, whether there is close approach and/or contact with wildlife or not, need to be increased from the existing protocols (COMNAP/SCAR 2010). Other pragmatic measures reducing the risk of non-native introductions through non-human vectors also need to be implemented, e.g. fresh food checks, cargo sterilisation (Hughes et al. 2011, 2013). All measures must be efficient and effective, and standardised at all gateway ports and at all landing sites/destinations. Ideally measures would include redundancies to minimise the risks of introductions—e.g. prophylactic measures that are implemented at departure and at arrival points.

Long-term investments in biosecurity measures and environmental monitoring are needed in order to reduce the risk of introductions, and manage and monitor introductions and established species when they occur. At the same time, more research is needed to create an inventory of natural biodiversity in the Antarctic and to develop techniques in order to identify and remove newly established non-native species (SCAR 2010; Hughes and Convey 2012).

Similar research and policy needs exist for the issue of wildlife diseases in the Antarctic. Inventories of endemic diseases and infectious disease-causing agents are urgently needed. Current background levels of diseases and agents need to be quantified in order to provide a baseline for future assessments. Research is also needed to identify the opportunities that exist for introductions and establishment of novel diseases and agents or mechanisms of contagion, and universal disease surveillance and reporting procedures need to be implemented (Kerry et al. 1998). Disease outbreak contingency plans also need to be developed and adopted (Kerry and Riddle 2009).

2.4 Antarctica 2010–2060: Conservation Needs and Challenges

2.4.1 Contribution of Climate Change

Predictions as to how climate change will affect the Antarctic and Southern Ocean vary in their estimates of magnitude, intensity and imminence (e.g. Turner et al. 2009a, b; ACE CRC 2011). Concomitant with these predictions are various estimates of the changes and adaptations required of Antarctic wildlife, particularly those species that are closely associated with sea ice, such as emperor penguins and Weddell seals (*Leptonychotes weddellii*) (e.g. Siniff et al. 2008; Jenouvrier et al. 2009; Ainley et al. 2010b). Unfortunately, many of the predictions and their various assumptions can only be tested post hoc. Rather than predicting a particular state in 2060 (or at any other year–the most common being 2100: Turner et al. 2009a; Jenouvrier et al. 2009), Ainley et al. (2010b) described the qualitative changes to populations, abundances and distributions of Adélie and emperor penguins to modelled habitat changes as the mean tropospheric temperatures reached 2 °C above pre-industrialised levels. They noted that significant changes will be evident when that criterion is reached well before 2060. Similar analyses may provide models for other vertebrate species in the Antarctic, and serve to develop proactive and holistic conservation and management strategies that incorporate and implement a precautionary approach embodying the Precautionary Principle.

Irrespective of the rate of climate alteration, there can be no doubt that climate change will act hierarchically (i.e. top-down) and synergistically with existing anthropogenic threats to the marine and terrestrial wildlife and environments of the Antarctic, potentially realising additive or multiplicative responses from the existing threats (e.g. Halpern et al. 2008a, b; Hoegh-Guldberg and Bruno 2010). It is apparent that the threats will increase in their intensity, frequency and spatial extents into the future. In addition, novel pressures will emerge, including ocean acidification (Kerr 2010), and there will likely be an increase in the frequency and severity of extreme weather events. The effects of these synergistic and cumulative impacts on the resilience of the Antarctic marine and terrestrial ecosystems are presently unknown, but are highly likely to reduce the resilience to further anthropogenic threats and pressures, and exacerbate the existing threats, placing greater stress on ecosystem functions, tropho-dynamics and ecosystem services than present (Ainley and Tin 2012). A comprehensive and integrated understanding of how climate change will affect Antarctic ecosystems is currently lacking, and more research into climate change impacts is urgently needed (Hoegh-Guldberg and Bruno 2010; but see Turner et al. 2009a).

2.4.2 Gaps, Uncertainties and Opportunities

The present lack of quantitative data on the relative impacts to Antarctic wildlife prevents a ranking of the threats discussed here. Were such data available, analyses could identify spatial and temporal patterns, extents and trends in each threat discussed to generate holistic, regional and whole-of-ecosystem threat assessments that could be used to direct research efforts and resources in a pro-active, adaptive conservation management framework.

However, some preliminary contemporary assessments are possible. More than 90 % of the commercial tourist activities visit sites in the Scotia Arc/Antarctic Peninsula (Jabour 2009), an area with the greatest number and concentration of summer and winter research stations (Headland 2009). The greatest pressures on the Antarctic environment and its wildlife are presently occurring in this area during the summer months with the greatest intensity and diversity of human activities. In addition, fishing efforts for Antarctic krill are concentrated in this region (SC-CAMLR 2010b), placing further pressure on the region's wildlife.

We note that there is a wide-range of efforts presently underway to improve the conservation status of Antarctic wildlife (e.g. the designation of MPAs, the implementation of international regulation to reduce seabird bycatch, and the priority given to the consideration of climate change and non-native species by the Antarctic Treaty Consultative Parties) in recognition of the increasing spectrum of threats to the region and we expect them to continue to evolve and expand. However, the lack of quantitative data prevents an objective assessment of the efficacy of existing management frameworks and the claimed sustainability of various activities, including commercial fisheries. Meanwhile, it is very clear that the vast majority of the contemporary threats to Antarctic wildlife are increasing in their spatial and temporal extents and in their intensities, and thus can be expected to increase further by 2060, assuming a Business-As-Usual approach for the next 50 years. Just how realistic this assumption is is certainly debatable, but comparing the rate at which other conservation strategies are adopted and implemented, and the rate of expansion of human activities and appearance of new threats, we see that a reactive, *ad-hoc* approach to conservation and management of the Antarctic environment is unlikely to be able to keep up with the demands of human use of the Antarctic in the twenty-first century.

It is very likely that there are other threats to wildlife resulting from interactions and synergies amongst and between the threats listed above in Sect. 2.3, particularly in association with climate change (see Sect. 2.4.1). These interactions are likely to generate cumulative impacts beyond our contemporary assessment protocols, and are thus beyond our ability to predict. They are, however, likely to be greater than the sum of their parts. In an overwhelming majority of cases, it is currently impossible to quantify the effects or impacts of various human activities on Antarctic wildlife, despite the extensive research undertaken to date (see de Villiers 2008; Tin et al. 2009 for reviews). To overcome this, greater efforts must be made in the future to collect quantitative data that can be used to assess threat levels and impacts to wildlife and to the environment. Until then, a greater level of adoption and application of the Precautionary Principle is warranted in light of the increase in threats to Antarctic wildlife predicted here.

2.4.3 Strategic Conservation Needs

To close, we take a step back from the discussion of specific activities and threats and propose a number of strategic actions that address the overarching context in which Antarctic wildlife—and indeed, the Antarctic environment—can be appropriately protected into the future. While activity-, threat- or species-specific management actions are necessary (and are typically the initial response), it is important not to lose sight of the large-scale strategic context that has the ability to influence the effectiveness of any individual decision or action.

- A holistic and proactive approach, recognising and incorporating cumulative impacts, needs to be adopted for the management of the Antarctic and its wildlife (e.g. Halpern et al. 2008a). The Precautionary Principle needs to be adopted and implemented in the management of all aspects of human activities in the Antarctic in recognition of the substantial data gaps that exist in relation to the impacts of existing human activities in the Antarctic. Proactive measures will provide greater capacity to distinguish between natural and anthropogenic forcing of populations and environmental changes. Concomitantly, criteria for the identification of cumulative impacts to wildlife are required to reduce their occurrence and frequency in the region. Where a meaningful assessment of cumulative impacts is not possible, monitoring programmes need to be established as a matter of priority in order to resolve uncertainties and validate or repudiate assumptions.
- Efforts to obtain baseline data for key, 'indicator' species of wildlife need to be increased substantially. Potentially following the example of the Census of Antarctic Marine Life (CAML), fundamental ecological and biological data on the distributions and abundances for many Antarctic terrestrial species urgently need to be collected. Very few biogeographical studies of the biota on the Antarctic continent exist (but see Howard-Williams et al. 2006 and following, Bergstrom et al. 2009; Terauds et al. 2012) and the various data gaps reduce the scales and extents of current EIAs, and prevent quantitative ecological risk assessments for existing or planned human activities. The data gaps also prevent the adoption and implementation of holistic and pro-active conservation and management strategies and the full description of ecosystem services and functions.
- In the face of climate-generated uncertainty, the potential for managing Antarctica, the peri-Antarctic islands and adjacent seas under frameworks similar to those used for National Parks and Marine Sanctuaries should be investigated (e.g. Bastmeijer and Roura 2004). Approaches adopted and implemented elsewhere where wildlife and environmental values are protected from intensive human visitation (e.g. seasonal access restrictions, including visitor quotas) could be readily adopted within a future management framework for the Antarctic. No-take marine protected areas need to be used more widely to minimise the risks of overfishing and increasing shipping traffic. Types of protection include: species being fished along with related and dependent species, critical

life history stages or habitats, such as spawning seasons and areas, or establishment of reference or study areas to partition effects of climate from fishing on the structure and function of ecosystems. Further, no-take marine reserves are required to allow benthic communities to, if possible, recover. In fact, these benthic communities provide habitat for fishes.
- Develop continental- and ocean-wide monitoring programmes in order to assess the long-term effects of persistent contaminants in Antarctic organisms and food chains and to predict possible responses of terrestrial and marine ecosystems to climate changes and anthropogenic activities.
- Promote international agreements and the transfer of financial aid and technologies from rich countries to developing countries in the Southern Hemisphere in order to address global environmental threats (Bargagli 2008). Educate and raise public awareness on environmental issues on a global scale in order to contribute towards climate change mitigation and reducing global consumption and waste production.
- Acknowledge the potential for mineral extraction in the Antarctic and its potential substantial environmental impacts. Recent claimant state interest in their supposed rights as coastal states under the United Nations Convention on the Law of the Sea has reflected a clear intention to reserve positions about the Antarctic continental shelf, revealing a real and ongoing interest in resource realisation in both the Antarctic Treaty Area and the peri-Antarctic islands subject to national jurisdiction (Hemmings and Stephens 2010). This suggests a tension between national commitment to environmental protection in Antarctica and an interest in realising potential economic benefits from resources such as hydrocarbons and living resources.

2.5 Conclusions

Clearly not all of our proposals can be implemented immediately or simultaneously, but strategic adoption is necessary to address the ever-increasing spectrum and intensity of threats to Antarctic wildlife from the consistently increasing number of people in the Antarctic each year. These threats will also increase in their complex synergies and interactions, giving further increasing urgency to adopting a more precautionary approach to managing human activities in the Antarctic. Failure to act now may well see future generations managing an Antarctic region with degraded environmental values and ecosystem functions, more typical of the rest of the planet. Such an outcome is indefensible and unacceptable in light of our current knowledge and our ability to mitigate the worst of the potential impacts with considered and effective measures.

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References

ACE CRC. (2011). *Position analysis*: *climate change and the Southern Ocean*. Retrieved from http://www.acecrc.org.au/Publications/Position%20Analyses.

Ainley, D. G. (1990). The incidence of plastic in the diets of Antarctic Seabirds. In R. S. Shomura & M. L. Godfrey (Eds.), *Proceedings of the second international symposium on marine debris, 2–7 April, 1989, Honolulu, Hawaii* (pp. 682–691). Washington, D.C.: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Ainley, D. G., & Brooks, C. (2012). Exploiting the Southern Ocean: Rational use or tragedy of the commons? In D. Liggett, A. D. Hemmings, & G. Steel (Eds.), *Exploring Antarctic values*. Christchurch, New Zealand: University of Canterbury, Gateway Antarctica Special Publication Series.

Ainley, D. G., & Tin, T. (2012). Antarctica. In J. Hilty, C. C. Chester, & M. Cross (Eds.), *Climate and conservation: Landscape and seascape science, planning and action*. Washington, D.C.: Island Press.

Ainley, D. G., Ballard, G., Blight, L. K., Ackley, S., Emslie, S. D., Lescroël, A., et al. (2010a). Impacts of cetaceans on the structure of southern ocean food webs. *Marine Mammal Science, 26*, 482–489.

Ainley, D. G., Russell, J., Jenouvrier, S., Woehler, E. J., Lyver, P. O'. B., Fraser, W. R., et al. (2010b). Antarctic penguin response to habitat change as earth's troposphere reaches 2 °C above pre-industrial levels. *Ecological Monographs, 80*, 49–66.

Ainley, D. G., Brooks, C. M., Eastman, J. T., & Massaro, M. (2012). Unnatural selection of Antarctic toothfish in the Ross Sea, Antarctica. In F. Huettmann (Ed.), *Protection of the three poles* (pp. 53–75). Tokyo, Japan: Springer.

Amelung, B., & Lamers, M. (2006). Scenario development for Antarctic tourism: Exploring the uncertainties. *Polarforschung, 75*(2–3), 133–139.

Antarctica New Zealand. (2011). *Ross island wind energy*. Retrieved from http://www.antarcticanz.govt.nz/scott-base/ross-island-wind-energy.

Aronson, R. B., Thatje, S., McClintock, J. B., & Hughes, K. A. (2011). Anthropogenic impacts on marine ecosystems in Antarctica. *Annals of the New York Academy of Sciences, 1223*, 82–107.

ASOC. (2010). *Antarctic krill fisheries and rapid ecosystem change*: *the need for adaptive management*. Information Paper 10 Presented at Antarctic Treaty Meeting of Experts on Climate Change, 6–9 April 2010, Svolvær, Norway.

ASOC. (2011a). *Antarctic tourism—what next? Key issues to address with binding rules*. Information Paper 84 Presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, 20 June–1 July, 2011.

ASOC. (2011b). *Developing a mandatory polar code—progress and gaps*. Information Paper 85 Presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, 20 June–1 July, 2011.

ATS. (2012a). *Site guidelines for visitors*. Retrieved from http://www.ats.aq/e/ats_other_siteguidelines.htm.

ATS. (2012b). *Antarctic treaty database*. Retrieved from: http://www.ats.aq/devAS/info_measures_list.aspx?lang?e.

Atkinson, A., Siegel, V., Pakhomov, E. A., Rothery, P., Loeb, V., Ross, R. M., et al. (2008). Oceanic circumpolar habitats of Antarctic krill. *Marine Ecology Progress Series, 362*, 1–23.

Auman, H. J., Woehler, E. J., Riddle, M. J., & Burton, H. (2004). First evidence of ingestion of plastic debris by seabirds at sub-Antarctic Heard Island. *Marine Ornithology, 32*, 105–106.

Australia. (2009). *Threat abatement plan for the impacts of marine debris on vertebrate marine life*. Canberra, Australia: Department of Sustainability, Environment, Water, Population and Communities. Retrieved May 15, 2012, from http://www.environment.gov.au/biodiversity/threatened/publications/tap/marine-debris.html.

Australian Antarctic Division. (2011). *Mawson wind farm*. Retrieved from http://www.antarctica.gov.au/living-and-working/station-life-and-activities/station-amenties-and-operations/renewable-energy/wind-power/mawson-wind-farm.
Barbosa, A., & Palacios, M. J. (2009). Health of Antarctic birds: a review of their parasites, pathogens and diseases. *Polar Biology, 32*, 1095–1115.
Bargagli, R. (2008). Environmental contamination in Antarctic ecosystems. *Science of the Total Environment, 400*, 212–226.
Barnes, D. K. A., & Fraser, K. P. P. (2003). Rafting by five phyla on man-made flotsam in the Southern Ocean. *Marine Ecology Progress Series, 262*, 289–291.
Bastmeijer, K. (2007). Special offer—7 days fly and drive Antarctica: The role of wilderness protection in deciding whether (Semi) permanent tourist facilities in Antarctica should be prohibited. In A. Watson, J. Sproull & L. Dean (Eds.), *Science and stewardship to protect and sustain wilderness values*: *Eighth world wilderness congress symposium*: *September 30–October 6*, *2005*, *Anchorage*, *AK*, *USA* (pp. 190–196). Proceedings RMRS-P-49. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
Bastmeijer, K., & Roura, R. (2004). Regulating Antarctic tourism and the precautionary principle. *The American Journal of International Law, 98*, 763–781.
Bastmeijer, K., & Roura, R. (2008). Environmental impact assessment in Antarctica. In K. Bastmeijer & T. Koivurova (Eds.), *Theory and practice of transboundary environmental impact assessment* (pp. 176–219). Leiden, Netherlands: Martinus Nijhof.
Bastmeijer, K., Lamers, M., & Harcha, J. (2008). Permanent land-based facilities for tourism in Antarctica: The need for regulation. *Review of European Community & International Environmental Law, 17*(1), 84–99.
Baum, J. K., & Worm, B. (2009). Cascading top-down effects of changing oceanic predator abundances. *Journal of Animal Ecology, 78*, 689–714.
Bell, C. M., & Dieterich, R. A. (2010). Translocation of reindeer from South Georgia to the Falkland Islands. *Rangifer, 30*, 1–9.
Benninghoff, W. S., & Bonner, W. N. (1985). *Man's impact on the Antarctic environment*. Cambridge, UK: Scientific Committee on Antarctic Research.
Bergstrom, D. M., Convey, P., & Huiskes, A. H. L. (Eds.). (2006). *Trends in Antarctic terrestrial and limnetic ecosystems. Antarctica as a global indicator*. Dordrecht, Netherlands: Springer-Verlag.
Bergstrom, D. M., Lucieer, A., Kiefer, K., Wasley, J., Belbin, L., Pedersen, T. K., et al. (2009). Indirect effects of invasive species removal devastate World Heritage Island. *Journal of Applied Ecology, 46*, 73–81.
Black, A. (2005). Light induced seabird mortality on vessels operating in the Southern Ocean: incidents and mitigation measures. *Antarctic Science, 17*, 67–68.
Braun, C., Fritz, H., Mustafa, O., Nordt, A., Pfeiffer, S., & Peter H. -U. (2013). Environmental assessment and management challenges of the fildes Peninsula region. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures*: *Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer-Verlag.
Braun, C., Mustafa, O., Nordt, A., Pfeiffer, S., & Peter H. -U. (2012). Environmental monitoring and management proposals for the fildes region (King George Island, Antarctic). Polar Research *31*, 18206. Retrieved from http://dx.doi.org/10.3402/polar.v31i0.18206.
Briggs, J. C. (2011). Marine extinctions and conservation. *Marine Biology, 158*, 485–488.
CEP. (2011). *Non-native species manual*. Buenos Aires, Argentina: Secretariat of the Antarctic Treaty.
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*(1), 45–60.
Chown, S. L., Gremmen, N. J. M., & Gaston, K. J. (1998). Ecological biogeography of Southern Ocean islands: Species-area relationships, human impacts, and conservation. *American Naturalist, 152*, 562–575.

CCAMLR. (2009). *Report of the twenty-eighth meeting of the commission*, *Hobart*, *Australia 26 October–6 November 2009* (paras 7.1). Hobart, Australia: CCAMLR.

CCAMLR. (2010). *Statistical bulletin 22*. Hobart, Australia: CCAMLR.

CCAMLR. (2011a). *Report of the thirtieth meeting of the commission*, *Hobart*, *Australia 24 October–4 November 2011* (para 2.7). Hobart, Australia: CCAMLR.

CCAMLR. (2011b). *Statistical bulletin 23*. Hobart, Australia: CCAMLR.

CCAMLR. (2011c). *Report of the thirtieth meeting of the commission*, *Hobart*, *Australia 24 October–4 November 2011* (paras 9.2 & 9.6). Hobart, Australia: CCAMLR.

CCAMLR. (2012). *Statistical bulletin 24*. Hobart, Australia: CCAMLR.

CCAMLR Performance Review Panel. (2008). *Report of the CCAMLR performance review panel*. Hobart, Australia: CCAMLR.

Clapham, P., Childerhouse, S., Gales, N., Rojas, L., Tillman, M., & Brownell, R. (2007). The whaling issue: Conservation, confusion and casuistry. *Marine Policy, 31*(3), 314–319.

Clark, C. W. (2009). Challenges in marine capture fisheries. In R. Q. Grafton, R. Hilborn, D. Squires, M. Tait, & M. Williams (Eds.), *Handbook of marine fisheries conservation and management* (pp. 638–645). USA: Oxford University Press.

Constable, A. J. (2011). Lessons from CCAMLR on implementation of the ecosystem approach to the management of fisheries. *Fish and Fisheries, 12*(2), 138–151.

Constable, A. J., de la Mare, W. K., Agnew, D. J., Everson, I., & Miller, D. G. M. (2000) Managing fisheries to conserve the Antarctic marine ecosystem: practical implementation of the Convention on the conservation of Antarctic marine living resources (CCAMLR). *ICES Journal of Marine Science, 57*, 778–791.

Cook, A. J., Poncet, S., Cooper, A. P. R., Herbert, D. J., & Christie, D. (2010). Glacier retreat on South Georgia and implications for the spread of rats. *Antarctic Science, 22*, 255–263.

Cooper, J. (1982). Methods of reducing mortality of seabirds caused by underwater blasting. *Cormorant, 10*, 109–113.

COMNAP. (2012a). *Main Antarctic facilities operated by national Antarctic programs in the Antarctic treaty area* (*South of 60º latitude south*). Retrieved from https://www.comnap.aq/Members/Shared%20Documents/Antarctic_Facilities_List_3Feb2012.xls.

COMNAP. (2012b). *COMNAP publications*. Retrieved from https://www.comnap.aq/Publications/SitePages/Home.aspx.

COMNAP/SCAR. (2010). *Checklists for supply chain managers of national Antarctic programs to reduce the risk of transfer of non-native species*. Retrieved from https://www.comnap.aq/Publications/Comnap%20Publications/Forms/DispForm.aspx?ID=51.

Cowan, D. A., Chown, S. L., Convey, P., Tuffin, M., Hughes, K. A., Pointing, S., et al. (2011). Non-indigenous microorganisms in the Antarctic: Assessing the risks. *Trends in Microbiology, 19*(11), 540–548.

Croxall, J. P., & Nicol, S. (2004). Management of Southern Ocean fisheries: Global forces and future sustainability. *Antarctic Science, 16*, 569–584.

Curry, C. H., McCarthy, J. S., Darragh, H. M., Wake, R. A., Todhunter, R., & Terris, J. (2002). Could tourist boots act as vectors for disease transmission in Antarctica? *Journal of Travel Medicine, 9*, 190–193.

de Villiers, M. S. (2008). *Review of recent research into the effects of human disturbance on wildlife in the Antarctic and sub-Antarctic region*. Appendix I to Working Paper 12 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine, 2–13 June 2008.

Emslie, S. D., & Patterson, W. P. (2007). Abrupt recent shift in 13C and 15 N values in Adélie penguin eggshell in Antarctica. *Proceedings of the National Academy of Sciences of the USA, 104*, 1666–1669.

Eppley, Z. A., & Rubega, M. A. (1989). Indirect effects of an oil spill. *Nature, 340*, 513.

Eppley, Z. A., & Rubega, M. A. (1990). Indirect effects of an oil spill: reproductive failure in a population of South Polar skuas following the 'Bahia Paraiso' oil spill in Antarctica. *Marine Ecology Progress Series, 67*, 1–6.

Fabra, A., & Gascón, V. (2008). The convention on the conservation of Antarctic marine living resources (CCAMLR) and the ecosystem approach. *The International Journal of Marine and Coastal Law, 23*(3), 567–598.

Fosså, J. H., & Skjoldal, H. (2009). Conservation of cold water Coral Reefs in Norway. In R. Q. Grafton, R. Hilborn, D. Squires, M. Tait, & M. Williams (Eds.), *Handbook of marine fisheries conservation and management* (pp. 215–230). USA: Oxford University Press.

Fraser, W. R., & Trivelpiece, W. Z. (1994). *Report of workshop on researcher-seabird interactions, July 15–17 1993, Monticello, Minnesota USA*. Arlington, VA: National Science Foundation.

Frenot, Y., Chown, S. L., Whinam, J., Selkirk, P., Convey, P., Skotnicki, M., et al. (2005). Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews, 80*, 45–72.

Frenot, Y., Convey, P., Lebouvier, M., Chown, S. L., Whinam, J., Selkirk, P. M., et al. (2008). Antarctic biological invasions: sources, extents, impacts and implications. In M. Rogan-Finnemore (Ed.), *Non-native species in the Antarctic* (pp. 53–96). Christchurch, New Zealand: Gateway Antarctica.

Gales, N. J., Kasuya, T., Clapham, P., & Brownell, R. L. (2005). Japan's whaling plan under scrutiny: useful science or unregulated commercial whaling? *Nature, 435*, 883–884.

Goldsworthy, L., & Hemmings, A. D. (2009). The Antarctic protected area approach. In S. Hart (Ed.), *Shared resources*: *Issues of governance* (pp. 105–128). IUCN Environmental Policy and Law Paper No. 72. Gland, Switzerland: International Union for Conservation of Nature.

Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings–entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society Series B, 364*, 2013–2025.

Grant, S. M., Convey, P., Hughes, K. A., Phillips, R. A., & Trathan, P. N. (2012). Conservation and management of Antarctic ecosystems. In A. D. Rogers, N. M. Johnston, E. J. Murphy, & A. Clarke (Eds.), *Antarctic Ecosystems: An Extreme Environment in a Changing World*. Chichester, UK: John Wiley & Sons.

Grimaldi, W., Jabour, J., & Woehler, E. J. (2010). Considerations for minimising the spread of infectious disease in Antarctic seabirds and seals. *Polar Record, 240*, 56–66.

Gröndahl, F., Sidenmark, J., & Thomsen, A. (2008). Survey of waste water disposal practices at Antarctic research stations. *Polar Research, 28*(2), 298–306.

Guinet, C., & Tixier, P. (2011). Crozet killer whales: a remote but changing environment. *Journal of the American Cetacean Society, 40*, 33–38.

Hale, R. C., Kim, S. L., Harvey, E., La Guardia, K. J., Mainor, T. M., Bush, E. O., et al. (2008). Antarctic research bases: local sources of Polybrominated Diphenyl Ether (PBDE) flame retardants. *Environmental Science and Technology, 42*, 1452–1457.

Halpern, B. S., McLeod, K. L., Rosenberg, A. A., & Crowder, L. B. (2008a). Managing for cumulative impacts in ecosystem-based management through ocean zoning. *Ocean and Coastal Management, 51*, 203–211.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., d'Agrosa, C., et al. (2008b). A global map of human impact on marine ecosystems. *Science, 319*, 948–952.

Headland, R. K. (2009). Antarctic winter scientific stations to the International Polar Year, 2007–2009. *Polar Record, 232*, 9–24.

Harris, C. M. (Ed.) 2006. *Wildlife Awareness Manual: Antarctic Peninsula, South Shetland Islands, South Orkney Islands*. Wildlife Information Publication No 1. Prepared for the UK Foreign & Commonwealth Office and HMS Endurance. Environmental Research & Assessment, Cambridge, UK, pp. 136.

Headland, R. K. (2012). History of exotic terrestrial mammals in Antarctic regions: A further note. *Polar Record, 48*, 144.

Hemmings, A. D. (2011a). Environmental law–Antarctica. In K. Bosselmann, D. S. Fogel & J. B. Ruhl (Eds.), *The law and politics of sustainability* (pp. 188–194). Volume 3 of the Berkshire Encyclopedia of Sustainability. Great Barrington, MA: Berkshire.

Hemmings, A. D. (2011b). Why did we get an international space station before an international Antarctic station? *The Polar Journal, 1*, 5–16.
Hemmings, A. D., & Kriwoken, L. K. (2010). High level Antarctic EIA under the Madrid Protocol: state practice and the effectiveness of the comprehensive environmental evaluation process. *Journal of International Environmental Agreements: Politics, Law & Economics, 10*, 187–208.
Hemmings, A. D., & Roura, R. (2003). A square peg in a round hole: Fitting impact assessment under the Antarctic environmental protocol to Antarctic tourism. *Impact Assessment and Project Appraisal, 21*, 13–24.
Hemmings, A. D., & Stephens, T. (2010). The extended continental shelves of sub-Antarctic islands: implications for Antarctic governance. *Polar Record, 46*, 312–327.
Hoegh-Guldberg, O., & Bruno, J. F. (2010). The impact of climate change on the world's marine ecosystems. *Science, 328*, 1523–1528.
Hoek, A. (2010). Sea Shepherd Conservation Society vs. Japanese Whalers, the showdown: Who is the real villain? *Stanford Journal of Animal Law & Policy, 3*, 159–171.
Hofman, R. J. & Jatko, J. (Eds.). (2000). *Assessment of the possible cumulative impacts of commercial ship-based tourism in the Antarctic Peninsula area*. Proceedings of a workshop held in La Jolla, California, 7–9 June 2000. Arlington, VA: National Science Foundation
Hofmeyr, G. J., Bester, M. N., Kirkman, S. P., Lydersen, C., & Kovacs, K. (2006). Entanglement of Antarctic fur seals at Bouvetøya, Southern Ocean. *Marine Pollution Bulletin, 52*, 1077–1080.
Howard-Williams, C., Peterson, D., Lyons, W. B., Cattaneo-Vietti, R., & Gordon, S. (2006). Measuring ecosystem response in a rapidly changing environment: the Latitudinal Gradient Project. *Antarctic Science, 18*, 465–471.
Hughes, K. A., & Convey, P. (2010). The protection of Antarctic terrestrial ecosystems from inter- and intra-continental transfer of non-indigenous species by human activities: A review of current systems and processes. *Global Environmental Change, 20*, 96–112.
Hughes, K. A., & Convey, P. (2012). Determining the native/non-native status of newly discovered terrestrial and freshwater species in Antarctica–current knowledge, methodology and management action. *Journal of Environmental Management, 93*(1), 52–66.
Hughes, K. A., Convey, P. & Huiskes, A. H. L. (2013). Global movement and homogenisation of biota: challenges to the environmental management of Antarctica? In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures*: *Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer-Verlag.
Hughes, K. A., Lee, J. E., Tsujimoto, M., Imura, S., Bergstrom, D. M., Ware, C., et al. (2011). Food for thought: risks of non-native species transfer to Antarctica with fresh produce. *Biological Conservation, 144*, 1682–1689.
IAATO. (2008). *Land-based tourism and the development of land-based tourism infrastructure in Antarctica*: *An IAATO perspective*. Information Paper 84 Presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine, 2–13 June 2008.
IAATO. (2010). *IAATO guidelines to minimize seabirds landing on ships*. Information Paper 24 Presented at XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay, 3–14 May 2010.
IAATO. (2012a). *Tourism statistics*. *Tourism Summary 2010–2011*. Retrieved from http://iaato.org/tourism-statistics;jsessionid=50735A39CD0151AA4A12E6D2DE8406CD.
IAATO. (2012b). *By-laws*, *Article X*: *Operational procedures*. Retrieved from http://iaato.org/bylaws#article10.
IAATO. (2012c). *Guidelines and resources*. Retrieved from http://iaato.org/guidelines-and-resources.
ICJ. (2012). *Whaling in the Antarctic*, *Australia vs*. *Japan*. Documents retrieved from http://www.icj-cij.org/docket/index.php?p1=3&p2=3&code=aj&case=148&k=64.
IWC. (2012). *Status of whales*: *A simple overview of the status of whales by species and ocean basin*. Retrieved from http://iwcoffice.org/conservation/status.htm.
Ivar do Sul, J. A., Barnes, D., Costa, M. F., Convey, P., Costa, E. S., & Campos, L. (2011). Plastics in the Antarctic environment: Are we looking only at the tip of the iceberg? *Oecologia Australis, 15*(1), 150–170.

Jabour, J. (2009). National Antarctic programs and their impact on the environment. In K. R. Kerry & M. J. Riddle (Eds.), *Health of Antarctic wildlife: a challenge for science and policy* (pp. 211–229). Berlin-Heidelberg, Germany: Springer-Verlag.

Jabour, J. (2012a). The value of official Antarctic inspections: Symbolism without sanction. In D. Liggett, A. D. Hemmings, & G. Steel (Eds.), *Exploring Antarctic values*. Christchurch, New Zealand: University of Canterbury, Gateway Antarctica Special Publication Series.

Jabour, J. (2012b). Maritime security: Investing in safe shipping operations to help prevent marine pollution. In A. D. Hemmings, D. R. Rothwell, & K. N. Scott (Eds.), *Antarctic Security in the twenty-first century: Legal and policy perspectives* (pp. 238–256). London: Routledge.

Jabour, J. (2013). Strategic management and regulation of Antarctic tourism. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures*: *Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer-Verlag.

Jenouvrier, S., Caswell, H., Barbraud, C., Holland, M., Stoeve, J., & Weimerskirch, H. (2009). Demographic models and IPCC climate projections predict the decline of an emperor penguin population. *Proceedings of the National Academy of Sciences of the USA, 106*, 1844–1847.

Johnstone, G. W. (1985). Threats to birds on subantarctic islands. In P. J. Moors (Ed.), *Conservation of island birds* (pp. 101–121)., ICBP Technical Publication 3 Cambridge, UK: International Council for Bird Preservation.

Jones, H. P., Tershy, B. R., Zavaleta, E. S., Croll, D. A., Keitt, B. S., Finkelstein, M. E., et al. (2008). Severity of the effects of invasive rats on seabirds: A global review. *Conservation Biology, 22*, 16–26.

Jones, M. G. W., & Ryan, P. G. (2010). Evidence of mouse attacks on albatross chicks on sub-Antarctic Marion Island. *Antarctic Science, 22*, 39–42.

Kawaguchi, S., Nicol, S., & Press, A. J. (2009). Direct effects of climate change on the Antarctic krill fishery. *Fisheries Management and Ecology, 16*, 424–427.

Kawaguchi, S., Kurihara, H., King, R., Hale, L., Berli, T., Robinson, J. P., et al. (2011). Will krill fare well under Southern Ocean acidification? *Biology Letters, 7*, 288–291.

Kennicutt, M. C., I. I. (Ed.). (1996). *Monitoring of environmental impacts from science and operations in Antarctica*. College Station, TX: Texas A&M University for SCAR and COMNAP.

Kennicutt, M. C., I. I., & Sweet, S. T. (1992). Hydrocarbon contamination on the Antarctic Peninsula III. The Bahia Paraiso—two years after the spill. *Marine Pollution Bulletin, 25*(9–12), 303–306.

Kennicutt, M. C., Klein, A., Montagna, P., Sweet, S., Wade, T., Palmer, T., et al. (2010). Temporal and spatial patterns of anthropogenic disturbance at McMurdo Station Antarctica. *Environmental Research Letters, 5*, 034010. doi:10.1088/1748-9326/5/3/034010.

Kerr, R. A. (2010). Ocean acidification unprecedented, unsettling. *Science, 328*, 1500–1501.

Kerry, K. R., & Riddle, M. (2009). *Health of Antarctic wildlife: A challenge for science and policy*. Berlin-Heidelberg, Germany: Springer-Verlag.

Kerry, K., Riddle, M. & Clarke, J. (1998). *Diseases of Antarctic wildlife*. *A report for the Scientific Committee on Antarctic Research* (*SCAR*) *and the Council of Managers of National Antarctic Programs* (*COMNAP*). Retrieved from: http://cep.ats.aq/cep/MediaItems/ml_376365140972222_wp006eApp001.pdf.

Klein, A. G., Sweet, S. T., Kennicutt II, M. C., Wade, T. L., Palmer, T. A. & Montagna, P. (2013). Long term monitoring of human impacts to the terrestrial environment at McMurdo station. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.) *Antarctic futures*: *human engagement with the Antarctic environment.* Dordrecht, Netherlands: Springer-Verlag.

Koch, K.-H. (1992). *Antarctic fish and fisheries*. Cambridge, UK: Cambridge University Press.

Kompas, K., Grafton, R. Q., Van Ha, P., Che, N., & Chu, L. (2009). Bioeconomic modeling of marine reserves with environmental uncertainty. In R. Q. Grafton, R. Hilborn, D. Squires, M. Tait, & M. Williams (Eds.), *Handbook of marine fisheries conservation and management* (pp. 659–665). USA: Oxford University Press.

Leaper, R., & Miller, C. (2011). Management of Antarctic baleen whales amid past exploitation, current problems, emerging threats and complex marine ecosystems. *Antarctic Science, 23*(6), 503–529.

Leaper, R. & Childerhouse, S. (2013). Present and future conservation management of Antarctic baleen whales. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures*: *Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer-Verlag.

Lee, J. E., & Chown, S. L. (2007). *Mytilus* on the move: transport of an invasive bivalve to the Antarctic. *Marine Ecology Progress Series, 339*, 307–310.

Lee, J. E., & Chown, S. L. (2009). Temporal development of hull-fouling assemblages associated with an Antarctic supply vessel. *Marine Ecology Progress Series, 386*, 97–105.

Liggett, D., McIntosh, A., Thompson, A., Storey, B., & Gilbert, N. (2010). Stakeholder perspectives on the governance of Antarctic cruise tourism. In M. Lück, P. T. Maher, & E. Stewart (Eds.), *Cruise tourism in Polar Regions: Promoting environmental and social sustainability* (pp. 167–179). London: Earthscan.

Longhurst, A. (2010). *Mismanagement of marine fisheries*. Cambridge, UK: Cambridge University Press.

Lynch, H. J., Crosbie, K., Fagan, W. F., & Naveen, R. (2010). Spatial patterns of tour ship traffic in the Antarctic Peninsula region. *Antarctic Science, 22*(2), 123–130.

Marschoff, E. R., Barrera-Oro, E. R., Alescio, N. S., & Ainley, D. G. (2012). Slow recovery of previously depleted demersal fish at the South Shetland Islands, 1983–2010. *Fisheries Research, 125*(126), 206–213.

Marsden, S. (2011). Introducing strategic environmental assessment to the Madrid Protocol: Lessons from international experience. *The Polar Journal, 1*, 36–50.

McCurry, J. (2012, February 24). Amazon removes whale meat products from Japanese site. *The Guardian*. Retrieved from http://www.guardian.co.uk/environment/2012/feb/24/amazon-whale-meat-japan.

Melvin, E. F., & Baker, G. B. (2006). *Summary report*: *seabird bycatch mitigation in pelagic longline fisheries workshop*. Museum of Natural History, Hobart, Tasmania, October 14, 2006. Seattle, WA: Washington Sea Grant, University of Washington

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

Miller, D. G. M. (2011). Sustainable management in the Southern Ocean: CCAMLR science. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science, and the governance of international spaces* (pp. 103–121). Washington, D.C.: Smithsonian Institution.

Miller, D. G. M. (2013). Antarctic marine living resources – 'the future is not what it used to be'. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures*: *Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer-Verlag.

Morato, T., Watson, R., Pitcher, T. J., & Pauly, D. (2006). Fishing down the deep. *Fish and Fisheries, 7*, 24–34.

Morrison (2006). Initial environmental evaluation for proposed reintroduction of hydro electric power at Grytviken, South Georgia. Stanley, Falkland Islands: Morrison Construction Services Ltd

Murray, C., & Jabour, J. (2004). Independent expeditions and Antarctic tourism policy. *Polar Record, 40*, 309.

Naveen, R. (1996). Human activity and disturbance: building an Antarctic site inventory. In R. Ross, E. Hofman, & L. Quetin (Eds.), *Foundations for ecosystem research in the western Antarctic Peninsula region* (pp. 389–400). Washington, DC: American Geophysical Union.

New Zealand (2009). *Updated analysis of representation of Annex V categories and environmental domains in the system of Antarctic specially protected and managed Areas*. Working Paper 3 Presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, 6–17 April 2009.

New Zealand (2005). *A review of the Antarctic protected area system*. Working Paper 11 Presented at XXVIII Antarctic Treaty Consultative Meeting, Stockholm, Sweden, 6–17 June 2005.

Nicol, S., Bowie, A., Jarman, S., Lannuzel, D., Meiners, K. M., & van der Merwe, P. (2010). Southern Ocean iron fertilization by baleen whales and Antarctic krill. *Fish and Fisheries, 11*, 203–209.

Nicol, S., Foster, J., & Kawaguchi, S. (2012). The fishery for Antarctic krill—recent developments. *Fish and Fisheries, 13*(1), 30–40.

Orheim, O., Press, A., & Gilbert, N. (2011). Managing the Antarctic environment—the evolving role of the committee for environmental protection. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. Young (Eds.), *Science diplomacy Antarctica, science, and the governance of international spaces*. Washington, D.C: Smithsonian Institution Scholarly Press.

Pauly, D., Alder, J., Bennett, E., Christensen, V., Tyedmers, P., & Watson, R. (2003). The future for fisheries. *Science, 302*, 1369–1361.

Peter, H. -U., Buesser, C., Mustafa, O., & Pfeiffer, S. (2008). *Risk assessment for the fildes Peninsula and Ardley Island, and development of management plans for their designation as specially protected or specially managed areas*. Dessau, Germany: German Environmental Agency. Retrieved from http://www.umweltdaten.de/publikationen/fpdf-l/3478.pdf.

Roeschke, J. E. (2009). Eco-terrorism and piracy on the high seas: Japanese whaling and the rights of private groups to enforce international conservation law in neutral waters. *The Villanova Environmental Law Journal, 20*(1), 99–136.

Rothwell, D. (2012, January 13). Our government fiddles as Japan makes a mockery of the whale sanctuary. *National Times*. Retrieved from http://www.nationaltimes.com.au/opinion/politics/our-government-fiddles-as-japan-makes-a-mockery-of-the-whale-sanctuary-20120112-1pxf7.html.

Roura, R., & Hemmings, A. D. (2011). Realising strategic environmental assessment in Antarctica. *Journal of Environmental Assessment Policy and Management, 13*, 483–514.

Ruoppolo, V., Woehler, E. J., Morgan, K., & Clumpner, C. J. (2012). Wildlife and oil in the Antarctic: a recipe for cold disaster. Polar Record. doi:10.1017/S0032247411000763.

Sandelson, M. (2011, March 3). Berserk's captain could face charges. *The Foreigner*. Retrieved from http://theforeigner.no/pages/news/berserks-captain-could-face-charges/.

Sánchez, R. A., & Njaastad, B. (2013). Future challenges in environmental management of National Antarctic Programs. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures*: *Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer-Verlag.

SCAR. (2006). *SCAR report on marine acoustics and the Southern Ocean*. Working Paper 41 Presented at XXIX Antarctic Treaty Consultative Meeting, Edinburgh, UK, 12–23 June, 2006.

SCAR. (2009). *SCAR's environmental code of conduct for terrestrial scientific field research in Antarctica*. Information Paper 4 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, 6–17 April, 2009.

SCAR. (2010). *Current knowledge for reducing risks posed by terrestrial non-native species*: *towards an evidence-based approach*. Working Paper 6 Presented at XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay, 3–14 May, 2010.

SCAR. (2011a). *SCAR'S code of conduct for the exploration and research of subglacial aquatic environments*. Information Paper 33 Presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, 20 June–1 July, 2011.

SCAR. (2011b). *SCAR'S code of conduct for the use of animals for scientific purposes in Antarctica*. Information Paper 53 Presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, 20 June–1 July, 2011.

SC-CCAMLR. (2010a). *Report of the twenty-ninth meeting of the scientific committee*, *Hobart*, *Australia 25–29 October 2010* (para 6.6). Hobart, Australia: CCAMLR.

SC-CCAMLR. (2010b). *Report of the twenty-ninth meeting of the scientific committee*, *Hobart*, *Australia 25–29 October 2010* (para 3.10). Hobart, Australia: CCAMLR.

Shears, J. R., Downie, R. H., & Malaos, A. M. (2007). *Oil spill contingency plan: rothera research station*. Cambridge, UK: British Antarctic Survey.

Siniff, D. B., Garrott, R. A., Rotella, J. J., Fraser, W. R., & Ainley, D. G. (2008). Projecting the effects of environmental change on Antarctic seals. *Antarctic Science, 20*, 425–435.

Smith, J. J., & Riddle, M. (2009). Sewage disposal and wildlife health in Antarctica. In K. R. Kerry & M. Riddle (Eds.), *Health of Antarctic wildlife: A challenge for science and policy* (pp. 271–315). Berlin Heidelberg, Germany: Springer.

Stewart, E. J., Draper, D. L., & Johnston, M. E. (2005). Tourism research in the Polar Regions. *Arctic, 58*(4), 383–394.

Summerson, R., & Riddle, M. J. (2000). Assessing wilderness and aesthetic values in the Antarctic. In W. Davison, C. Howard-Williams, & P. Broady (Eds.), *Antarctic ecosystems: Models for wider ecological understanding* (pp. 303–307). Christchurch, New Zealand: University of Canterbury.

Terauds, A., Chown, S. L., Morgan, F., Peat, H. J., Watts, D. J., Keys, H., et al. (2012). Conservation biogeography of the Antarctic. *Diversity and Distributions, 18*(7), 726–741.

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., et al. (2009). Impacts of local human activities on the Antarctic environment. *Antarctic Science, 21*, 3–33.

Tin, T., Sovacool, B. K., Blake, D., Magill, P., El Naggar, S., Lidstrom, S., et al. (2010). Energy efficiency and renewable energy under extreme conditions: Case studies from Antarctica. *Renewable Energy, 35*(8), 1715–1723.

Tin, T., Lamers, M., Liggett, D., Maher, P.T., & Hughes, K. A. (2013) Setting the scene: Human activities, environmental impacts and governance arrangements in Antarctica. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures*: *Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer-Verlag.

Trathan P. N., Ratcliffe N. & Masden E. A. (2012). Ecological drivers of change at South Georgia: The krill surplus, or climate variability. *Ecography*. doi:10.1111/j.1600-0587.2012.07330.x.

Trivelpiece, W. Z., Jefferson, I., Hinke, T., Miller, A. K., Reissa, C. S., & Trivelpiece, S. G. (2011). Variability in krill biomass links harvesting and climate warming to penguin population changes in Antarctica. *Proceedings of the National Academy of Sciences of the USA, 109*(9), 3434–3439.

Tuck, G. N., Polacheck, T., & Bulman, C. M. (2003). Spatio-temporal trends of longline fishing effort in the Southern Ocean and implications for seabird bycatch. *Biological Conservation, 114*, 1–27.

Turner, J., Bindschadler, R., Convey, P., di Prisco, G., Fahrbach, E., Gutt, J., et al. (Eds.). (2009a). *Antarctic climate change and the environment*. Cambridge, UK: SCAR.

Turner, J., Comiso, J. C., Marshall, G. J., Lachlan-Cope, T. A., Bracegirdle, T., Maksym, T., Meredith, M. P. & Wang, Z. (2009b). Non-annular atmospheric circulation change induced by stratospheric ozone depletion and its role in the recent increase of Antarctic sea ice extent. *Geophysical Research Letters*, *36*, L08502, doi:10.1029/2009GL037524.

UNEP. (2002). *Regionally based assessment of persistent toxic substances*. *Antarctica–Regional Report*. Geneva, Switzerland: UNEP Chemicals.

van den Brink, N. W., & de Ruiter-Dijkman, E. M. (1997). Trans-nonachlor, octachlorostyrene, mirex and photomirex in Antarctic seabirds. *Antarctic Science, 9*, 414–417.

van Waerebeek, K., Baker, A. N., Félix, F., Gedamke, J., Iñiguez, M., Sanino, G. P., et al. (2007). Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals, 6*(1), 43–69.

Wilson, K.-J., Taylor, R. H., & Barton, K. J. (1990). The impact of man on Adélie Penguins at Cape Hallett, Antarctica. In K. R. Kerry & G. Hempel (Eds.), *Antarctic ecosystems: Ecological change and conservation* (pp. 183–190). Berlin-Heidelberg, Germany: Springer-Verlag.

Woehler, E. J. (2004). Hearing abilities in Antarctic penguins. *Polarforschung, 72*, 95–98.

Woehler, E. J. (2006). Status and conservation of the seabirds of Heard Island and the McDonald Islands. In K. Green & E. J. Woehler (Eds.), *Heard Island, Southern Ocean Sentinel* (pp. 128–165). Chipping Norton, Australia: Surrey Beatty and Sons.

WWF & Whale and Dolphin Conservation Society. (2009). *Sink or swim: The economics of whaling today*. Gland, Switzerland: WWF.

Chapter 3
Antarctic Marine Living Resources: 'The Future is not What it Used to be'

Denzil G. M. Miller

Abstract This chapter examines the notion that improperly managed marine living resource exploitation is a major challenge to the Antarctic marine ecosystem's future integrity and good function. The current marine living resource harvesting, management and governance prevailing in the Antarctic is outlined. The key objectives of the Convention on the Conservation of Antarctic Marine Living Resources are highlighted, as is the role of its attached Commission (CCAMLR) in developing and promulgating ecosystem-based and precautionary management measures. A brief history of the Antarctic krill fishery is provided in the context of its dominant trends, potentially attendant global circumstances and possible harvest effects. Similarly, a summary of CCAMLR management actions outlines the current management regime for regulating the krill fishery. Key areas identified include the application of small-scale management units and ecosystem conservation/environmental protection measures. The latter include CCAMLR-sponsored activities associated with ecosystem assessment, environmental protection from fishing activities, small-scale research units to spread harvest risk, marine protected areas to conserve biodiversity, avoidance of damage to vulnerable marine ecosystems and mitigating potential climate change effects. In terms of predicting potential future trends for the Antarctic ecosystem in general, and krill fishery in particular, the future is contrasted to the past. Management achievements, failures and threats are identified. These are analysed in an objectively-based process to assess risk, uncertainty and the future in terms of a krill sustainability framework addressing ecological, social-ecological and socio-economic considerations. Key predicted impacts and ecosystem performance breakdowns comprise the following, in priority order: **climate change, increased uncertainty, harvested stock sustainability, political will and compliance enforcement**. Recognising that both effective governance and cost-efficient environmental management are at the center of sustainably managing Antarctic marine living resources and protecting their associated ecosystems in the future, a number of suggestions for further consideration are identified.

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3.1 Introduction

Clarke and Harris (2003) suggest that improperly managed marine living resources are a major threat to the future integrity of the Antarctic[1] marine ecosystem. In their view, 'the future of stocks will depend on the ability of various regulatory bodies to develop and implement sustainable fishery regimes' (Clarke and Harris 2003, p. 21). Furthermore, Clarke and Harris anticipate that cumulative impacts from multiple sources, such as climate change and other environmental impacts (e.g. pollution, tourism, support activities (including science) and mineral exploitation), will also influence Antarctic marine ecosystem functioning.

Trathan and Reid (2009) highlight an earlier view (Croxall et al. 2002) that historic Antarctic marine living resource exploitation patterns confound interpretations of potential climate change effects on the ecosystem(s) concerned. For example, observed krill (*Euphausia superba*) population decreases (Atkinson et al. 2004, 2009) may indicate increased predator pressure on krill associated with post-exploitation restoration of Southern Ocean[2] whale and seal populations. Equally, they may reflect lower krill recruitment levels attributable to climate-induced reduction of sea-ice. Such conclusions reflect those for the Icelandic herring fishery, where high levels of marine exploitation elsewhere have acted in concert with environmental pressures to compromise fishery yields (Drinkwater 2002; Perry et al. 2010). Similar environmental-fishery antecedents were implicated in the collapse of Atlantic cod (Perry et al. 2010).

These examples highlight the potential dangers of mismatches between the scales over which management decisions are taken concerning harvested stock sustainability, the dynamics of the stock itself and socio-economic needs. Perry and Ommer (2003) note that mismatches generally occur within 'social-ecological' systems. They are usually derived from inherent conflicts between economic expectations and the biological productivity limits of exploited 'wild' resources. This implies that assessment of future fisheries impacts is an uncertain 'art', particularly when faced with limited knowledge about socio-economic dynamics, and the potential ecological or environmental, impacts of the fishery concerned.

[1] The Antarctic (and 'Southern Ocean'), its marine ecosystems and its marine living resources are considered to be situated south of 60°S Lat. and in the area between that latitude and the Antarctic Convergence as per Article I of the 1980 Convention on the Conservation of Antarctic Marine Living Resources ('CAMLR Convention or the Convention')—Retrieved from http://www.ccamlr.org/en/organisation/camlr-convention-text. References to 'Antarctic' marine living resources, fisheries etc. are made interchangeably with 'Southern Ocean' marine living resources, fisheries etc.

[2] Taken to be the oceanic area in which the Antarctic marine ecosystem is located.

An additional complication is that, like many high seas fisheries (Pauly et al. 1998; Zeller and Pauly 2007), Antarctic marine harvesting has tended to fish 'down-the-food chain' from high-value to lesser-value species (Miller 1991, 2007). Consequently the risk of overexploiting target stocks has increased in respect to the biological capital available; a situation aggravated for high seas stocks, which often comprise slow-growing, long-lived species (Cochrane and Doulman 2005; Pauly et al. 2005). In turn, the ecological risks of over-exploitation are progressively magnified by long-term biological effects attributable to diminishing stock productivity, ecosystem/biodiversity impacts and genetic variability arising from fishing impacts (Allsopp et al. 2009). The interactive accumulation of these effects leads to ecosystem functional changes that are long-lasting, hard to reverse and usually detrimental. Once such 'tipping points' are reached, they challenge the ability of the fishery, the 'human-environmental system', to adapt to consequent climate regime shifts (CBD 2010). The increased likelihood of stock collapses, and fishing-down-the-food-chain mandate that high seas capture fisheries need to be considered in all their human, economic, social, biological and ecological dimensions (Cochrane and Doulman 2005).

This chapter focuses on the future of the Southern Ocean krill fishery, particularly in light of the serious threat posed by unsustainable regulation of the fishery and the attached consequences for the Antarctic marine ecosystem as a whole. Special consideration is given to the sustainable management of the Southern Ocean krill (*Euphausia superb*) fishery and the challenges it faces. Future krill fishing scenarios are analysed and exploitation management outcomes likely to arise from application of Convention principles are discussed. The attached analyses address the question 'How will the future be different from the past?'

3.1.1 Harvesting, Management and Governance Regime

The Southern Ocean largely comprises the 'high seas', as per Part VII, Sect. 2 of the 1982 United Nations Convention on the Law of the Sea (UNCLOS). Under UNCLOS Article 116, the right to fish the high seas is moderated by a requirement for States to cooperate in taking and supporting measures necessary for the conservation of the resources being exploited. These conditions are largely applicable in the CAMLR Convention Area, but there are some exceptions.

The area south of 60°S Lat. (including all ice shelves) falls under the 1959 Antarctic Treaty (the 'Treaty'), where Article IV effectively 'freezes' all claims to territorial sovereignty in the Treaty Area (Hemmings 2007). This implies that there are no Coastal States to exercise national sovereignty in waters adjacent to national territories south of 60°S Lat. Furthermore, Treaty Article VI clearly indicates that nothing in the Treaty 'shall prejudice or in any way affect the rights, or the exercise of the rights, of any State under international law with regards to the high seas in the area'.

Together, these provisions imply that CCAMLR[3] management measures[4] apply throughout the Treaty Area on the high seas and elsewhere. Convention Articles III to V outline a delicate relationship between the Convention and the Treaty concerning sovereignty in the Treaty Area. This means that the provisions of Treaty Article VI apply to CCAMLR Contracting Parties, whether they are parties to the Treaty or not. Therefore, Treaty Article IX (1)(f) implies that all Convention Contracting Parties are bound to further the Treaty's objectives, specifically including measures regarding 'preservation and conservation of living resources' in the Treaty Area.

However, certain Southern Ocean Islands are subject to undisputed territorial sovereignty in the Convention Area north of 60°S Lat. These 'Coastal States' enjoy all the rights and obligations attached to their adjacent 'territorial seas' (UNCLOS Article 2 and 3), and insofar as such rights are extended to the attached Exclusive Economic Zones (EEZs) under UNCLOS Part V (Articles 56, 58 and 61–62 in particular). Consequently, CCAMLR Coastal States rightly determine allowable catches (Article 61) and promote optimum utilisation of living resources (Article 62) in their EEZs as they see fit. They also determine which other States fish therein.

To ensure harmony between CCAMLR-adopted management measures and those applied by Coastal States in their waters within the Convention Area, the CCAMLR Chairman's Statement[5] provides a legal framework for how this should be done. Nonetheless, two CCAMLR Coastal States often reserve their positions on application of CCAMLR CMs in their Southern Ocean EEZs north of the Antarctic Treaty Area. This has raised questions about the EEZs concerned.

The Treaty's unique solution to potentially contentious sovereignty issues south of 60°S Lat. is preserved in its various daughter instruments[6]. In particular, the Madrid Protocol and the Convention reflect the interconnected nature of Antarctica's ecosystems, both south and north of 60°S Lat., and highlight 'protection of the Antarctic environment' and 'related ecosystems'. The preservation and conservation of Antarctic living resources under Treaty Article IX(1)(f) is a consistent theme of such protection.

Aside from the Antarctic Treaty System (ATS), various other international agreements apply directly, or indirectly, to the Southern Ocean and many exhibit concern for its environmental wellbeing (see Miller 2000: Appendix F). These agreements address matters such as environmental protection, environmental management, mutual security, scientific information exchange and regional governance. The most notable

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[3] The acronym 'CCAMLR' refers to the Commission for the Conservation of Antarctic Marine Living Resources established under Article VII of the Convention. Only Members of the Commission are able to take part in decisions under Convention Article XII, the allocation of fishing opportunities is currently limited to Commission Members only/.

[4] CCAMLR management measures are adopted under Convention Article IX and are termed 'Conservation Measures' (CMs).

[5] http://www.ccamlr.org/en/organisation/camlr-convention-text#Chair.

[6] Collectively termed the 'Antarctic Treaty System' (ATS) and comprising the 1972 Convention on the Conservation of Antarctic Seals (CCAS), the CAMLR Convention and the 1991 Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol).

Southern Ocean applicable agreements include the 1946 International Convention for the Regulation of Whaling (ICRW), UNCLOS, 1992 Convention on Biological Diversity (CBD),[7] 1998 Protocol for the Prevention of Pollution from Ships (MARPOL),[8] 1993 Food and Agricultural Organization Agreement to Promote Compliance with International Conservation Measures by Fishing Vessels on the High Seas ('FAO Compliance Agreement')[9] and the 1995 United Nations Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNFSA)[10]. All these agreements strive to promote 'responsible' and sustainable marine living resource exploitation, while aiming to preserve environmental wellbeing and protect biodiversity in conformity with the Madrid Protocol and CBD in particular.

3.1.2 The CAMLR Convention

In the mid-1970s, Antarctic marine living resource exploitation expanded rapidly so that by the end of the decade several fish species, such as the Antarctic Marbled Rock Cod (Notothenia rossii), were severely depleted through over-fishing. These events were accompanied by growing concern that unregulated harvesting of a key food species like krill might place the entire Antarctic marine ecosystem at risk (Mitchell and Sandbrook 1980). With impetus provided by the Third United Nations Conference on the Law of the Sea (UNCLOS—III) negotiations, these concerns prompted the 1975 Eighth Antarctic Treaty Consultative Meeting (ATCM) to consider marine living resource conservation in the context of Treaty Article IX. Consequently, the recognised need for conservation of, and research into, krill, combined with interests outside the ATS[11] culminated in the Convention's signing on 20 May 1980. The Convention entered into force on 7 April 1982 and there are currently 36 Contracting Parties (CPs), 25 of which are Commission Members under Article VII[12].

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[7] Retrieved from http://www.cbd.int/doc/handbook/cbd-hb-01-en.pdf.

[8] MARPOL Annex V (Regulations for the Control of Pollution by Garbage from Ships) is particularly important.

[9] Retrieved from http://www.fao.org/docrep/meeting/003/x3130m/X3130E00.HTM.

[10] Retrieved from http://www.un.org/Depts/los/convention_agreements/texts/fish_stocks_agreement/CONF164_37.htm.

[11] In organisations such as Greenpeace International and the International Union for the Conservation of Nature (IUCN) (Parsons 1987). Relevant research was also being carried out by the Scientific Committee on Antarctic Research (SCAR) under the international Biological Investigations of Antarctic Marine Ecosystems and Stocks (BIOMASS) Program (El-Sayed 1994).

[12] Only Members of the Commission take decisions (Convention Articles VII and XII). The Commission (CCAMLR) serves as the executive arm responsible for implementing the Convention. It draws on scientific advice from a permanent Scientific Committee (SC-CAMLR) (Articles XIV and XV) and its day-to-day functions are supported by a permanent Secretariat (Articles XII and XVII).

The Convention is one of the few multi-lateral agreements in force that aims to conserve and manage marine living resource exploitation from an ecosystem-based and precautionary perspective (Miller 2000). Many of its key provisions complement the preservation and conservation principles of Treaty Article IX(1)(f) noted above. These principles are reflected in other ATS instruments, notably the 1964 Agreed Measures for the Conservation of Antarctic Fauna and Flora, Annex II of the Protocol and CCAS.

Much has been written about CCAMLR's management approach and its ecosystem antecedents (e.g. Agnew 1997; Constable et al. 2000; Everson 2002). An obvious and ongoing issue is how ecosystem (i.e. multi-species) considerations can be formally incorporated into CCAMLR management decisions (Constable 2005). Convention Article IX(1)(f) indicates that Conservation Measures (CMs) are to be formulated, adopted or revised on 'the basis of the best scientific evidence available'[13] subject to the provisions of paragraph 5 in the same Article. This requires that CCAMLR takes full account of any relevant measures or regulations adopted elsewhere (i.e. by other ATS instruments or fisheries commissions) when these are relevant to the CCAMLR Area.

An initial scientific hurdle facing CCAMLR was the requirement to address scale-driven organisation of species, particularly krill, in relation to a suite of spatially compatible, iterative, interactive and scientifically derived processes (Miller 2002: Fig. 6). In turn, these processes relate to the 'physical' (i.e. natural) and 'management' worlds, with the latter being limited to the activity of fishing itself. Consequently, the management of CCAMLR fisheries, as well as potentially affected ecosystem components, comprises a series of inter-dependent ecological associations of which fishing (Miller 2000, 2007), individual species, as well as their ecological interactions are bound in space and time (Miller 2002). By taking special account of key ecological factors, the approach facilitates assessment of 'ecosystem status' and 'health'.[14] It also promotes the scientific and systematic development of management measures for a sustainable krill fishery in particular (Constable 2002; Everson 2002; Miller 2002).

CCAMLR management decisions account for uncertainty associated with imperfect knowledge in terms of both science and process (Miller 2007; Constable 2011).

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[13] The term 'scientific evidence' in Convention Article IX(1)(f) implies a formative standing to scientific information, or advice, used by CCAMLR for management purposes. In 1990 (CCAMLR 1990), the Commission agreed that 'it should regard the Scientific Committee (SC-CAMLR) as the source of the best scientific evidence available'—an agreement that effectively endorses the provenance of the Committee's scientific advice to this day. SC-CAMLR was established under Article XIV of the Convention. It functions (Article XV) as a 'forum for consultation and co-operation concerning the collection, study and exchange of information' on the resources to which the Convention applies.

[14] CCAMLR views 'ecosystem health' as reflecting the adequacy of harvested species safeguards so that fishing does not prejudice the long-term future of dependent species. An 'ecosystem assessment' ensures that all Convention Article II management requirements of are operationally met (Everson 2002).

As far as possible, resource use is preceded, or accompanied, by surveys of exploited stocks to assess potential yield, to monitor resource status and to provide for associated analyses of ancillary (i.e. population) data. The approach recognises that the primary aim is not to manage the Antarctic marine ecosystem per se, but rather to regulate human activities (i.e. harvesting) therein. Scientific-based advice aims for operational outcomes that are repeatable and objective (Butterworth 1986).

The CCAMLR management approach thus comprises rules to adjust harvest levels, which in turn are based on scientifically objective assessments, (Kock 2001). The rules are sufficiently rigorous and flexible to ensure that conservation objectives have a high probability of being met. For its part, the CCAMLR Ecosystem Monitoring Programme (CEMP) aims to monitor ‘dependent and related species’ (predominantly krill predators) to assess the status (‘health’) of the Southern Ocean marine ecosystem (Everson 2002). Ideally, regular assessments account for uncertainty associated with ecosystem functioning, as well as potential relationships between resource monitoring and key ecosystem components and properties. The latter includes the physical environment. CEMP-based assessments focus on discerning changes in exploited stock status attributable to fishing as opposed to natural variability (Agnew 1997).

Over the years, CCAMLR has developed a comprehensive suite of CMs using various traditional fishery management[15] approaches. Currently, CMs are integrated to deal with a number of the management, including environmental, concerns highlighted by the Convention (e.g. Miller et al. 2004). These measures are kept under constant review to evaluate their performance and, if necessary, to provide for revision, or adoption, of new CMs. They have also served to improve management of key CCAMLR stocks globally; an approach most recently encapsulated in a suite of specific compliance and trade-related measures (Sabourenkov and Miller 2004).

3.2 Antarctic Marine Living Resources Exploitation

Despite its remoteness and inclement weather, the Southern Ocean has not escaped the ‘tragedy of the commons’, where little regulation or restraint are associated with immediate exploitation of newly discovered marine living resources (Agnew and Nicol 1996; McWhinnie 2007). Initially, opportunistic harvesting of seabirds, seabird eggs, seals and fish supplemented the food stores of ship-based exploratory expeditions (Laws 1989; Miller 2000). From the late 1800s onwards, four major phases of exploitation progressively targeted seals, whales, finfish and krill respectively (Knox 2006). With the exception of krill harvesting, each of these phases was characterised by unregulated harvesting. In the case of whales and finfish, later regulation was not sufficient to counter the decline of

[15] See http://www.ccamlr.org/en/conservation-and-management/conservation-measures.

target populations to near biological extinction and non-profitable levels (Sage 1985; Laws 1989). Given the many, and long-running, accounts of marine living resource exploitation in the Southern Ocean (e.g. Weddell 1827; Sage 1985; Laws 1989; Miller 1991; Clarke and Harris 2003; Miller 2007), the issue will not be elaborated further here. Rather, this chapter will focus on the most relevant and current phase of Southern Ocean living marine resource exploitation—krill harvesting. It aims to provide an overview of contemporary and future krill harvest trends, as well as related harvest effects.

3.2.1 Krill Harvest Trends

Exploratory fishing for krill was initiated by Japan and the Soviet Union in the early 1960s (Miller 1991), and a fully fledged experimental commercial fishery began in the summer of 1973/1974 (Nicol and Endo 1997; Miller and Agnew 2000). As highlighted in Fig. 3.1, between 1973 and 1994, catches rose steadily from 19,785 tonnes in 1973/1974 to a peak of 528,201 tonnes in 1981/1982. After 1982, catches declined sharply in 1983/1984 to a level (130,875 tonnes) similar to that during the triggering phase of the fishery's expansion in 1977/1978. They then increased to a second peak (446,673 tonnes) in 1985/1986 and subsequently plateaued at about 300,000–400,000 tonnes until the dissolution of the Soviet Union in 1991. The krill fishery in Subarea 48.1 (South Shetlands) was closed in 2009/2010 when the catch reached 99.8 % of the trigger level (155,000 tonnes) for that subarea under CCAMLR CMs 51-01 and 51-07 (CCAMLR 2010).[16] This was the first areal closure for krill fishing under apportioned trigger levels requirements introduced in 2009 (CM 51-07).

Nineteen countries have fished for krill. By 2008/2009, the former Soviet Union (Russia and Ukraine post-1992) States and Japan had taken the bulk (88 %) of the total krill catch (7.2 million tonnes) since 1972/1973. In descending order, Norway, Vanuatu, USA, Chile, Korea and Poland had accounted for a further 11.9 %. Other sporadic participants in the fishery have included Argentina, Bulgaria, the German Democratic Republic, India, Panama and the United Kingdom.

In the past decade, there has been a gradually increasing krill catch trend (Fig. 3.1) from close to 100,000 tonnes in 2000/2001 to more than 150,000 tonnes

[16] The 'trigger level' is used to allocate the total allocated areal krill catch between smaller management units in particular area (CCAMLR CM 51-01). Currently it is only applied in CCAMLR Statistical Area 48 (Subareas 48.1–48.4) and is aimed at distributing the krill catch to avoid predator populations, particularly land-based predators being disproportionately affected by fishing activity. The percentage proportions of the allocated catch in Area 48 to be applied when the subareal trigger level is reached are: Subarea 48.1(South Shetlands)—25%; Subarea 48.2 (South Orkneys)—45%; Subarea 48.3 (South Georgia)—45% and Subarea 48.4 (South Sandwich Islands)—15% (CCAMLR CM 51-07).

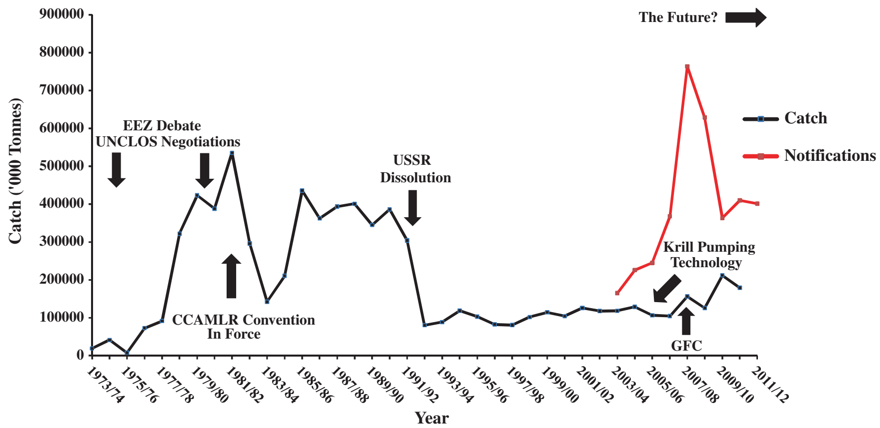

Fig. 3.1 Total krill catches reported to CCAMLR between 1973 and 2011. Also shown are notifications by CCAMLR members of anticipated catches (in tonnes) from one year to the next. Various events likely to have impacted the krill fishery are marked (*EEZ*—Exclusive Economic Zone; *GFC*—Global Financial Crisis)

in 2010/2011. This has been reflected by a substantial increase in pre-notified catch levels by CCAMLR Members from 150,000 tonnes in 2002/2003 to just below 900,000 tonnes in 2008/2009 (see Nicol et al. 2011). The increase in interest is reflected in the mix of nations and vessel types participating in the fishery, and it is attributable to increased catches associated with the recently developed continuous catch pumping method used by Norwegian krill fishing vessels since 2007 (Nicol et al. 2011).[17]

Until the early 2000s, krill products from the fishery were initially limited by cost, processing methods (Budzinski et al. 1985), and low demand for saleable products (livestock feed, human supplements and aquaculture feed) (Nicol and Endo 1997; Nicol and Foster 2003). The recent developments in fishing technology highlighted above have been accompanied by an expansion in the range of products extracted from the krill harvest in the recent past. This is manifested by increased demand from the aquaculture industry (Olsen et al. 2006) and through enhanced marketing of omega-3 rich krill oil supplements by the nutraceutical industry (e.g. Tandy et al. 2009). Such developments have led Nicol et al. (2011) to suggest that the nature of the Antarctic krill fishery is in flux and currently changing. While, it is generally perceived that current krill catches are relatively low compared to estimates of the species' potential yield (Miller and Agnew 2000), Nicol et al. (2011) further suggest that recent increased interest in the fishery is reflected by rapid diversification of krill products and a growing number

[17] The method appears to resolve some of the processing problems associated with the use of trawls (Anon 2007) and is referred to as 'eco-friendly trawling' due to its high selectivity and reduced spillage, or wastage, of the catch.

of krill fishing countries. Such developments all point towards the fishery greatly expanding in the short to medium-term. Equally, the recent Marine Stewardship Council (MSC) certification of krill has undoubtedly underscored the fishery's attraction to 'the environmentally conscious investor' (see Footnote 20).

Figure 3.1 illustrates the coincidental association of four major events with discernible changes in Southern Ocean krill catches. First, the late 1960s and early 1970s were characterised by considerable international debate about the concept of Exclusive Economic Zones (EEZs) as a mechanism to extend Coastal State fishing and other rights to 200 nautical miles offshore. The debate was central to the Third United Nations Conference on the Law of the Sea that culminated with UNCLOS in 1982. Consequently, the emerging and impending restrictions for EEZs can be viewed as an incentive for far seas fishing nations, such as the Soviet Union, to undertake unregulated fishing in open access fisheries, as they became progressively precluded from fishing in coastal waters. Increasing Antarctic krill catches were a manifestation of this expectation between 1973/1974.

The Convention's entry into force in early 1982 coincided with a decline in krill catches during 1983/1984. This was followed by catches reaching their highest levels in 1985/86 as it probably became clear that CCAMLR was unlikely to impose severe restrictions on fishing levels. Large krill catches (~300,000 tonnes/year) then prevailed until the Soviet Union's dissolution in 1991/1992, when there was a dramatic decline in catches to less than 100,000 tonnes in 1992/1993. With the Soviet Union being the dominant krill fishing nation at the time, economic uncertainty created by its demise and the loss of centralised fishing subsidies were reflected in the declining krill catch levels. Catches then fluctuated around 100,000 tonnes until 1999/2000. They remained around 120,000 tonnes until the introduction of the new Norwegian harvesting and processing techniques from about 2005 onwards.

The krill fishery's development was accompanied by a noticeable increase in catches to around 200,000 tonnes in the 2009/2010 season, when the South Shetland Islands environs (Subarea 48.1) were closed to krill fishing as the areal precautionary catch limit was reached. As already intimated, the period was also characterised by increasing pre-season notification of anticipated krill catch levels for the ensuing season. Therefore, a reduction of notifications between 2007/2008 and 2009/2010 probably reflects economic uncertainties associated with the emergence of the Global Financial Crisis (GFC) in 2008.

The patterns described suggest that Norwegian-pioneered fishing and processing techniques in recent years have favoured an expansion of krill catches, a pattern that is likely to persist in the foreseeable (2–5 years) future. Furthermore, the development of krill-focused bioprospecting for new products has also raised expectations of noticeable near-future increases in the fishery.[18] Together, these

[18] The increasing number of patents for krill-related products now stands in excess of 800, more than double those lodged in 1999 (Nicol et al. 2011).

considerations not only compound uncertainty about the krill fishery's future course, they also underscore the importance of having scientifically robust management procedures in place to manage the fishery.

Figure 3.1 emphasises that the krill fishery is sensitive to market and other economic, or political, forces. This has as much to do with the fishery's relative remoteness and inaccessibility as it does with the price of fuel and product demand (Nicol and Endo 1997). While the fishery remained at comparatively low levels for a number of years, the recent upward catch trend tends to reinforce the role played by the drivers of the fishery's expansion highlighted above. Coupled with the krill fishery becoming more competitive compared to other fisheries, there is good reason to assume that any future developments of a bulk-driven, high catch krill fishery will enhance the upward catch trends already observed.

Together with a diminishing availability of underexploited stocks elsewhere, it seems logical to assume that a fishery five times the current level (i.e. of the order of 1 million tonnes year^{-1}) is not an unrealistic expectation (Miller 2011a). This would place the krill fishery amongst the world's top ten for global catches from 'wild' stocks. While krill catches close to the estimated biomass are unlikely to be sustainable, there is considerable scope for expansion in the levels of krill fishing to date. As noted by Nicol et al. (2011) the persistent failure of CCAMLR to agree on how krill precautionary catch limits may be apportioned in terms of small-scale management units (SSMUs), or other criteria, remains a blight on the operational implementation of CCAMLR's precautionary approach for the fishery in terms of allowing for more rigorous conservation of available stocks and associated ecosystem components.

Finally, the possibility of future illegal, unregulated and unreported (IUU) krill fishing[19] is obviously a matter of concern. Given that considerable midwater trawling surplus capacity is available globally (Kirkley et al. 2002), the potential deployment of this capacity into a rapidly expanding krill fishery would not only expand the fishery's global market share, but also its inherent value. As for IUU fishing globally (Vidas 2004; Sumaila et al. 2006), the incentives for an IUU krill fishery would increase as a function of perceived advantages attached to fishing outside the 'system' (i.e. avoiding CCAMLR regulations). Such incentives largely enhance an expectation of greater economic returns and higher profit margins (Baird 2006). Along with the possibility that major krill fisheries will develop in the northern hemisphere (Nicol and Endo 1999), the emergence of an IUU krill fishery in the Southern Ocean cannot be ruled out. In effect, deployment of krill fishing effort would become a global affair as it could operate year round during the summer months in both the northern and southern hemispheres.

[19] The term 'IUU fishing' was initially proposed by CCAMLR in 1996, It was subsequently defined formally in the 2001 FAO International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU) (At: http://www.fao.org/docrep/003/y1224e/y1224e00.HTM). For a full account of IUU fishing in the CCAMLR Area, see Baird (2006).

3.2.2 Harvest Effects

In spite of early fears, indications of negative effects attributable to krill fishing are largely equivocal. However, concerns have been expressed for some time that over-concentration of the fishery in areas where krill predators, especially land-based predators, are concentrated may cause short-to-medium term negative impacts on associated predators (Miller and Hampton 1989; Hewitt and Linen Low 2000; Nicol et al. 2011). Equally, concerns are growing over the ecological uncertainties likely to arise from 'fishing down the Antarctic marine food web, given krill's relatively low trophic status and its standing as a key food item' (Nicol et al. 2011). A noticeable avenue for addressing such concerns has been outlined by Butterworth and Punt (2001). This draws on projections by Thomson et al. (2000) for Antarctic fur seal population responses to variability in krill abundance. This approach highlights the need for harvest rules to take explicit account of risk, uncertainty, precautionary and ecosystem considerations into account—a situation consistent with Convention Article II objectives.

Pursuant to concerns about uncertainty, noticeable inefficiencies are also associated with krill trawling where animals fail to survive extrusion through the net mesh and where crushing affects the quality of the catch being landed (Zimarev 1991; Nicol and Endo 1999). In both instances, it is speculated that such impacts may lead to underestimation of total krill removals by as much as 60 % (Zimarev 1991). These uncertainties suggest that historical krill catches were larger than estimated, with consequent implications for assessing long-term stock productivity projections.

Furthermore, there is still considerable uncertainty as to whether the krill fishery may take large quantities of fish larvae from time-to-time in particular areas (Watters 1996; Nicol and Robertson 2003; Agnew et al. 2010). Incidental mortality of fur seals in krill trawls may be higher than initially thought (SC-CAMLR 2003). Net escapement panels were introduced by CCAMLR in 2003 and their use has reduced seal mortality significantly (Hooper et al. 2005).

As noted, the krill fishery by the Norwegian company Aker BioMarine, largely in the CCAMLR Statistical Area 48 (South West Atlantic), has been granted MSC certification as a 'sustainable fishery'.[20] However, this certification was not without controversy, with a number of concerned environmental organisations indicating that 'progress against the certification criteria will be monitored via annual surveillance audits, and stakeholder organisations will have further opportunities to review the resulting data and how it relates to the fishery's performance'.

[20] Retrieved from http://www.msc.org/newsroom/news/aker-biomarine-krill-fishery-gains-msc-certification/. Also at Anon (2010).

3.3 Regulating Harvesting

A context for exploitation of Southern Ocean marine living resources in general would not be complete without at least a cursory examination of CCAMLR management action (i.e. CMs). The summary presented below is limited to a few selected initiatives, while a more comprehensive account of such action, and description of the role that science plays in developing appropriate measures, may be found in Miller (2011a). These initiatives are all expected to play an important role in managing future krill exploitation in terms of conserving and protecting the marine ecosystem as a whole.

3.3.1 Small-Scale Management Units

CCAMLR krill CMs require precautionary catch limits to be subdivided into smaller spatial areas (Small-Scale Management Units - 'SSMUs'), when catches reach a 620,000 tonne 'trigger level' set in CCAMLR CM 51-01. The Scientific Committee for CAMLR (SC-CAMLR) has advised the Commission to agree on a spatial distribution formula for krill fishing effort or catch to preclude large catches being taken in restricted areas as the trigger level is approached.

Work to finalise CCAMLR deliberations on spatial allocation of krill catch limits to SSMUs in Area 48 remains important and continues (e.g. Nicol and Constable 2002; SC-CAMLR 2002). The implementation of a feedback management strategy for the fishery was afforded a high priority in 2010 (CCAMLR 2010) and 2011 (CCAMLR 2011).

3.3.2 Ecosystem Conservation and Environmental Protection

SC-CAMLR has long accepted that krill fishing may cause intolerable influences on Antarctic marine ecosystems trophic dynamics (SC-CAMLR 1995: Annex IV; Constable et al. 2000). While CCAMLR's krill management approach implicitly accounts for this possibility (Miller and Agnew 2000), CEMP was predicated on the assumption that improving understanding of relationships between fisheries and krill, as well as between fisheries, krill and krill predators, is fundamental for management action consistent with Article II of the Convention (Everson 2002).

Over the past decade and a half, SC-CAMLR has sought to develop predictive models of such relationships to refine its krill management decision rules (Miller and Agnew 2000; Miller 2011a). A notable advance has been the development of a framework (e.g. Constable 2005) to evaluate krill management procedures in an ecosystem context. This framework allows, and facilitates, explicit assessment of uncertainty in the modelled management systems.

Nevertheless, explicit linking of CEMP-derived predator information, krill availability and fishing activity remains elusive in the process of formulating CCAMLR CMs to address all Convention Article II objectives (Butterworth and Thomson 1994). This is particularly true in a functional sense due to a dearth of plausible models to address specific relationships between krill, predators and the fishery (Mangel and Switzer 1998; Constable 2005). Reid et al. (2008) highlight that work is still required to: (1) detect effects of fishing on particular process/ecosystem components in an operationally useful way, and in respect to agreed reference point(s); (2) remain cognizant of appropriate trade-offs between CEMP aims and prevailing uncertainties about ecosystem function; and (3) promote a realistic appreciation of CEMP's ability to provide relevant data for krill fishery management objectives, or for krill-associated predators.

3.3.2.1 Ecosystem Assessment

Krill predators have been on CCAMLR's agenda since 1997. CEMP-derived predator parameters are examined annually, and various models are available to explain attached trends. While de la Mare and Constable (2000) have developed CEMP parameter summaries, identifying specific responses to changes in parameter values remains a challenge. The on-going development of objective approaches to scale CCAMLR management decisions remains a priority (Constable 2001, 2011; Constable et al. 2000). Clearly applicable strategies for risk evaluation remain largely elusive, particularly when selecting appropriate levels of statistical significance for estimating the power to categorise detected CEMP parameter changes induced by fishing. The specific evaluation of risk in terms of identifying Type I and Type II errors (see Field et al. 2004) remains outstanding (Reid et al. 2008) in this regard.

3.3.2.2 Environmental Protection

Aside from SSMUs, CCAMLR is considering, or has initiated, spatially bound measures to address Convention Article II precautionary and ecosystem-directed elements. One such measure (CM 26-01) applies to the entire CCAMLR Area, and aims to minimise the risks of alien-species contamination and marine pollution from fishing vessels. All CCAMLR environmental measures agreed to date aim to mitigate the potential dangers of fishing activities on the Antarctic marine environment.

3.3.2.3 Small-Scale Research Units

Small-Scale Research Units (SSRUs) developed by CCAMLR aim to spread the risk of spatially concentrated fishing when scientific knowledge of the stock(s) concerned is limited (e.g. CM 41-01). Initially applied to experimental crab fisheries (CCAMLR 1993[21]; Watters 1997), the approach has been subsequently expanded to exploratory Toothfish fisheries in CM 41-01. SSRUs not only impose a degree of precaution by spreading fishing effort, they also promote collection of essential operational data from the fishery; a responsibility assumed by CCAMLR Scientific Observers[22] aboard the vessels involved.

3.3.2.4 Marine Protected Areas

Over the past decade, CCAMLR has considered spatial management measures to facilitate biodiversity conservation consistent with the targets set by the 2002 World Summit on Sustainable Development (WSSD). CCAMLR and the Committee for Environmental Protection (CEP)[23] have afforded high priority to identifying Southern Ocean marine areas for biodiversity conservation (CCAMLR 2004; CEP 2006). In 2007, CCAMLR began to develop Southern Ocean benthic and pelagic bioregionalisations[24] (CCAMLR 2007) as a basis for designing a representative network of Marine Protected Areas (MPAs) in the Convention Area. In 2009, CCAMLR adopted CM 91-03 as a contribution to biodiversity conservation in Subarea 48.2 (South Orkney Islands). It has endorsed further development of MPAs as a priority SC-CAMLR task (CCAMLR 2010), which is complemented by the attached drive to finalise SSMU development (see above).

3.3.2.5 Vulnerable Marine Ecosystems

United Nations General Assembly (UNGA) Resolution 61/105 (UNGA 2007) made a call to close areas to bottom fishing until appropriate protection measures are in place. CCAMLR responded to the UNGA resolution by formulating CMs 22-06 and 22-07 in 2007 (Reid 2011). CM 22-06 froze the current bottom fishing footprint to areas approved for such fisheries. CCAMLR's approach to Vulnerable Marine Ecosystems (VMEs) remains under development and care needs to be taken to ensure that that the current CMs (CMs 22-06 and 22-7) are not viewed as 'having done the job'. In these terms, CM 22-07 remains a true interim measure. Despite recently increased research (Brandt et al. 2007), data and knowledge available for managing benthic fauna in the Southern Ocean remain limited.

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[21] Originally CM 75/XII.

[22] Scientific observers appointed on a bilateral basis under the CCAMLR Scheme of International Scientific Observation—Retrieved from http://www.ccamlr.org/en/document/publications/basic-documents.

[23] Established under Articles 11 and 12 of the Madrid Protocol. Retrieved from http://www.ats.aq/e/cep.htm.

[24] A 'bioregion' is considered an area that constitutes a natural ecological community with characteristic flora, fauna and environmental conditions. The area is bounded by natural rather than artificial borders.

3.3.2.6 Climate Change

Few Regional Fisheries Management Organisations (RFMOs) have placed high seas climate issues on their agendas. In 2007, CCAMLR tasked SC-CAMLR with addressing climate change in the context of conserving Antarctic marine living resources (CCAMLR 2007; Nicol et al. 2007; Trathan and Agnew 2010). Resolution 30/XXVIII, adopted in 2009, urges consideration of Southern Ocean climate impacts so as to better inform CCAMLR management decisions. The issue remains a high priority for CCAMLR (2010, 2011)[25], but it appears unlikely that the broader socio-economic considerations associated with climate effects on Southern Ocean fisheries will be addressed in the near future (Miller 2011b).

3.4 The Future Is Not What It Used to Be[26]

Clarke and Harris (2003) imply that several factors constrain prediction of future Antarctic marine ecosystem functioning. Predominantly, these comprise incomplete knowledge of the ecosystem and a lack of accurate models to simulate polar region eco-dynamics generally. Put another way, uncertainty is seriously impeding the reliability of future predictions.

Constable (2005, 2011) goes on to indicate that developing and evaluating krill fishery management procedures are largely contingent on providing plausible models for the ecosystem in which the krill fishery find itself. Consequently, managing krill fishing in a climate-impacted world requires that models provide a robust basis for decision making and that specific account is taken of inherent uncertainty and risk[27] for both fishery, harvested stock and related ecosystem elements.

For obvious reasons, cumulative impacts from both climate change and unsustainable marine living resource exploitation compound such concerns. For these reasons, CCAMLR's achievements, failures and threats are important in terms of a broad suite of factors likely to impact the Southern Ocean's and Antarctica's future. Therefore, a formal assessment of such factors is essential to providing a contemporary and representative prediction for the Antarctic marine ecosystem's vulnerability to the potential consequent effects of various drivers. In this section, a vulnerability framework is developed as a contemporary contrast to Clarke and Harris' (2003) more generalised predictions outlined earlier.

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[25] Retrieved from http://www.ccamlr.org/en/ccamlr-xxxi.

[26] Quotation attributed to Paul Valery (1871–1945)—French author and critic

[27] Descriptions of 'uncertainty' and 'risk' often depend on the context in which the terms are being used. For this paper: **Uncertainty** is taken to mean a lack of certainty where a limited state of knowledge makes it impossible to exactly describe an existing state or future outcome, and/or when more than one possible outcome is possible. Conversely, **Risk** represents a state of uncertainty where possible outcomes may have an undesired effect or may induce a significant loss of some key quality.

3.4.1 Southern Ocean Fisheries Management: Achievements, Failures and Threats

Ecological uncertainties attached to effectively, and fully, meeting CAMLR Convention objectives have required innovative thinking from a holistic, scientific and ecologically-based management perspective (Constable et al. 2000; Constable 2011). The operational implementation of Convention Article II necessitates a balance between 'conservation' and 'rational use'[28] to ensure that existing ecological relationships between harvested, dependent and related species are maintained and that depleted populations are restored to levels where biological productivity is greatest. To date, this task has been impeded by limited knowledge of harvested species (especially krill) population dynamics, as well as by equally limited knowledge of functional relationship(s) between harvested (particularly krill) and other species (i.e. birds, seals and whales) (Hill et al. 2007, 2009). Determining these functional relationships remains a key CCAMLR priority in terms of fulfilling Article II requirements. It is also crucial for determining likely effects of future Antarctic ecosystem impacts by a potentially large krill fishery.

In 'minimizing the risks of irreversible changes' in the Southern Ocean marine ecosystem, including the climate and ecosystem effects, CCAMLR has some way to go in developing the necessary management actions, and/or formal decision-making procedures, to explicitly account for climate and ecosystem effects. Notably, these include more formal considerations of broad ecosystem effects, the scaling of management decisions using CEMP-derived indices and advancing consideration of potential climate-induced impacts. In the latter regard, inherent uncertainty, and operational, gaps remain in predicting how climate, or other, impacts may induce key 'tipping points' for harvested species, as well as those dependent on, or related to them.

Despite such limitations, it is widely recognised that CCAMLR CMs and related initiatives have pioneered development of innovative ways to address both precautionary and ecosystem concerns (Everson 2002; Willock and Lack 2006). However, lack of agreement on the apportioning of krill precautionary catch limits within SSMUs, or in response to other criteria, is rightly perceived as a failure in implementation of CCAMLR's precautionary approach for the krill fishery (Nicol et al. 2011).

Furthermore, given the species' key ecological standing, explicitly acknowledging uncertainty about the krill fishery's future remains essential for predicting its likely ecosystem consequences. As Fig. 3.1 illustrates, the krill fishery's sensitivity to market and other economic, or political forces, confounds any efforts to

[28] The Convention Article II term 'rational use' is subject to various interpretations. These apply when ecological as opposed to economic perspectives are assumed in the context of managing exploited resources. For this reason, CCAMLR has developed a working definition for the term. *Inter alia*, this term is considered to imply that: (1) harvesting of resources is on a sustainable basis and (2) harvesting on a sustainable basis means that harvesting is conducted to ensure that the highest possible long-term yield from the resource, subject to the general conservation principles outlined in paragraph 3 of Convention Article II (CCAMLR 1988).

predict such consequences. The inferred dangers attached to failed fishery regulation are self-evident, particularly for a persistent, large-scale krill IUU fishery. If left unaddressed, unregulated or improperly managed krill fishing will undermine CCAMLR's efforts to meet the sustainability requirements of Convention Article II.

Other CCAMLR initiatives with more positive outcomes extend the organisation's environmental protection regime beyond conservation of harvest target species alone. These initiatives include efforts to protect the Southern Ocean marine environment from fisheries-associated activities, either directly or via the adoption of risk aversion strategies for fisheries by-catch and fisheries-induced incidental mortality (Miller et al. 2004; Miller 2011a). While there is still work to be done, CCAMLR has enhanced biodiversity conservation through its bioregionalisation efforts, MPA development and VME protection measures.

In addressing the Convention's objectives, CCAMLR recognises that CM compliance poses a serious challenge to ensuring the effective and consistent implementation of management measures in a manner supportive of 'responsible' fishing (Miller et al. 2004). The adequate enforcement of CCAMLR decisions and CMs is also essential for compliance. Both considerations are compounded by the Convention Area's size (35 million km^2), remoteness and relatively open-access, particularly given that the Area is predominantly 'high seas' (Molenaar 2001). In this regard, CCAMLR's successful development of a compliance and scientific observation regime[29] is worth noting. In practice, CCAMLR's robust and extensive monitoring, control and surveillance (MCS) measures have been afforded considerable credit for the success of the organisation's efforts to combat toothfish IUU fishing in particular (Willock and Lack 2006; Miller et al. 2010).

3.4.2 Risk, Uncertainty and the Future

Given the Southern Ocean's history of marine living resource exploitation, it is difficult to expect that past practices bode well for the future. Systemic failures in the sustainable exploitation of seals, whales and some finfish, all indicate that the open access nature of Southern Ocean fisheries has largely succumbed to economic greed with target stock sustainability ultimately being compromised (Bonner, 1986; Miller 2007). Contemporary IUU fishing for toothfish is an obvious example of historic 'lessons' attached to economic greed not being learned and past 'mistakes' being repeated.

Figure 9.9 in Miller (2011b) summarises the ecological, direct and socio-economic impacts associated with Southern Ocean fisheries. The inferred consequences of these impacts highlight the fact that interactions between fishing activities and the ecosystem work in both directions, as well as within the

[29] This culminated in the CCAMLR System of Inspection (in 1988) and the Scheme of International Scientific Observation(in 1992) to improve at-sea fisheries enforcement and monitoring respectively (Rayfuse 1998).

Southern Ocean 'social-ecological system' associated with fishing. By way of an example, if the krill fishery is affected by reduced ecosystem productivity then fishery outputs will also be affected. Alternatively, fishing activities are likely to be impacted by socio-economic (e.g. fuel price or market demand) and direct effects (e.g. increased climate variability leading to inclement weather). Fishing activities themselves may also affect ecosystem processes, both directly and cumulatively. Together, various impact pathways interact and all pathways play a role in affecting fisheries development, profitability and sustainability (Miller 2011b).

There is, therefore, a need to consider the likely effects on, and consequences of, Southern Ocean fisheries in terms of: (a) exposure to various impacts (including climate impacts), (b) resultant sensitivity to associated social-ecological and social-human processes and (c) steps to be taken to mitigate potentially detrimental impacts on fisheries and the ecosystem. Key to evaluating the cost-efficacy of (c) is the extent to which the social-ecological, or 'human', subsystem and the ecosystem ('natural subsystem') come to be valued. As noted, the fisheries themselves are likely to exert impacts on the marine ecosystems in which they take place (Miller 2011a).

The 'ecological effects' (e.g. yield and species distribution changes) alluded to by Miller (2011b) raise important questions in their own right concerning the relevance of understanding future consequences for, and of, living resource exploitation in the Southern Ocean marine ecosystem—(1) what social-ecological system components contribute to high, or low, vulnerability or resilience, of the Southern Ocean marine ecosystem?, and (2) what can be learnt from the Southern Ocean marine social-ecological systems, where exploitation of marine living resources is considered in terms of relevant and interactive subsystem sustainability? Assessing the 'resilience' of the Southern Ocean marine ecosystem to potential impacts, both human and environmentally induced, is crucial for answering these two questions.

'Biological resilience' is defined as 'the ability of a natural system to absorb and accommodate future events in whatever unexpected form they may take' (Holling 1973, p. 14). This definition can be extended to 'ecosystem' and 'social systems resilience' on the basis of the structural, functional and organisational changes that the systems are able to withstand, or absorb (Gunderson and Holling 2001; Perry et al. 2010).

The Intergovernmental Panel on Climate Change (IPCC) considers 'resilience', 'vulnerability' and 'adaptive capacity' to be important in the context of climate effects on human communities. Consequently, the definition of 'resilience' can be recast as 'social-ecological resilience', or "the capacity of inter-linked social-ecological systems to absorb potential impacts while still retaining essential 'structures', 'processes' and 'feedbacks'" (Adger et al. 2005, p. 1036). As illustrated in Fig. 3.2, *exposure* (E) of Southern Ocean fish production to specific environmental, or fisheries, impacts combines with consequent economic/ecological *sensitivity* (S) to determine the extent of *potential impacts* (Pi). *Adaptive capacity* (Ac) is then the ability of the system[30] to respond to environmental changes, impacts

[30] Here a 'system' is considered to be a Southern Ocean region, state, fisher, fishery sector or fishery operator.

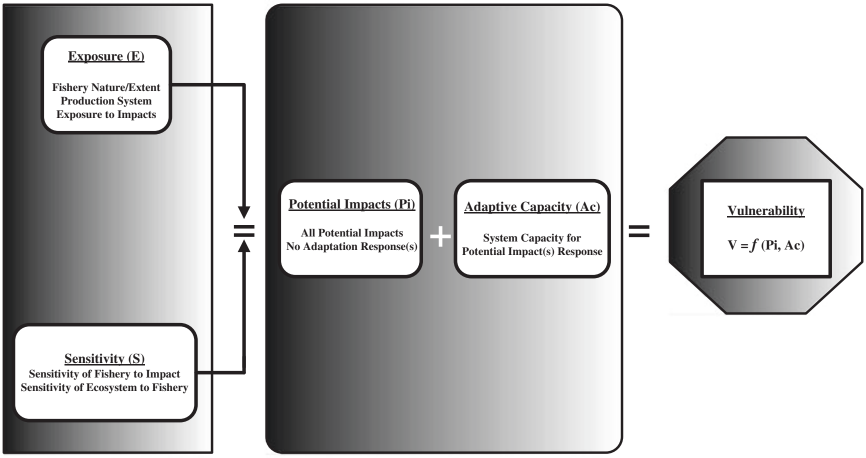

Fig. 3.2 Southern Ocean marine ecosystem vulnerability framework illustrating system responses to potential impact-induced stress/stresses. Adapted from Fig. 9.10 in Miller (2011b)

(including from overfishing), or contingencies, in such a way as to promote marine living resource sustainability while retaining ecological, economic and socio-political opportunities. Building on IPCC (2007) thinking, adaptive capacity would thus reflect the ability of the Southern Ocean marine ecosystem to adjust to impacts [including natural variability, extremes and human-induced change(s)] in ways that moderate potential damage and take advantage of possible opportunities, and/or copes with any consequences. The future vulnerability (V) of the Southern Ocean marine ecosystem and its marine living resources is thus likely to be a function of the nature, magnitude, rate of change and variation attached to a fishery in terms of the ecosystem sensitivity and adaptive capacity to such exposure.

Following Daw et al. (2009), Miller (2011b) has developed a ‘sustainability framework’ for Southern Ocean fisheries, where fisheries are viewed as ‘assets’ with significant ‘capital value’ attached (Table 3.1). For example, the krill fishery possesses both ‘natural’ and ‘physical’ capital where the former is dependent on the natural attributes of the stock(s) being fished. The latter comprises the physical assets (e.g. vessels and processing capabilities) required to undertake fishing. The human, natural, physical, social and financial capital of the fishery is interdependent and subject to various potential impacts in a vulnerability context, while policies, institutions, processes and industrial outcomes potentially affect the krill resource’s status as an economic asset. In turn, controlling influences reside with management action that affects resource access. It is also a function of extreme events, trends and seasonality that impact krill fishing and hence the fishery’s capital asset value.

Therefore, the key factor in determining how a krill sustainability framework may unfold rests with the inherent values ascribed to the fishery, and the contingent costs associated with its management. This requires that benefit values of the Antarctic marine ecosystem are seen to include long-term conservation, economic

Table 3.1 Southern Ocean fisheries sustainability framework assets

Natural capital	Resource stocks (e.g. fish, genetic, ecosystem) and/or environmental attributes (e.g. oceanic conditions) underpinning resource production and from which fisheries derived
Physical capital	Physical assets required to support and derived from fisheries, including basic infrastructure and producer goods to support such fisheries and associated industries (e.g. ship building)
Human capital	Accumulated skills, knowledge, labour, health and physical capability for successfully pursuing a viable industrial sustainability framework for fisheries
Economic/Financial capital	Capital base (e.g. cash, credit, investment, savings and other economic assets) essential for pursuing a viable industrial sustainability framework strategy for fisheries
Social capital	Social resources (e.g. networks, claims, cooperation) which require coordinated actions to pursue different industrial sustainability framework for fisheries

and cultural advantages (Sumaila 2004, 2008; Sumaila and Walters 2005). While fishery values are usually based on economic preferences alone (Arrow et al. 1993), the historic exploitation of Southern Oceans marine living resource (e.g. whaling) have largely compromised such values (Leaper and Childerhouse 2013). Here, economic imperatives have waived trade-offs attached to target resource sustainability in favour of limited time constraints and maximisation of economic expectations. For seals, whales and some finfish, including toothfish IUU, exploited stock sustainability has been substantially sacrificed for economic gain (Woehler et al. 2013). In the case of sealing and whaling, this sacrifice has impacted ecosystem function (e.g. see Laws 1989).

Cochrane and Doulman (2005) suggest that unsustainable fishing practices are the result of a systematic failure to balance biological and ecological, sustainability with socio-economic expectations. In these terms, current valuations of Southern Ocean fisheries run the danger of focusing on economic benefits alone, with associated marine ecosystems being viewed solely as sources for derived commodities which are then sold (Perry et al. 2010; Neufeld et al. 2013). The status of the ecosystem(s) then becomes vulnerable to a 'clear and present danger' when a fishery has so much invested in its operation that there is general resistance to its closure, even when income, profits and livelihoods are declining (Pollnac and Poggie 2008). Such 'self-actualisation' epitomised Southern Ocean whaling (Darby 2007), and is at the center of an on-going global debate concerning fisheries subsidies where potential economic 'hardships' arising from unsustainable exploitation are economically supported for political, or social, reasons (Cochrane 2000). It therefore seems logical to expect that any future failure to adequately regulate fishing in the Southern Ocean, particularly of a key species such as krill, will significantly impact the target stock(s). A secondary result is the increased likelihood that catastrophic breakdowns will occur in the sustainability framework alluded to above. Therefore, is it possible to forecast, or predict, such breakdowns in the context of future consequences for the Southern Ocean marine ecosystem and its harvested resources?

3.4.3 Forecasting Impacts on the Southern Ocean Marine Ecosystem

A subtext to the discussions here are the inherent difficulties associated with separating harvested stock and ecosystem impacts from those attributable to the Southern Ocean's natural variability. The situation is common to most ocean areas, but the Southern Ocean's extreme environmental and geographic conditions have long been viewed as crucially important in determining krill eco-physiology, ecology and biology in particular (Miller and Hampton 1989; Atkinson et al. 2009). The situation is further complicated by extreme events such as changes in the extent, or nature, of oceanic upwelling, other ocean circulation changes due to atmospheric forcing [e.g. El Niño-Southern Ocean Oscillation (ENSO)] and habitat changes (Hewitt and Lipsky 2008).

For such reasons, interactions between krill fishing and the Southern Ocean environment assume prominence if the associated social-ecological systems are forced into states that pose unacceptable challenges to CCAMLR's sustainable management of the fishery. Should ecological or marine living resource thresholds ('tipping points') be reached, piecemeal management is unlikely to achieve sustainable outcomes for target stocks. The management regime is also likely to be insufficient in providing for effective, long-term mitigation policies, strategies or actions (Daw et al. 2009).

To date, the future performance of the krill fishery has not been specifically evaluated in terms of likely impacts on the stocks being exploited and the ecosystems in which fishing takes place. In the latter respect, the reverse is equally true in that climate effects have not been formally assessed, but are likely to impact significantly on Southern Ocean marine living resources such as krill (Atkinson et al. 2009). To forecast, or predict, future krill fishery impacts on the Antarctic marine ecosystem, it is important to objectively contrast these considerations with the past in a coherent framework.

The framework here offers a pragmatic and cost-effective way of evaluating the future of both the krill resource and the Southern Ocean marine ecosystem. It focuses on a risk management process (Fig. 3.3 and Appendix I) that relies on—(1) identifying potential risks attached to fisheries performance through an analysis/assessment of performance breakdowns, (2) nominating high performance, impact-risk items to be addressed, (3) precisely defining high risk items to be targeted, (4) developing metrics (e.g. numerical ranks ranging from 'Low' to 'High') to reflect the potential impacts of targeted risk items, (5) developing strategies, unique to targeted risk items, to provide remedial action and reduce negative effects of Southern Ocean fisheries-induced ecosystem performance breakdowns, (6) developing and

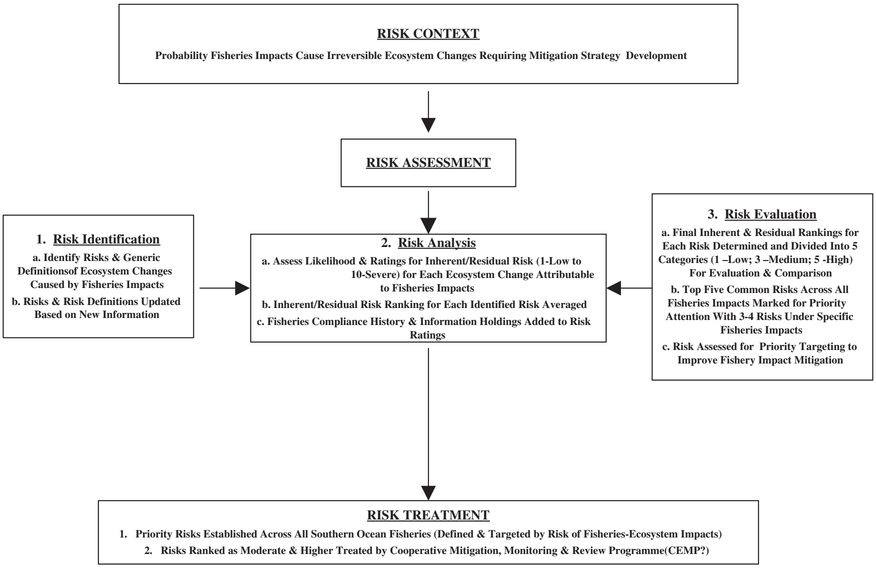

Fig. 3.3 A Southern Ocean fisheries impact risk assessment and management process. See text and Appendix I for explanation

implementing formal impact management plans to monitor, review and adjust remedial action for, including risk mitigation of, such breakdowns and (7) developing appropriate reporting procedures to disseminate information on the above.

The process identifies impacts and addresses performance breakdowns. It shows that the most important individual 'impact' ratings for the future fall within a critical range that includes, in order of priority, **climate change**, **increased uncertainty**, **harvested stock sustainability**, **political will** and **compliance enforcement**.

3.5 Conclusions

This chapter has examined Clarke and Harris's (2003) general assertion that harvesting and unsustainable fishing are the most dominant future threats to the Southern Ocean marine ecosystem, along with associated cumulative impacts from climate change and pollution. The analyses undertaken here largely substantiate this assertion. However, a major 'break' with the past is that physico-biological (climate change) impacts are likely to dominate the ecosystem's future, particularly when they are coupled with growing uncertainty attached to fully ascribing impact 'cause and effect' properties to climate change. Sustainable fishing and effective harvested resource management are also important drivers for the future. Thus, compliance with, and enforcement of, effective management solutions for human activities in the Southern Ocean marine realm remain serious considerations in terms of applying the necessary ‘political will’ to ameliorate human impacts in the future. Put simply, the potentially negative impacts of increased ecological uncertainty, along with unsustainable and badly managed exploitation of Antarctic marine living resources, rank alongside the potential risks associated with climate impacts. To a large extent, this conclusion vindicates Clarke and Harris’s (2003) earlier analyses.

Nonetheless, if ‘the future is not what it used to be’, the potential development of a large-scale krill fishery in the foreseeable future could be viewed as the last step in ‘fishing down the Antarctic marine food chain’. In turn, the risk of what Ősterblom et al. (2010) have termed ‘fishing down the governance index’ would increase the risk of unregulated fishing and the krill resource becoming economically ‘run down’. Any impending threat to the krill fishery from unregulated fishing is therefore likely to have profound implications for both the Antarctic marine ecosystem and its management.

Mitigation measures to counter potentially negative impacts by the Southern Ocean krill fishery on the marine ecosystem can be consolidated into three key actions: (1) promoting increased fisheries/ecosystem resilience, (2) adopting long-term adaption planning and (3) improving environmental and fisheries management/monitoring. With respect to (3), the recent convergence of work undertaken by SC-CAMLR and the CEP in relation to MPAs cannot be over-emphasised.

As few fisheries management agencies explicitly address high seas fisheries climate impact issues on their agendas (Nicol et al. 2007), there is some merit in formalising such considerations, and in commencing development of interactive risk-based approaches to augment the current fisheries-climate impact-management ‘toolbox’ (Miller 2011b). For example, a climate impact decision-making schema could be formalised. As a first step, management decision pathways should be identified, based on physical, ecological, economic/social and management/monitoring/research qualities. These would then be incorporated into a matrix of stated objectives for such considerations as GHG[31] emissions, physical changes, harvested species productivity, fisheries and socio-economic factors. Specific model attributes would be linked to a defined expert-based, decision-making model schema (Miller 1987), which then may be used within one, or more, decision scenarios (Starfield et al. 1988). This would allow decision trade-offs to be identified and evaluated in terms of specific parameter (e.g. fishing) levels. These levels may then be related to any dramatic change in other attributes (e.g. harvested stock yields), and combined with a specified environmental impact (e.g. sea temperature). The same model could be applied to improve precision of key parameter estimates, thereby reducing the variance of potential outcomes used for identifying research, or management, priorities.

Despite the complexities outlined, CCAMLR arguably has the best record of integrating environmental considerations into the management of the fisheries for which it is responsible (Croxall and Nicol 2004; Small 2005; Willock and Lack, 2006).

[31] Green House Gas.

As confirmed by the 2008 appraisal of its performance (CCAMLR 2008), CCAMLR applies precaution and a scientifically based ecosystem approach to pursue sustainable and ecosystem 'friendly' harvesting practices. In so doing, CCAMLR takes full account of the needs of dependent and related species, even if only implicitly in its krill management procedures at this stage (Miller and Agnew 2000; Miller 2011a). It also mandates minimum reporting standards for catch, fishing effort and bycatch. These are essential to building current, and future, knowledge of important harvested species, fishery and ecosystem dynamics.

However, the future of sustainable fishing in the Southern Ocean is critically dependent on effective implementation of, and compliance with, essential CMs. Both the present and the future are very different from the past largely due to CCAMLR's very existence and the impending scope of the krill fishery. However, as Croxall and Nicol (2004) have intimated, the future wellbeing of the Southern Ocean marine ecosystem does not rest with CCAMLR alone. In common with other ocean areas, there is a global need to—(1) eliminate IUU fishing, particularly by outlawing flags of 'non-compliance', (2) develop new, and vastly improve current, efforts to coordinate management and the effective governance of ocean spaces, particularly the high seas, and their attached ecosystems, (3) enhance adaptability to a changing world through the improved incorporation of focused ecosystem-based principles into appropriate management practices and (4) improve knowledge of potential linkages between the physical environment and biological productivity at all scales, so as to improve the levels of confidence attached to scientific advice on which management decisions are based.

While global interest in Antarctica and the Southern Ocean remains high, the seamless integration of the ATS with more global instruments, such as UNCLOS, remains unclear in some instances.[32] As a result, there is merit in considering how the understandings set out in various ATS instruments, most notable the Treaty itself and the Convention, might be used to take account of more global considerations (e.g. IUU fishing) and other commercial activities (e.g. bioprospecting) in the Southern Ocean (Hughes and Bridge 2010). It is here that the need to ensure that the 'future is not what it used to be' comes to the fore. With krill's lowly trophic status, the species' overexploitation is likely to provide for more serious ecological consequences than Southern Ocean whaling ever did.

If both effective governance and cost-efficient environmental management are at the center of sustainably managing Antarctic marine living resources, then protecting their associated ecosystems is an equally important consideration. It remains to be seen whether the ATS in general, and CCAMLR in particular, have a role to play in providing for the future health of the Antarctic marine ecosystem. At a minimum, the following four key areas (after Miller 2000) should be pursued.

First, there is a need to preserve the Antarctic Treaty's key environmental protection provisions through continued promotion of peaceful coexistence, freedom

[32] For example, claims relating to the limits of the continental shelf in the Antarctic Treaty Area (Armas-Pfirter 2010, pp. 489– 492) have drawn at least three different responses from Antarctic claimant and non-claimant states.

of scientific investigation and cooperation. This is augmented by a need to delineate more clearly the Treaty's powers and responsibilities in respect to the Convention's objectives. Southern Ocean bioprospecting (Cohen 2010), the continued prosecution of objective science (Hughes and Bridge 2010) and areal (i.e. biodiversity) protection (CCAMLR 2004) are of particular concern.

Second, thought should be given to how the ATS might be expanded to broaden political representativeness from a global perspective. This would aim for wider participation by the global community in decision making associated with the Southern Ocean's environmental wellbeing (Parsons 1987), particularly if the krill fishery expands to a globally significant level. CCAMLR's response on VMEs to UNGA Resolution 61/105 is a clear example of where global and CCAMLR concerns have converged.

Third, technical, cost-effective and cooperative ways should be carefully considered to promote ATS objectives in terms of sustaining Southern Ocean marine ecosystem health (Miller 2002; Everson 2002).

Fourth, ways should be sought to strengthen links between ATS environmental conservation and protection provisions, as well as with other relevant global instruments aimed at managing human activities in the marine environment. The strength of such linkages is particularly important for ameliorating the effects of climate change in the Southern Ocean as a whole (Trathan and Agnew 2010).

Such considerations are congruent with the long-recognised need to reflect on changes to be made in pursuance of the Southern Ocean's governance remaining responsive to all humankind's needs and interests (Parsons 1987). The continued environmental 'well-being' of the Antarctic marine ecosystem is a pervasive such need, particularly if the global challenges of environmental uncertainty, climate change impact, food security and sustainable capture fisheries are ever to be satisfactorily understood, equitably addressed and effectively managed. As Garcia and Rosenberg (2010, p. 2876) have stressed—'the nutrition and livelihoods of many hundreds of millions of dependent people, will rest critically on managing fisheries more responsibly'. The Southern Ocean and its attached krill fishery are no exception to this insightful observation, while the multiple failures of past exploitation in the region sound a strong warning on why the future should differ from the past.

Appendix I

Figure 3.3 outlines the future evaluation and risk management process used. The process aims to identify and predict the severity of specific impacts on, or breakdowns in, Southern Ocean marine living resource sustainability and associated ecosystem qualities in the medium to long-term (5–25 years). It comprises three steps: (1) the setting of a high order objective to bound the risk inherent in Southern Ocean human activity, or ecosystem, breakdowns in respect of potential impact effects; (2) assessment to identify, analyse and evaluate risk attached to such break

Table 3.2 Future impacts affecting Southern Ocean marine living resources and/or ecosystems

Impact drivers	Impact categories		
	Impact	Likelihood	Severity
Physico–biological impacts			
Climate change	5	4	20
Ocean circulation	4	3	12
Sea temperature	4	3	12
Ecological impacts			
Productivity	4	3	12
Trophic shift(s)	4	3	12
Increased uncertainty	4	5	20
Fishery impacts			
Stock sustainability	5	4	20
Unregulated fishing (IUU)	4	3	12
Ecological	3	3	9
Socio–economic impacts			
Economic needs/expectations	4	2	8
Sustainability framework(s)	4	3	12
Food security	3	3	9
Management impacts			
Management legitimacy	4	3	12
Compliance enforcement	4	4	16
Political will	4	5	20
Governance impacts			
Environment	4	3	12
Social	4	3	12
Legal	4	3	12

Impacts (i.e. 'impacts on') are graded into five categories ranging from 'negligible' (1) to 'critical' (5) (Table 3.4). Impact likelihood is the mean of the impact's estimated duration and the probability of its occurrence. The estimated impact duration is grouped into five time period categories (1–5) of 1–5, 6–10, 11–20, 21–50 and 51+ years. The impact probability ranks from 1 (unlikely) to 5 (highly probable). The matrix in Table 3.5 sets the values used to designate the final impact severity and is the product of the impact grading and likelihood. This score is ranked according to the severity matrix levels (minor to critical) identified in Table 3.5

downs and (3) a treatment of the identified risks themselves. In its entirety, the process is a systematic, and objective, attempt to identify impacts, address performance breakdowns and improve any attached impact mitigation strategies.

Five specific impact categories (Table 3.2[33]) and a number of specific 'impact drivers' (Table 3.3) are identified. The potential impacts were subject to the predictive evaluation process as follows. The impact ratings for each category were graded according to the criteria ('negligible' to 'critical') outlined in Table 3.4. The 'likelihood' of each impact category occurring was also identified following the procedure outlined in the legend to Table 3.2. Likelihood was ranked from 1 ('unlikely') to 5 ('certain') in terms of the perceived probability that an impact will affect a harvested

[33] The 'impact drivers' identified in Table 3.2 are outlined in more detail in Table 3.3.

Table 3.3 Description of 'impact drivers' analysed as outlined in the text, Tables 3.4 and 3.5

Impact driver	Description
Physico–biological impacts	
Climate change	Impacts attributable to direct (e.g. decreased sea-ice) and/or indirect (e.g. sea-level rise) climate impacts on Antarctic marine ecosystem
Ocean circulation	Changes in ocean circulation patterns affecting biota attributable to environmental variability and/or climate change
Sea temperature	Sea temperature impacts on biota physiology, distribution and productivity
Ecological impacts	
Productivity	Ecologically linked impacts (.e.g. increased UV-B due to ozone depletion) affecting biological productivity directly and/or indirectly
Trophic shifts	Impacts on ecological functional relationships between species
Increased uncertainty	Ecological impacts from extreme events and increased variability
Fisheries impacts	
Stock sustainability	Fishing compromising/seriously affecting harvested stock sustainability
Unregulated (IUU) fishing	Fishing compromising harvested stock sustainability and function attributable to unregulated fishing
Ecological	Fishing impacts on marine ecosystem (e.g. bycatch and incidental mortality)
Socio-economic impacts	
Economic needs/expectations	Economic impacts on harvested stock sustainability
Sustainability framework(s)	Impacts on Southern Ocean sustainability framework
Food security	Impacts arising from food security issues
Management impacts	
Management legitimacy	Impacts from perceptions/status of management and/or regulatory legitimacy
Compliance enforcement	Impacts attributable to implementation efficacy of monitoring, control and surveillance measures/actions
Political will	Financial, political and logistical impacts on implementation of management/regulatory measures
Governance impacts	
Environment	Impacts affecting balance of marine ecosystem capacity/function with human impacts (e.g. pollution)
Social	Impacts on sustainability framework in context of FAO Code of Conduct for Responsible Fisheries[a] core principles
Legal	Impacts affecting standing, standardisation and/or implementation of international fisheries agreements/provisions, as well as development of appropriate new agreements/provisions

[a]1995 Food and Agriculture Organization Code of Conduct for Responsible Fisheries. Retrieved from ftp://ftp.fao.org/docrep/fao/005/v9878e/v9878e00.pdf

Table 3.4 Values for different impact levels of impact on, or by, Southern Ocean marine living resource activities and the marine ecosystem

Value	Potential impact
1	Negligible impact on the Southern Ocean ecosystem or fishery. management implications/consequences are also negligible
2	Minor impact on the Southern Ocean ecosystem or fishery with no medium or long-term effects. management implications/consequences are also minor
3	Major impact on the Southern Ocean ecosystem or fishery with no long-term effects. management implications/consequences are also major
4	Serious impact on the Southern Ocean ecosystem or fishery with potential long-term effects. management implications/consequences are also serious
5	Critical Impact on the Southern Ocean ecosystem or fishery with potentially enduring effects. management implications/consequences are also critical

Table 3.5 Impact severity score matrix with score levels indicating impact consequences—Minor = 1-4; Major = 5-9; Serious = 10-15; Critical = 16-25

Impact Duration	Impact				
	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

stock, marine ecosystem or physical environment. To determine the potential severity each impact, a matrix of four severity levels was used (Table 3.4), where:

- *Minor Severity*: Impact × Likelihood = Severity Score of 1–4
- *Major Severity*: Impact × Likelihood = Severity Score of 5–9
- *Serious Severity*: Impact × Likelihood = Severity Score of 10–15
- *Critical Severity*: Impact × Likelihood = Severity Score of 16–25

Each impact's severity level provides a rank for its future importance in terms of the probability that it will exert a notable effect on either the Southern Ocean's marine resource sustainability or marine ecosystem. The highest ranked impacts carry the greatest risk of inducing 'irreversible ecosystem changes', thereby requiring development, or application, of appropriate mitigation, or management, strategies.

Based on the average score per category, Table 3.3 shows that management (16), climate change (15), ecological (15) and fisheries impacts (14) appear most likely to affect the future of the Southern Ocean marine ecosystem. In terms of fisheries, the most important individual 'impacts' falling within the critical range include climate change, increased uncertainty, stock sustainability, political will and compliance enforcement. The predictive evaluation of potential future scenarios identifies the most important individual 'impacts' falling within a critical range include climate change, increased uncertainty, stock sustainability, political will and compliance enforcement.

References

Adger, W. N., Hughes, T. P., Folke, C., Carpenter, S., & Rockström, J. (2005). Social-ecological resilience to coastal disasters. *Science, 309*, 1036–1039.

Agnew, D. J. (1997). Review: The CCAMLR ecosystem monitoring programme. *Antarctic Science, 9*, 235–242.

Agnew, D. J., & Nicol, S. (1996). Marine disturbances—commercial fishing. In E. E. Hofmann, & L. B. Quetin (Eds). *Foundations for ecological research west of the Antarctica Peninsula* (417–435). Antarctic Research Series, 70.

Agnew, D. J., Grove, P., Peatman, T., Burn, R., & Edwards, C. T. T. (2010). Estimating optimal observer coverage in the Antarctic krill fishery. *CCAMLR Science, 17*, 139–154.

Allsopp, M., Page, R., Johnston, P., Santillo, D., et al. (2009). *State of the World's Oceans*. Berlin: Springer.

Anon (2007). Krill ship set to be ordered. *Fishing News International*, January, p. 3.

Anon (2010). MSC certification for Antarctic krill fishery. *Fishing News International,* August, p. 10.

Armas-Pfirter, F. M. (2010). Submissions on the outer limit of the continental shelf: Practice to date and some issues of debate. In D. Vidas (Ed.), *Law technology and science for oceans in globalization* (pp. 477–492). Leiden: Brill.

Arrow, K., Solow, R., Portney, P. R., Leamer, E. E., Radner, R., & Schuman, H. (1993). Report of NOAA panel on contingent violation. *Federal Register, 58*(10), 4601–4614.

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

Atkinson, A., Siegel, V., Pakhomov, E. A., Jessop, M. J., & Loeb, V. (2009). A re-appraisal of the total biomass and annual production of Antarctic krill. *Deep-Sea Research I, 56*, 727–740.

Baird, R. J. (2006). *Aspects of illegal, unreported and unregulated fishing in the Southern Ocean*. Dordrecht: Springer.

Bonner, W. N. (1986). The future of Antarctic resources. *The Geographical Journal, 152*(2), 248–255.

Brandt, A., Gooday, A. J., Brandão, S. N., Brix, S., Brökeland, W., Cedhagen, T., et al. (2007). First insights into the biodiversity and biogeography of the Southern Ocean deep sea. *Nature, 447*, 307–311.

Budzinski, E., Bykowski, P., & Dutkiewicz, D. (1985). Possibilities of processing and marketing of products from Antarctic krill. *FAO Fisheries Technical Paper, 268*, 1–46.

Butterworth, D. S. (1986). Antarctic ecosystem management. *Polar Record, 23*, 37–47.

Butterworth, D. S., & Thomson, R. B. (1994). Possible effects of different levels of krill fishing on predators—some initial modelling attempts. *CCAMLR Science, 2*, 79–97.

Butterworth, D. S., & Punt, A. E. (2001). The role of harvest laws, risk and uncertainty and the precautionary approach to ecosystem-based management. *Conference on Responsible Fisheries in the Marine Ecosystem*. Reykjavik, Iceland. ftp://ftp.fao.org/fi/document/reykjavik/pdf/18Butterworth.pdf (accessed 17.02.11).

CBD. (2010). Biodiversity scenarios: Projections of 21st century change in biodiversity and associated ecosystem services. *CBD Technical Series, 50*, 30–32.

CCAMLR. (1988). *Report of the 7th meeting of the commission (CCAMLR-VII)*. Hobart: CCAMLR.

CCAMLR. (1990). *Report of the 9th meeting of the commission (CCAMLR-IX)*. Hobart: CCAMLR.

CCAMLR. (1993). *Report of the 12th meeting of the commission (CCAMLR-XII)*. Hobart: CCAMLR.

CCAMLR. (2004). *Report of the 23rd meeting of the commission (CCAMLR-XXIII)*. Hobart: CCAMLR.

CCAMLR. (2007). *Report of the 26th meeting of the commission (CCAMLR-XXVI)*. Hobart: CCAMLR.

CCAMLR. (2008). *Report of the 27th meeting of the commission (CCAMLR-XXVII)*. Hobart: CCAMLR.

CCAMLR. (2009). *Report of the 28th meeting of the commission (CCAMLR-XXVIII)*. Hobart: CCAMLR.

CCAMLR. (2010). *Report of the 29th meeting of the commission (CCAMLR-XXIX)*. Hobart: CCAMLR.

CCAMLR. (2011). *Report of the 30th meeting of the commission (CCAMLR-XXX)*. Hobart: CCAMLR.

CEP. (2006). *Report of the committee for environmental protection*. CEP-IX/XXIX Antarctic Treaty Consultative Meeting, Edinburgh, United Kingdom.

Clarke, A. C., & Harris, C. M. (2003). Polar marine ecosystems: Major threats and future change. *Environmental Conservation, 30*(1), 1–25.

Cochrane, K. L. (2000). Reconciling sustainability, economic efficiency and equity in fisheries: The one that got away? *Fish and Fisheries, 1*, 3–21.

Cochrane, K. L., & Doulman, D. J. (2005). The rising tide of fisheries instruments and the struggle to keep afloat. *Philosophical Transactions of the Royal Society B, 360*, 77–94.

Cohen, H. (2010). Some reflections on bioprospecting in the polar regions. In D. Vidas (Ed.), *Law technology and science for oceans in globalization* (pp. 339–352). Leiden: Brill.

Constable, A. J. (2001). The ecosystem approach to managing fisheries: Achieving conservation objectives for predators of fished species. *CCAMLR Science, 8*, 37–64.

Constable, A. J. (2002). CCAMLR ecosystem monitoring and management: Future work. *CCAMLR Science, 9*, 233–256.

Constable, A.J., & Nicol, S. (2002). Defining smaller-scale management units to further develop the ecosystem approach in managing large-scale pelagic krill fisheries in Antarctica. *CCAMLR Science, 9*, 117–131.

Constable, A. J. (2005). A possible framework in which to consider plausible models of the Antarctic marine ecosystem for evaluating krill management procedures. *CCAMLR Science, 12*, 99–115.

Constable, A. J. (2011). Lessons from CCAMLR on the implementation of the ecosystem approach to managing fisheries. *Fish and Fisheries, 12*, 138–151.

Constable, A. J., de la Mare, W. K., Agnew, D. J., Everson, I., & Miller, D. G. M. (2000). Managing fisheries to conserve the Antarctic marine ecosystem: Practical implementation of the convention on the conservation of antarctic marine living resources. *ICES Journal of Marine Science, 57*, 778–791.

Croxall, J. P., & Nicol, S. (2004). Management of Southern Ocean fisheries: Global forces and future sustainability. *Antarctic Science, 16*, 569–584.

Croxall, J. P., Trathan, P. N., & Murphy, E. J. (2002). Environmental change and Antarctic seabird populations. *Science, 297*, 1510–1514.

Darby, A. (2007). *Harpoon: Into the heart of whaling*. Crows Nest: Allen and Unwin.

Daw, T., Adger, W. N., & Brown, K. (2009). Climate change and capture fisheries: Potential impacts, adaptation and mitigation. In K. Cochrane, B. De Young & D. Soto (Eds.), *Climate change implications for fisheries and aquaculture. overview of current scientific knowledge* (vol. 530, pp. 107–150). FAO Fisheries and Aquaculture Technical Paper.

de la Mare, W. K., & Constable, A. (2000). Utilising data from ecosystem monitoring for managing fisheries: Development of statistical summaries of indices arising from the ccamlr ecosystem monitoring programme. *CCAMLR Science, 7*, 101–117.
Drinkwater, K. (2002). A review of the role of climate variability in the decline of northern cod. *American Fisheries Society Symposium Series, 32*, 113–130.
El-Sayed, S. Z. (1994). History, organization and accomplishments of the BIOMASS programme. In S. Z. El-Sayed (Ed.), *Southern ocean ecology: The BIOMASS perspective* (pp. 1–8). Cambridge: Cambridge University Press.
Everson, I. (2002). Consideration of major issues in ecosystem monitoring and management. *CCAMLR Science, 9*, 213–232.
Field, J., Tyre, A. J., Jonzen, N., Rhodes, J. R., & Possingham, H. P. (2004). Minimizing the cost of environmental management decisions by optimizing statistical thresholds. *Ecology Letters, 7*, 669–675.
Garcia, S. M., & Rosenberg, A. A. (2010). Food security and marine capture fisheries: Characteristics, trends, drivers and future perspectives. *Philosophical Transactions of the Royal Society B, 365*, 2869–2880.
Gunderson, L. H., & Holling, C. S. (2001). *Panarchy: Understanding transformations in systems of humans and nature*. Washington: Island Press.
Hemmings, A. D. (2007). Globalisation's cold genius and the ending of Antarctic isolation. In L. L. Kriwoken & J. Jabour (Eds.), *Looking south: Australia's Antarctic agenda* (pp. 176–190). Leichhardt: Federation Press.
Hewitt, R. P., & Linen Low, E. H. (2000). The fishery on Antarctic krill: Defining an ecosystem approach to management. *Reviews in Fisheries Science, 8*, 235–298.
Hewitt, R. P., & Lipsky, J. (2008). Krill and other plankton. In W. F. Perrin, B. Wursig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 658–664). London: Academic Press.
Hill S. L., Reid K., Thorpe S. E., Hinke J. & Watters G. M. (2007). A compilation of parameters for ecosystem dynamics models of the Scotia Sea-Antarctic Peninsula region. *CCAMLR Science, 14*, 1–25.
Hill, S. L., Trathan, P. N., & Agnew, D. J. (2009). The risk to fishery performance associated with spatially resolved management of Antarctic krill (*Euphausia superba*) harvesting. *ICES Journal of Marine Science, 66*, 2148–2154.
Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Reviews of Ecology and Systematics, 4*, 1–23.
Hooper, J., Clark, J. M., Charman, C., & Agnew, D. (2005). Seal mitigation measures on trawl vessels fishing for krill in CCAMLR Subarea 48.3. *CCAMLR Science, 12*, 195–205.
Hughes, K. A., & Bridge, P. D. (2010). Potential impacts of bioprospecting and associated commercial activities upon Antarctic science and scientists. *Ethics in Science and Environmental Politics, 10*, 13–18.
IPCC (2007). Contribution of working group III to the 4th assessment report of the intergovernmental panel on climate change. B. Metz, O. R. Davidson, P. R. Bosch, R. Dave & L. A. Meyer (Eds.), Cambridge: Cambridge University Press.
Kirkley, J., Morrison, P. C. J., & Squires, D. (2002). Capacity and capacity utilization in common-pool resource industries. *Environmental & Resource Economics, 22*, 71–97.
Knox, G. A. (2006). *The biology of the Southern Ocean* (2nd ed.). Boca Raton: CRC Press.
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. *Reviews in Fish Biology and Fisheries, 11*, 31–56.
Laws, R. M. (1989). *Antarctica the last frontier*. London: Boxtree.
Leaper, R. & Childerhouse, S. (2013). Present and future conservation management of Antarctic baleen whales. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.
Mangel, M., & Switzer, P. V. (1998). A model at the level of the foraging trip for the indirect effects of krill (*Euphausia superba*) fisheries on krill predators. *Ecological Modelling, 105*, 235–256.

McWhinnie, S. (2007). The tragedy of the commons in international fisheries: An empirical examination. *Research Paper,* 2007–05. Adelaide: University of Adelaide, School of Economics.

Miller, D. G. M. (1987). Modelling and decision making as part of the CCAMLR management regime. *SC-CAMLR Selected Scientific Papers, 1986*, 295–322.

Miller, D. G. M. (1991). Exploitation of Antarctic marine living resources: A brief history and a possible approach to managing the krill fishery. *South African Journal of Marine Science, 10*, 321–339.

Miller, D. G. M. (2000). The Southern Ocean: A global view. *Ocean Yearbook, 14*, 468–513.

Miller, D. G. M. (2002). Antarctic krill and ecosystem management: From Seattle to Sienna. *CCAMLR Science, 9*, 175–212.

Miller, D. G. M. (2007). Managing fishing in the Sub-Antarctic. *Papers and Proceedings of the Royal Society of Tasmania, 141*, 121–140.

Miller, D. G. M. (2011a). Sustainable management in the Southern Ocean: CCAMLR science. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science Diplomacy: Antarctica, science, and the governance of international spaces* (pp. 103–121). Washington: Smithsonian Institution.

Miller, D. G. M. (2011b). Climate change and the management of high seas, straddling and migratory fish stocks. In OECD, *The economics of adapting fisheries to climate change*. (pp. 277–346). Paris: OECD Publishing.

Miller, D. G. M., & Hampton, I. (1989). Biology and ecology of the Antarctic krill (*Euphausia superba* Dana). *BIOMASS Scientific Series, 9*, 1–166.

Miller, D. G. M., & Agnew, D. J. (2000). Krill fisheries in the Southern Ocean. In I. Everson (Ed.), *Krill: biology, ecology and fisheries* (pp. 300–337). Fisheries and Aquatic Resources Series 6. Oxford: Blackwell Science.

Miller, D. G. M., Sabourenkov, E. N., & Ramm, D. C. (2004). Managing Antarctic marine living resources: The CCAMLR approach. *International Journal of Marine and Coastal Law, 19*, 317–363.

Miller, D. G. M., Slicer, N. M., & Sabourenkov, E. N. (2010). IUU fishing in Antarctic waters: CCAMLR actions and regulations. In D. Vidas (Ed.), *Law, technology and science for oceans in globalisation* (pp. 175–196). Leiden and Boston: Martinus Nijhoff.

Mitchell, B., & Sandbrook, R. (1980). *The management of the Southern Ocean. report to the international institute for environment and development*. London: Temtex Printers.

Molenaar, E. J. (2001). CCAMLR and Southern Ocean fisheries. *International Journal of Marine and Coastal Law, 13*, 465–499.

Neufeld, E., O'Reilly, J. O., Summerson, R. & Tin, T. (2013). Valuing Antarctica: emerging views from international studies. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer-Verlag.

Nicol, S. & Endo, Y. (1997). Krill fisheries of the world. *FAO fisheries technical paper*, 367.

Nicol, S., & Endo, Y. (1999). Krill fisheries—their development, management and ecosystem implications. *Aquatic Living Resources, 12*, 105–120.

Nicol, S., & Foster, J. (2003). Perspective—recent trends in the fishery for Antarctic krill. *Aquatic Living Resources, 16*, 42–45.

Nicol, S., & Robertson, G. (2003). Ecological effects of Southern Ocean harvesting. In N. Gales, M. Hindell, & R. Kirkwood (Eds.), *Marine mammals: Fisheries, tourism and management issues* (pp. 48–61). Australia: CSIRO.

Nicol, S., Croxall, J., Trathan, P., Gales, N., & Murphy, E. (2007). Paradigm misplaced? Antarctic marine ecosystems are affected by climate change as well as biological processes and harvesting. *Antarctic Science, 19*(3), 291–295.

Nicol, S., Foster, J., & Kawaguchi, S. (2011). The fishery for Antarctic krill—recent developments. *Fish and Fisheries, 13*, 30–40.

Olsen, R., Suontama, J., Langmyhr, E., Mundheim, H., Ringø, E., Melle, W., et al. (2006). The replacement of fish meal with Antarctic krill, *Euphausia superba*, in diets for Atlantic salmon. *Salmo salar*. *Aquaculture Nutrition, 12*(4), 280–290.

Österblom, H., Sumaila, U. R., Bodin, O., Sundberg, J. H., & Press, A. J. (2010). Adapting to regional enforcement: Fishing down the governance index. *PLoS ONE, 5*(9), 1–7.

Parsons, A. (1987). *Antarctica: The next decade*. Cambridge: Cambridge University Press.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., & Torres, F. C. (1998). Fishing down marine food webs. *Science, 279*, 860–863.

Pauly, D., Watson, R., & Alder, J. (2005). Global trends in world fisheries: Impacts on marine ecosystems and food security. *Philosophical Transactions of the Royal Society B, 360*, 5–12.

Perry, R. I., & Ommer, R. (2003). Scale issues in marine ecosystems and human interactions. *Fisheries Oceanography, 12*, 513–522.

Perry, R. I., Ommer, R. E., Allison, E. A., Badjeck, M.-C., Barange, M., Hamilton, L., et al. (2010). Interactions between changes in marine ecosystems and human communities. In M. Barange, J. G. Field, R. P. Harris, E. Hofmann, R. I. Perry, & F. E. Werner (Eds.), *Marine ecosystems and global change* (pp. 221–251). Oxford: Oxford University Press.

Pollnac, R. B., & Poggie, J. J. (2008). Happiness, well-being and psychocultural adaptation to the stresses associated with marine fishing. *Human Ecology Review, 15*, 194–200.

Rayfuse, R. (1998). Enforcement of high seas fisheries agreements: Observation and inspection under the convention on the conservation of Antarctic marine living resources. *International Journal of Marine and Coastal Law, 13*, 579–605.

Reid, K. (2011). Conserving Antarctica from the bottom up: Implementing UN general assembly resolution 61/105 in the commission for the conservation of Antarctic marine living resources. *Ocean Yearbook, 25*, 131–139.

Reid, K., Croxall, J. P., & Murphy, E. J. (2008). The power of ecosystem monitoring. *Aquatic Conservation: Marine and Freshwater Ecosystems, 17*, S79–S92.

Sabourenkov, E. N. & Miller, D. G. M. (2004). The management of transboundary stocks of Toothfish, *Dissostichus* spp., under the convention on the conservation of Antarctic marine living resources. In A. I. L. Payne, C. M. O'Brien, & S. I. Rogers (Eds.), *Management of shared fish stocks* (pp. 68–94). Oxford: Blackwell.

Sage, B. (1985). Conservation and exploitation. In W. N. Bonner & D. W. H. Walton (Eds.), *Key environments—Antarctica* (pp. 351–369). Oxford: Pergamon.

SC-CAMLR. (1995). *Report of the 14th meeting of the scientific committee (SC-CAMLR-XIV)*. Hobart: CCAMLR.

SC-CAMLR. (2002). *Report of the 21st meeting of the scientific committee (SC-CAMLR-XX)*. Hobart: CCAMLR.

SC-CAMLR. (2003). *Report of the 22nd meeting of the scientific committee (SC-CAMLR-XXII)*. Hobart: CCAMLR.

Small, C. (2005). *Regional fisheries management organisations: Their duties and performance in reducing bycatch of albatrosses and other species*. Cambridge: Birdlife International.

Starfield, A. M., Shelton, P. A., Field, J. G., Crawford, R. J. M., & Armstrong, M. J. (1988). Note on a modelling schema for renewable resource problems. *South African Journal of Marine Science, 12*, 1051–1060.

Sumaila, U. R. (2004). Intergenerational cost benefit analysis and marine ecosystem restoration. *Fish and Fisheries, 5*, 329–343.

Sumaila, U. R. (2008). Getting values and valuation right: A must for reconciling fisheries with conservation. *American Fisheries Society Symposium, 49*, 707–712.

Sumaila, R., Alder, J., & Keith, H. (2006). Global scope and economics of illegal fishing. *Marine Policy, 30*, 696–703.

Sumaila, U. R., & Walters, C. (2005). Intergenerational discounting: A new intuitive approach. *Ecological Economics, 52*, 135–142.

Tandy, S., Chung, R., Wat, E., Kamili, A., Berge, K., Griinari, M., et al. (2009). Dietary krill oil supplementation reduced hepatic steatosis, glycaemia and hypercholesterolemia in high-fat-fed mice. *Journal of Agricultural and Food Chemistry, 57*, 9339–9345.

Thomson, R. B., Butterworth, D. S., Boyd, I. L., & Croxall, J. P. (2000). Modelling the consequences of Antarctic krill harvesting on Antarctic fur seals. *Ecological Applications, 10*, 1806–1819.

Trathan, P. N., & Reid, K. (2009). Exploitation of the marine ecosystem in the Sub-Antarctic: Historical impacts and current consequences. *Paper and Proceedings of the Royal Society of Tasmania, 143*(1), 9–14.

Trathan, P. N., & Agnew, D. (2010). Climate change and the Antarctic marine ecosystem: An essay on management implications. *Antarctic Science, 22*(4), 387–398.

UNGA. (2007). Sustainable fisheries, including through the 1995 agreement for the implementation of the provisions of the United Nations convention on the law of the sea of 10 December 1982 relating to the conservation and management of straddling fish stock and highly migratory fish stocks, and related instruments. United Nations General Assembly Resolution 61/105.

Vidas, D. (2004). IUU fishing or IUU operations? Some observations on diagnosis and current treatment. In D. D. Caron & H. N. Scheiber (Eds.), *Bringing law to ocean waters* (pp. 1–20). Leiden: Martinus Nijhoff.

Watters, G. (1996). By-catch of fish captured by the krill fishing vessel *Chiyo Maru No. 2* in statistical area 58 (January to March 1995). *CCAMLR Science, 3*, 111–123.

Watters, G. (1997). Preliminary analysis of data collected during experimental phases of the 1994/95 and 1995/96 Antarctic Crab fishing season. *CCAMLR Science, 4*, 141–159.

Weddell, J. (1827). *A Voyage towards the South Pole: Performed in the years 1822–1824, containing and examination of the Antarctic Sea*. London: Longman, Hurst, Orme, Brown and Green.

Willock, A. & Lack, M. (2006). Follow the leader: Learning from experience and best practice in regional fisheries management organizations. Retrieved from assets.panda.org/downloads/rfmoreport06.pdf.

Woehler, E. J., Ainley, D. & Jabour, J. (2013). Human impacts to Antarctic wildlife: predictions and speculations for 2060. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment* (pp. 27–60). Dordrecht, Netherlands: Springer-Verlag.

Zeller, D. & Pauly, D. (Eds) (2007). Reconstruction of marine fisheries catches for key countries and regions (1950–2005). *Fisheries centre research reports*, (vol. 15, No. 2). Canada: Fisheries Centre, University of British Columbia.

Zimarev, Y. V. (1991). Brief programme and methods of investigations of krill damage by midwater trawl sections. *WG-Krill-91/18*, Hobart: CCAMLR.

Chapter 4
Present and Future Conservation Management of Antarctic Baleen Whales

Rebecca Leaper and Simon Childerhouse

Abstract The massive reduction of whales as a result of commercial whaling is one of the single largest human impacts to the Antarctic marine ecosystem. Systematic hunting of over 1.3 million whales, in only 70 years, almost eliminated an entire group from the marine ecosystem. While the setting of catch limits to zero for conservation and management purposes (the moratorium) has saved many heavily exploited populations from extinction, at the same time there has been a dramatic expansion of 'Special Permit' (scientific) whaling, conducted both within and outside of designated whale sanctuaries. Here we discuss a number of future management scenarios that include an expanding conservation agenda, a continuation of 'Special Permit' whaling, a cessation in whaling, and resumption of commercial whaling. To conclude, we briefly speculate on a number of potential threatening processes associated with growing levels of commercial, governmental and private human activity that may not only impact whales but Antarctica as a whole.

Keywords Cessation of whaling • Emerging threats • Future scenarios • Resumption of whaling

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4.1 Introduction

Despite the fact that Antarctica is the only continent not to have a long-term history of human contact and habitation, the massive reduction of baleen whales[1] as a result of commercial operations is one of the single largest human impacts to the Antarctic marine ecosystem. The International Whaling Commission[2] (IWC) was created when many of the major whale stocks were already in decline due to over-exploitation. As whale stocks crashed, the IWC set reduced or zero catch limits for some depleted species however, in 1982 the IWC adopted a decision (that came into force in 1986) setting all remaining commercial whaling catch limits to zero for an indefinite period[3] (the 'moratorium'). Commercial whaling continued until 1986 (and subsequently by nations with objections). The Southern Ocean Sanctuary (SOS) a 'no take' zone was established in the Southern Ocean in 1994.[4] The moratorium on commercial whaling is at the center of controversy between those who advocate for a continuation of whaling and those advocating for a continuation of protective measures to allow for the full recovery of whale populations and for the development of alternative, non-lethal uses (e.g. whale watching). In this chapter we discuss the present and future conservation management of Antarctic baleen whales under four different scenarios that include (1) ongoing considerations of the IWC, (2) continuing 'Special Permit' whaling, (3) cessation of whaling and (4) widespread whaling. Although difficult to assess, we also consider the future conservation management of baleen whales in the face of a range of other threatening processes that may impact all of Antarctica rather than just whales.

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[1] Six species of baleen whale are defined as true Antarctic whales. These species are humpback (*Megaptera novaeangliae*), blue (*Balaenoptera musculus intermedia*), Antarctic minke (*Balaenoptera bonaerensis*), fin (*Balaenoptera physalus*), sei (*Balaenoptera borealis*) and southern right (*Eubalaena australis*) whales and all are generally found south of the Antarctic Polar Front, at approximately 50–60°S.

[2] The intergovernmental body established in 1946 to 'provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry'.

[3] The decision is codified in Paragraph 10(e) of the IWC Schedule, which reads: 'Notwithstanding the other provisions of paragraph 10, catch limits for the killing for commercial purposes of whales from all stocks for the 1986 coastal and the 1985/86 pelagic seasons and thereafter shall be zero. This provision will be kept under review, based on the best scientific advice, and by 1990, at the latest the Commission will undertake a comprehensive assessment of the effects of this decision on whale stocks'.

[4] The northern boundary of the Sanctuary follows the 40°S parallel of latitude except in the Indian Ocean sector where it joins the southern boundary of that sanctuary at 55°S, and around South America and into the South Pacific where the boundary is at 60°S.

4.2 Past and Present Status of Baleen Whales

Baleen whales are an important ecological component of the Antarctic marine ecosystem not least by virtue of their large size and longevity, their (once) large biomass, and their specialisation in krill as a major food resource. Baleen whales are also ecologically significant as stores and movers of nutrients (iron, carbon and nitrogen especially) and energy, within and between different components of the ecosystem and across its boundaries (Trites et al. 2004; Nicol et al. 2010). They transfer biological production between different trophic levels, and across ocean basins through their long-range annual migrations that link breeding and calving events in low latitude tropical waters to feeding events in high latitude polar waters (Nicol et al. 2008). It is therefore likely that the loss of baleen whales had important and unique effects on the Antarctic marine ecosystem (Nicol et al. 2012).

Modern industrial whaling began in the Southern Ocean in 1904. By then, some species (e.g. southern right whales) were already severely depleted and no longer commercially viable. The total number of southern right whales killed between 1770 and 1900 is conservatively estimated at about 150,000 of which 48,000–60,000 were killed in the 1830s alone (Reilly et al. 2008a). Figure 4.1 shows the catch history for the remaining five Antarctic species. Humpback whales were heavily exploited early on in the twentieth century. Between 1904 and 1914, shore based whaling operated with remarkable efficiency taking a total catch of 36,605 whales, 85 % of which were humpbacks, with 69 % of these catches taken at South Georgia (Leaper et al. 2008). Large numbers (~43,000) were also illegally caught in the 1960s by the Soviet Union (Clapham et al. 2009). Blue whales were extremely abundant in the past but by the 1950s they were nearly extirpated in the Southern Ocean (Branch et al. 2008).

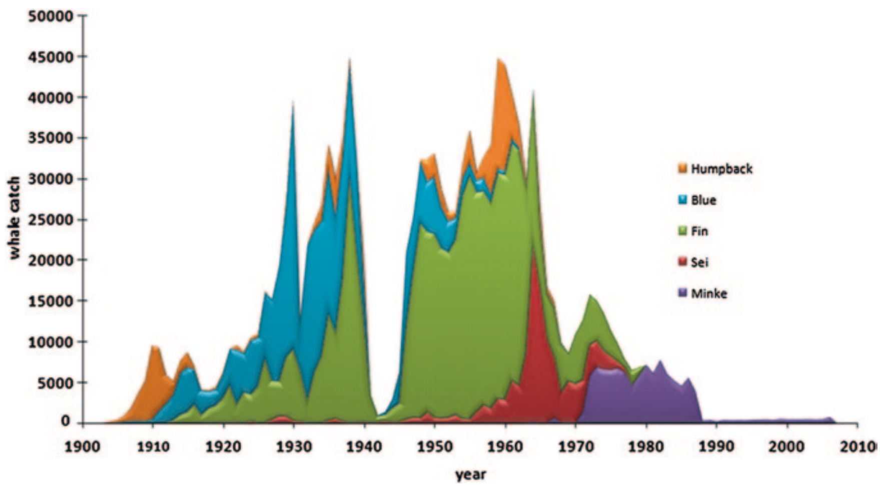

Fig. 4.1 Reported catch for five species of baleen whales south of 40°S. Catch data as reported in Leaper et al. (2008)

Fin whales were the most heavily exploited whale in the Southern Ocean (in terms of number of individuals) where during the twentieth century over 718,000 animals were caught (Leaper et al. 2008). As fin whales became overexploited, sei whale catching began and by 1977 over 125,000 sei whales had been caught (Leaper et al. 2008). Minke whales were the last of the baleen whales to be exploited, with over 104,500 caught, both in commercial and latterly the 'scientific' Special Permit whaling operations that continued after the moratorium (Leaper et al. 2008).

Notwithstanding the global moratorium on commercial whaling, most species are still at small fractions of their assumed former abundance despite decades of protection (Leaper and Miller 2011). In addition to the IWC's global ban on commercial whaling, there are other international agreements that relate to the protection of Antarctic whales. These include: (1) the Convention of the Trade in Endangered Species (CITES) controls international commercial trade in species listed on its Appendices; and (2) the Convention on Migratory Species (CMS) that is concerned with the conservation of migratory species, their habitats and migration routes. All six species of Antarctic baleen whale are listed in the CITES and CMS appendices (Table 4.1).

Most populations of humpback whales have increased since the end of whaling (Reilly et al. 2008b) and overall are estimated to be at 39 % of their former abundance (Leaper and Miller 2011). However, there are several humpback populations that remain small or for which no increase has yet been detected, i.e. the populations breeding in the South Pacific. Consequently, the International Union for Conservation of Nature (IUCN) has listed the Oceania subpopulation as 'Endangered' (Childerhouse et al. 2008). There are estimated to be just over 2,000 blue whales in Antarctica and their numbers are still about 1 % of their assumed pre-exploitation level (Branch et al. 2004). Accordingly blue whales are listed as 'Critically Endangered' and are considered one of the most at risk baleen whales

Table 4.1 Conservation status of Antarctic baleen whales

Sp./Subsp./Subpop.	Taxonomic level	CITES[1]	CMS
Humpback whale	Species	Appendix I	Appendix I
Oceania humpback whale	Subspecies	Not listed	Not listed
Antarctic blue whale	[2]	Appendix I	Appendix I
Fin whale	Species	Appendix I	Appendix I and II
Sei whale	Species	Appendix I	Appendix I and II
Antarctic minke whale	Species	Appendix I	Appendix II
Southern right whale	Species	Appendix I	Appendix I
Chile-peru southern right	Subspecies	Not listed	Not listed

[1]With respect to Appendix I of the Convention on trade in endangered species (*CITES*), Iceland, Norway and Japan hold reservations to specific listings that differ between the countries and populations. See http://www.cites.org/eng/app/reserve_index.shtml. However, even for these countries the reservations do not apply for the sei whale in areas from 0–70°E and from the equator to the Antarctic Continent, and for the fin whale in areas from 40°S to the Antarctic Continent and from 120–60°W

[2]The subspecific taxonomy of blue whales is not yet fully elucidated

in the Antarctic marine ecosystem (Reilly et al. 2008c). Fin whales are currently listed as 'Endangered' at just 2 % of an assumed pre-exploitation abundance of about 325,000 whales (Reilly et al. 2008d). Sei whales are the least known of the Antarctic baleen whales, and while there are currently no agreed estimates for Antarctica, the IUCN has classified them as 'Endangered' (Reilly et al. 2008e). There are no agreed estimates for minke whales, although total numbers are likely to be in the hundreds of thousands (Leaper et al. 2008). As a result, the IUCN has classified the minke whale as 'Data Deficient' until such time as IWC completes its comprehensive assessment of population data (Reilly et al. 2008f). Southern right whales appear to be making strong recoveries in some well-studied parts of the range, for example Argentina/Brazil, South Africa and Australia, (IWC 2001). Although still scarce relative to historic abundance at only 12 %, southern right whales are not considered under threat at the hemispheric level (Reilly et al. 2008a). Nonetheless, some breeding populations are still very small, and data are insufficient to determine whether they are recovering (Reilly et al. 2008a). Right whales have been relatively slow to recover, as compared to humpbacks, and many populations came perilously close to extinction during the late 19th and early 20th centuries (Jackson et al. 2009).

4.3 Current Regulation and Protection

Whales in the Southern Ocean are currently protected from commercial whaling under the IWC's global moratorium and the Southern Ocean Sanctuary (SOS). The International Convention for the Regulation of Whaling (ICRW) contains provisions for the taking of whales for scientific research[5] and since then the Japanese Whale Research Programme under 'Special Permit' in the Antarctic (JARPA I and II) has been conducted every year from the 1987/88 austral summer seasons, and by 2008/2009 has taken a total of 9,122 minke and 14 fin whales (Leaper and Miller 2011). Japan is the only nation to operate 'scientific' whaling in Antarctica. There has been widespread criticism of these 'scientific' programmes citing poor scientific design, unachievable and unobtainable objectives and with some scientists speculating that the poor quality of the underlying science provides good evidence that Article VIII is being used to sustain Japan's Antarctic whaling industry rather than simply to address scientific issues related to management as is stated by Japan (Gales et al. 2005; Clapham et al. 2006). Japan continues to reiterate that these programmes address areas of importance to the management of whales, whaling and the IWC (Japan 2005). In 2009, the Government of Australia

[5] ICRW Article VIII permits a Contracting Government to grant to any of its nationals a special permit authorising that national to kill,take and treat whales 'for purposes of scientific research subject to such restrictions as to number and subject to such other conditions as the Contracting Government thinks fit, and the killing, taking and treating of whales in accordance with the provisions of this Article shall be exempt from the operation of this Convention'.

instituted proceedings against Japan at the International Court of Justice seeking a ruling that the JARPA II programme is inconsistent with Article VIII of the ICRW but the case is unlikely to be heard until 2012 at the earliest (Australia 2010).

4.4 Future Regulation and Protection

The IWC has consistently and repeatedly been recognised as the primary authority for the management of whales in Antarctica (and elsewhere), both with respect to the management of whaling but also for their conservation (Gillespie 2005). However, there remains a considerable struggle between those member nations who support the resumption of commercial whaling and those defending a continuation of the moratorium. Supporters of the current moratorium are many of the countries who were directly responsible for whaling excesses of the past, most of which now express no desire to resume a commercial whaling programme. Supporters of commercial whaling are those countries maintaining that the primary purpose of the IWC is to '….thus make possible the orderly development of the whaling industry'. For example, Japan's whaling policy is in part based on the principle that whales are one of many valuable food resources. The tension between these approaches currently characterises much of the debate in the IWC, and recent efforts to resolve the impasse have failed (IWC 2010). This impasse is further complicated both by operations that undermine the moratorium such as (1) increased whaling under 'Special Permit' by Japan and commercial whaling under objection by Norway and Iceland, and (2) new and emerging non-whaling threats to whales that cannot be managed within the present framework of the IWC or by the IWC alone, such as climate change and marine pollution (Table 4.2). Unsurprisingly, the future for Antarctic whales into the next 50 years is unclear, especially given that there is scant data with which to assess the effects of non-whaling threats to baleen whales. We explore four contrasting scenarios to provide a range of perspectives into the future: (1) a future based on current IWC considerations, (2) a future based on the continuation of current 'Special Permit' whaling, (3) cessation of all whaling activities in the Southern Ocean and (4) a return to wide-spread whaling. To conclude, we briefly speculate on a number of potential threatening processes associated with growing levels of human activity that may not only impact whales but on Antarctica as a whole. While the four scenarios we present here by no means cover all possible scenarios for Antarctic baleen whales, they at least provide a basis for thinking about how the conservation of baleen whales and management of whaling activities may look like in the future.

4.4.1 Ongoing Considerations of the IWC

Since the implementation of the global moratorium, the IWC has discussed at length a management regime that can be used to regulate future commercial whaling. Such a 'Revised Management Scheme' (RMS) would likely include clauses

Table 4.2 Known and potential threats to Antarctic baleen whales adapted from Leaper and Miller (2011)

Actual/potential threat	Anthropogenic activity	Source literature for demonstrated impact in Antarctica
Commercial whaling	Direct capture	IWC (2010)
Scientific whaling	Direct capture	IWC (2007b)
Pollution		
Persistent Organic Pollutants (POPs)	Use of halogenated organic compounds	Yasunaga et al. (2006)
Oil spills	Shipping activity, research station resupply	
Sewage	Maintenance of research stations, tourism	
Noise	Shipping traffic, seismic activity, fishing	
Ship strikes	Shipping traffic, tourist operations	Van Waerebeek et al. (2007)
Tourism	Transit activities, disposal of sewage, small boat operations	Williams and Crosbie (2007)
Fisheries	Entanglement in fishing gear	Kock et al. (2006)
	Expanded commercial exploitation of whale prey (e.g. krill)	Nicol et al. (2012)
Climate change	Increased concentration of carbon dioxide in atmosphere	Leaper et al. (2006)
Temperature increase		
Decreasing sea ice		
Altered currents		
Change in prey distribution		

that specify the type of data to be collected, how those data would be used to provide management advice, and the incorporation of a feedback mechanism, i.e. a framework of observation and inspection schemes (Fig. 4.2). While certain components of the RMS, such as the 'Revised Management Procedure' (RMP)[6] are relatively fully developed, no mechanisms have yet been used to set catch limits.

One of the major stumbling blocks (and there are several) to agreeing an RMS are concerns regarding independent observation and inspection in whaling operations, as this was one of the key missing elements that led to the massive overexploitation of whales in the past (Clapham and Baker 2009). Other contentious issues include infractions of regulations and how they are dealt with and who would pay for such a complex and likely expensive, management scheme (i.e. just the nations undertaking whaling or all members of the IWC). With respect to

[6] Conceptually the new catch allocation approach differed from its predecessors in that management advice was to be based on a fully specified set of rules that would be tested in simulations of a wide variety of scenarios that would specifically take uncertainty into account.

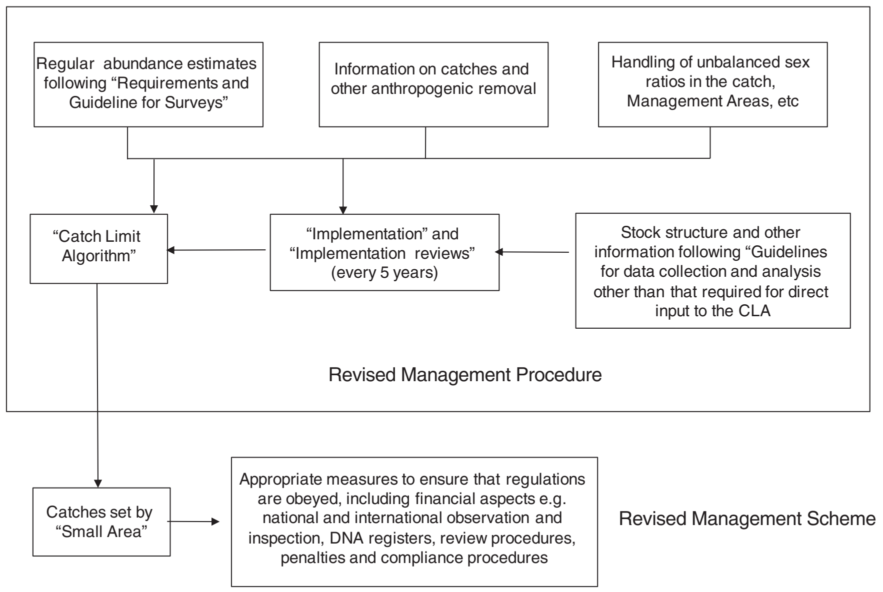

Fig. 4.2 IWC Management Procedure (adapted from Punt and Donavan 2007)

infractions, the IWC has no ability to impose sanctions or penalties directly and the Commission must depend on the whaling countries themselves to take the necessary action under domestic legislation which has not always been successful. Negotiation of the RMS was suspended by the IWC in 2006 due to the inability of the negotiation process to make progress (IWC 2007a).

While seemingly unlikely in the near future, it is always possible that there will be a negotiated return to commercial whaling through the IWC. Under this scenario commercial quotas could be set for baleen whales in Antarctica using the RMP which, if implemented correctly, is likely to allocate sustainable catch limits for some populations. However, before recommending that the RMP be applied to a species in a 'region' (generally part of an ocean basin), simulation trials must be developed and run to capture the uncertainties deemed to be the most important for that stock complex/region[7] (Punt and Donovan 2007). A precursor to such an 'Implementation' requires that a 'Pre-Implementation Assessment'[8] be conducted, but as yet none have been conducted for any species of Antarctic baleen whale

[7] This process, referred to as an 'Implementation' (in the IWC context, meaning that the Scientific Committee notifies the Commission that it could produce information on catch limits if asked to do so), focuses primarily on uncertainties about stock structure, in particular temporal and spatial variation in the mixing of stocks in areas where whaling is to take place.

[8] Where information about possible stock structure, specification of likely future removals (by both whaling and other anthropogenic causes), hypotheses about the size and spatial distribution of historical catches and the abundance and migration data are reviewed.

(with the exception of the minke whale which is now considerably out of date). Even if the RMP (and more importantly the RMS) was agreed for use in setting catch limits, current negotiations at the IWC are moving towards discarding carefully developed scientific procedure in favour of *ad hoc* allowances that attempt to balance the perceived need of whalers (i.e. the numbers they are presently killing) against what might be palatable to conservationists (see e.g. Cooke et al. 2010). The unwillingness to use the agreed version of the RMP is probably driven by the expectation that RMP catch limits would be small. The alternative *ad hoc* method of setting catch limits following a politically motivated and pseudo-scientific approach would likely expose whale populations to greater risks than when catches are subject to management procedures that are designed and tested to ensure long term sustainability (Cooke et al. 2009, 2010).

While the agenda of the IWC has previously been heavily weighted towards the 'management of whale resources' in recent years the IWC has tried to broaden its mandate by establishing a 'Conservation Committee' to consider threats other than whaling (IWC 2004). The stated aim of the Conservation Committee was 'to bring the IWC into the twenty-first century by transforming it from a traditional fishery management body to a modern conservation organisation with a comprehensive agenda covering all aspects of the conservation of whales including protection from environmental threats' (IWC 2004). At its 2005 meeting the Committee agreed a Conservation Agenda for work into the future (IWC 2006). In addition, the IWC has begun developing 'Conservation Management Plans' (CMPs), directed towards the delivery of conservation rather than exploitative outcomes (Australia 2008). The stated aims for CMPs is to 'support the recovery of vulnerable cetacean species or regional populations and to address threats that affect multiple species'. CMPs are proposed as internationally agreed, cooperative plans equipped to deal with all pertinent threats to given whale populations, including small cetaceans. The main conservation outcomes would include (1) reduction of by catch (2) regulation of whale watching (3) recovery of whale populations and (4) the establishment of effective sanctuaries. The precept for CMPs is synchronisation with other relevant international arrangements, strong support from member governments and national adaptation of the more wide reaching, regional CMPs (Australia 2008). As such, CMPs may provide a positive step forward for a Convention that aims to consider a comprehensive agenda covering all aspects of the conservation of whales. While it is unlikely that managed commercial whaling will commence in the near future, based on the repeated impasses in negotiation, in the mean time, it is possible that the impetus to focus IWC's work on conservation may gain ground, which could influence the negotiation and development of a management regime in the years to come.

4.4.2 Continuing 'Special Permit' Whaling

Under this scenario, the assumptions we make are that: (1) commercial whaling would remain prohibited in Antarctica, (2) 'Special Permit' whaling continues to only catch minke and fin whales in similar numbers to the existing catch limits and no new species are introduced and that (3) no new and emerging threats significantly impact baleen whales. Hence, under this scenario, we expect that there will be no impact from whaling on species other than minke and fin whales [and perhaps humpbacks if Japan follows through with its plan to hunt these whales as well; Japan (2005)]. This will allow for the recovery of these other species but the degree of recovery is unlikely to be consistent across all whale species and populations, given the considerable variation seen in present estimated rates of increase (Sect. 4.2). Some whale populations are likely to continue to show strong signs of recovery including some humpback whale stocks (i.e. those that breed along the coasts of west and east Australia, east coast Africa and east coast South America) currently estimated to be at more than 40 % of their estimated pre-exploitation size and which are still increasing strongly at ~10 % per annum (Leaper and Miller 2011). Some southern right whale populations are growing strongly and are estimated to be doubling in number every 10–12 years (Reilly et al. 2008a). By comparison, estimates from two independent, but preliminary analyses of Antarctic minke whale data have shown that minke whales are estimated to have declined by approximately 31–42 % between the 1980s and 1990s (IWC 2011: Table 6). ‘Special Permit’ catches of minke whales have been implicated in this decline but whaling is unlikely to be the major cause of the decline as whaling is only conducted in about one third of Antarctic waters and the largest declines are actually seen in areas where there is no whaling (IWC 2011: Table 6). Despite some populations of whales showing increases post-moratorium, some other ‘sub’ populations [e.g. South Pacific humpback whales (Childerhouse et al. 2008), South Georgia blue whales (Reilly et al. 2008c)] are showing little or no evidence of recovery despite decades of protection, leading to the inevitable conclusion that whaling may have extirpated some populations which may never recover (Clapham et al. 2008). Under this scenario, most whale populations are likely to continue to recover, however, other significant new negative influences, e.g. climate change, with concomitant changes in prey distribution and habitat, will certainly affect their recovery rates (see Sect. 4.5).

4.4.3 Cessation of Whaling Activities in the Southern Ocean

At present, the only whaling programme to operate in the Antarctic does so at a significant financial loss and is only viable due to large subsidies and low-interest loans from the Government of Japan (Ishii 2011). The increasing cost of fuel and the large costs associated with redevelopment or replacement of the only Japanese whaling factory ship that must be compliant with new legislation surrounding the use of heavy fuels in the Antarctic (ASOC 2009; IMO 2009) will make an expanded operation a financially risky venture. Furthermore, whale meat and other products would have to significantly increase in value before they would cover costs of such an operation, let alone generate a profit. In the past, many whaling nations did not necessarily abandon whaling for any real philosophical motivation to protect whales, but directly as a result of a low demand for products and/or coupled with the depletion of most whale stocks to uneconomic numbers. Some commentators have speculated that the primary motivation for the continuation of whaling operations in Japan is to keep the skills and industry alive and ongoing in preparation for a return to a commercial industry, in the event the moratorium is ever lifted (Holt 2007). Others forecast that changes in Japanese culture and diet are likely to lead to reduced consumption of whale meat which will, in turn, put an end to Japan's whaling activities (Hoek 2010). Interception of whaling fleets by environmental groups Greenpeace and Sea Shepherd in the Southern Ocean have succeeded in significantly disrupting whaling and reducing the number of whales killed, turning Japanese public opinion against whaling and eating whale meat (Roeschke 2009), while attracting considerable criticism from many quarters with regards to the methods deployed. In 2011 Japan cut its whaling season short '…in order to avoid any injury or threat to life of the [whaling] crew members and property of the fleet caused by the continued illegal attacks and sabotage of the Sea Shepherd' (ICR 2011).

4.4.4 Widespread Whaling

A three quarter majority of voting members of the IWC would need to agree for there to be any real prospect of a return to commercial whaling (and especially in Antarctica where the SOS would also need to be overturned). This would require a fundamental shift in the positions adopted by both pro-and anti-whaling countries which has not happened despite constant discussions over the 25 years. Therefore, it appears that, apart from whaling under 'Special Permit', there is no real prospect of large-scale high seas commercial whaling resuming in the foreseeable future. However, it is clear that a number of circumventions or exemptions to the moratorium are possible. Options were tabled at the IWC in 2010 that would allow for this by defining a new type of whaling that was not commercial, and therefore would not be bound by the moratorium which would remain in place (IWC 2010). Despite considerable efforts by parties to reach a compromise solution, negotiations stalled in 2010 and the IWC entered a 'period of reflection' without providing a clear vision for how to proceed.

Despite exceptions to the moratorium (which are likely to take protracted negotiations to resolve) perhaps another possible scenario for increased whaling (in Antarctic waters at least) will be through an expansion of the existing 'Special Permit' whaling programme conducted by the Government of Japan or through other nations issuing new permits (although the latter at this stage seems extremely unlikely). Any nation can unilaterally issue itself a 'Special Permit' to catch any number of whales, in any location and completely independent of the constraints of the moratorium. Small scale 'Special Permit' whaling was used by many nations prior to the moratorium but only Japan, Norway, Iceland and Korea (for only a single year in 1986) conducted 'Special Permit' whaling post-moratorium and of these, only Japan killed whales in Antarctic waters. In the case of Japan, a 'Special Permit' whaling programme has been conducted every year in the Antarctic since 1987. As Cooke et al. (2010) state, 'any constant level of catch, except a trivially small one, will engender a high risk of severe depletion or even extinction if continued for long enough, because it does not allow for corrective action in the event of the catch being unsustainable or during an environmentally related downturn'. As yet no other nation has issued a 'Special Permit' for whaling in the Antarctic which may in part due to the significant controversy and negative international political pressure that has been brought to bear on Japan (and earlier on Iceland), but also perhaps because other nations potentially interested in resuming whaling (i.e. Korea) have been politely (and appropriately) waiting for the issue of the moratorium to reach a negotiated settlement.

4.5 Synergies with Non-whaling Threats

Although whaling is likely to remain the most immediate threat to baleen whales in contemporary Antarctica, whales are facing an increasing number of impacts that are more subtle than whaling. Despite an increasing awareness of the potential impacts of human activities in the Antarctic marine ecosystem (see e.g. Tin et al. 2009), little has been done to undertake a thorough analysis of locations where human activity is occurring and concentrating, as well as a quantitative assessment of potential impacts with respect to baleen whales (Leaper and Miller 2011). Table 4.2 summarises the current evidence for known and potential threats to Antarctic baleen whales. Threats are thought to range from emerging and global problems—marine pollution and climate change—to localised issues including shipping, habitat disturbance and unregulated wildlife tourism and fishery activities, but detailed information of known impacts on a species by species basis is scant (Leaper and Miller 2011). In addition, the interpretation of the responses of baleen whale populations to new threats are especially difficult to disentangle from the effects of exploitation, and may not be detected (or in fact even be detectable) for some time given whales are such long-lived species. The contemporary Antarctic marine ecosystem is the product of the cumulative effects of exploitation over time as well as regional and global changes in the physical and biological environment (Nicol et al. 2008). The long term dynamics of Antarctic baleen whales will ultimately be affected by factors such as environmental change and density dependent limitations to growth. While baleen whales have developed life history strategies that keep them relatively buffered from interannual variability in environmental conditions (Wade 2009), it is their response to longer term environmental change that will be of primary importance to their long term recovery and future status. With the removal of huge numbers of predators (including whales) from the Antarctic marine ecosystem and the concomitant changes to the physical environment (Constable and Doust 2009), it would be unrealistic to expect no change in the structure and function of the Antarctic marine ecosystem. It is also likely that the current carrying capacity and ecosystem structure is now different from that prior to pre-exploitation on both the feeding and breeding grounds. How this might affect a new *status quo* for whale populations however, is yet unknown. While we are far from being able to understand the possible consequences of non-whaling threats to baleen whales, it is clear that that these threats will not be addressed by a focus solely on the management of whaling.

4.6 Conclusions

The global moratorium on commercial whaling implemented in 1986 continues to be at the center of controversy between those who advocate for whaling and those who oppose it. Since its implementation 25 years ago, the moratorium has saved many heavily exploited populations from extinction, allowed some populations to recover and seen the development of a conservation agenda within the IWC. However, the moratorium has also been circumvented by continued whaling in Antarctica through the loophole of 'Special Permit' whaling, and more recently, by efforts to abandon a carefully developed scientific procedure in favour of the *ad hoc* setting of politically motivated catch limits. Given the protracted stalemate in the IWC (the primary authority for the management of baleen whales), it is incredibly difficult to predict the future for whales and whaling in Antarctica especially in view of emerging non-whaling threats. It seems highly unlikely that a consensus compromise will be reached that will reopen the Antarctic to large scale whaling unless there are some significant shifts in member nations views regarding whales and whaling. In addition, given the entrenched positions of pro and anti-whaling nations, and the failure to move forward crucial debates concerning the capacity for countries to 'opt-out' of responsible collective management; the dramatic expansion of 'Special Permit' whaling; and the lack of a robust compliance and enforcement framework, one of the most plausible scenarios in the near term is that Japan will continue to be the only nation whaling in Antarctica, unilaterally setting a catch limit under 'Special Permit' provisions. For conservation outcomes one can only hope that the IWC closes the loophole of 'Special Permit' whaling and supports the continuation of protective measures to allow for the full recovery of whale populations (including the SOS) and for the development of alternative, non-lethal uses, while baleen whales quietly get on with their business of recovering (at least those not killed by 'Special Permit').

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References

ASOC. (2009). *IMO to consider ban on heavy fuel oil in Antarctic waters.* Press briefing by ASOC. Retrieved from: http://www.asoc.org/storage/documents/IMO/ASOC_heavy_fuel_oil_ban_briefing063009.pdf.

Australia. (2008). *Conservation management plans for improved Cetacean Management*. Paper IWC/60/15 presented to the 60th Annual Meeting of the IWC.

Australia. (2010). *Application of Japan's JARPA II program of scientific whaling* (*Austl.* v. *Japan*). Retrieved from: http://www.icj-cij.org/docket/files/148/15951.pdf [hereinafter Application].

Branch, T. A., Matsuoka, K., & Miyashita, T. (2004). Evidence for increases in Antarctic blue whales based on Bayesian modelling. *Marine Mammal Science, 20*(4), 726–754.

Branch, T. A., Allison, C., Michalev, Y. U., Tormosov, D., & Brownell Jr, R. L. (2008, June). *Historical catch series for Antarctic and pygmy blue whales*. Paper SC/60/SH9 presented to the IWC Scientific Committee, Santiago, Chile, 1–3.

Childerhouse, S., Jackson, J., Baker, C. S., Gales, N., Clapham, P. J., & Brownell Jr, R. L. (2008). *Megaptera novaeangliae (Oceania subpopulation). IUCN Red List of Threatened Species.* Version 2010.1. Retrieved from http://www.iucnredlist.org.

Clapham, P. J., & Baker, C. S. (2009). Whaling modern. In W. F. Perrin., B. Wursig., & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals second edition* (pp. 1239–1243). San Diego, CA: Academic Press.

Clapham, P. J., Aguilar, A., & Hatch, L. T. (2008). Determining spatial and temporal scales for management: Lessons from whaling. *Marine Mammal Science, 24*(1), 183–201.

Clapham, P. J., Childerhouse, S., Gales, N. J., Rojas, L., Tillman, M., & Brownell, R. L, Jr. (2006). The whaling issue: Conservation, confusion and casuistry. *Marine Policy, 31*, 314–319.

Clapham, P., Mikhavlev, Y. U., Franklin, W., Paton, D., Baker, C. S., Ivashchenko, Y. V., & Brownell JR, R. L. (2009). *Catches of humpback whales by the Soviet Union and other nations in the Southern Ocean*, 1947–1973. Marine Fisheries Review 71, 39–43.

Cooke, J., Leaper, L., & Papastavrou, V. (2009). Science should not be abandoned in a bid to resolve whaling disputes. *Biology Letters, 5*, 614–616.

Cooke, J., Holt, S., Leaper, L., & Papastavrou, V. (2010). Call for science to clear whaling confusion. *Science, 328*, 1481.

Constable, A. J., & Doust, S. (2009). *Southern Ocean Sentinel—an international program to assess climate change impacts on marine ecosystems: Report of an international workshop, Hobart*. ACE CRC, Commonwealth of Australia, and WWF-Australia.

Gales, N. J., Kasuya, T., Clapham, P. J., & Brownell JR, R. L. (2005). Japan's whaling plan under scrutiny: Useful science or unregulated commercial whaling? *Nature*, 435, 883–884.

Gillespie, A. (2005). *Whaling diplomacy: Defining issues in international environmental law*. Northampton, MA, USA: Edward Elgar Publishing.

Holt, S. J. (2007). Whaling: Will the phoenix rise again? *Marine Policy, 54*, 1081–1086.

Hoek, A. K. (2010). Sea shepherd conservation society v. Japanese whalers, the showdown: Who is the real villain? *Stanford Journal of Animal Law and Policy, 3*, 159–193.

IMO. (2009). *Amendments to MARPOL Annex I (Use or carriage of oils in the Antarctic area).* Document MEPC 60/5 presented to the 59th session of the Marine Environment Protection Committee, 22–26. March 2010. London, UK.

ICR. (2011). *JARPA II vessels return home*. Press release by ICR. Retrieved from: http://www.icrwhale.org/pdf/110218ReleaseENG.pdf.

IWC. (2001). Report of the workshop on the comprehensive assessment of right whales: a worldwide comparison. *Journal of Cetacean Research and Management, 2*, 1–60.

IWC. (2004). *IWC Resolution 2003–1. The Berlin Initiative on Strengthening the Conservation Agenda of the International Whaling Commission.* Chair's Report of the Fifty-Fifth Annual Meeting, Berlin, Germany, 16–19. June 2003. Annex C. Cambridge, UK: IWC.

IWC. (2006). Chairman's Report of the Fifty-Seventh Annual Meeting. Annex H. Report of the Conservation Committee. Annual Report of the International Whaling Commission, 2005, 62–63.

IWC. (2007a). *Chair's Report of the Fifty-Eighth Annual Meeting, St. Kitts and Nevis,* 16–20 June 2006 (p. 34). Cambridge, UK: IWC.

IWC. (2007b). Report of the Intersessional workshop to review data and results from special permit research on minke whales in the Antarctic, Tokyo 4–8 Dec 2006. Paper SC/59/Rep1 presented to the IWC Scientific Committee, June 2007, USA: Anchorage.

IWC. (2010). Chair's Summary Report of the 62nd Annual Meeting, Agadir, Morocco, June 2010. Cambridge, UK: IWC.

IWC. (2011). Report of the Scientific Committee, Tromsø, Norway, 30 May–11 June, 2011. Cambridge, UK: IWC.

Ishii, A. (2011). Japan and the whaling issue: A viewpoint based on a review of 'Whaling in Japan: Power, politics, and diplomacy' by Jun Morikawa. *Ocean and Coastal Management, 54*, 274–276.

Jackson, J. A., Carroll, E., Smith, T. D., Patenaude, N., & Baker, C. S. (2009). *Taking Stock: The historical demography of the New Zealand right whale (the Tohora)*. Progress Report #5 to the Ministry of Fisheries.

Japan. (2005). *Plan for the Second Phase of the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA II)—Monitoring of the Antarctic Ecosystem and Development of New Management Objectives for Whale Resources.* Paper SC/57/O1 presented to the IWC Scientific Committee June 2005, Ulsan, Korea.

Kock, K.-H., Purves, M. G., & Duhamel, G. (2006). Interactions between cetacean and fisheries in the Southern Ocean. *Polar Biology, 29*, 379–388.

Leaper, R., & Miller, C. (2011). Management of Antarctic baleen whales amid past exploitation, current problems, emerging threats and complex marine ecosystems. *Antarctic Science, 23*(6), 503–529.

Leaper, R., Cooke, J., Trathan, P., Reid, K., Rowntree, V., & Payne, R. (2006). Global climate drives southern right whale (*Eubalaena australis*) population dynamics. *Biology Letters, 2*(2), 289–292.

Leaper, R., Zerbini, A. N., Bannister, J. L., Branch, T. A., Clapham, P. J., Donovan, G. P., Matsuoka, K., & Reilly, S. (2008). *A review of abundance, trends, foraging and life history parameters of baleen whales in the Southern Hemisphere*. Paper CCAMLR-IWC-WS-08/4 presented to the joint CCAMLR-IWC workshop to review input data for Antarctic marine ecosystem models, 11–15 Aug 2008, Hobart, Australia.

Nicol, S., Worby, A., & Leaper, R. (2008). Changes in the Antarctic sea ice ecosystem: Potential effects on krill and baleen whales. *Marine and Freshwater Research, 59*, 361–382.

Nicol, S., Bowie, A., Jarman, S., Lannuzel, D., Meiners, K. M., & Van Der Merwe, P. (2010). Southern Ocean iron fertilization by baleen whales and Antarctic krill. *Fish and Fisheries, 11*, 203–209.

Nicol, S., Foster, J., & Kawaguchi, S. (2012). The fishery for Antarctic krill—recent developments. *Fish and Fisheries, 13*(1), 30–40.

Punt, A. E., & Donovan, G. G. (2007). Developing management procedures that are robust to uncertainty: Lessons from the international whaling commission. *ICES Journal of Marine Science, 64*, 603–612.

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell JR, R. L., Butterworth, D. S., Clapham, P. J., Cooke, J., Donovan, G. P., Urbán, J., & Zerbini, A. N. (2008a). Eubalaena australis. *IUCN Red List of Threatened Species.* Version 2010.1. Retrieved from http://www.iucnredlist.org.

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell JR, R. L., Butterworth, D. S., Clapham, P. J., Cooke, J., Donovan, G. P., Urbán, J., & Zerbini, A. N. (2008b). Megaptera novaeangliae. *IUCN Red List of Threatened Species.* Version 2010.1. Retrieved from http://www.iucnredlist.org.

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell JR, R. L., Butterworth, D. S., Clapham, P. J., Cooke, J., Donovan, G. P., Urbán, J., & Zerbini, A. N. (2008c). Balaenoptera musculus *spp. intermedia. IUCN Red List of Threatened Species.* Version 2010.1. Retrieved from http://www.iucnredlist.org.

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell JR, R. L., Butterworth, D. S., Clapham, P. J., Cooke, J., Donovan, G. P., Urbán, J., & Zerbini, A. N. (2008d). Balaenoptera physalus. *IUCN Red List of Threatened Species.* Version 2010.1. Retrieved from http://www.iucnredlist.org.

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell JR, R. L., Butterworth, D. S., Clapham, P. J., Cooke, J., Donovan, G. P., Urbán, J., & Zerbini, A. N. (2008e). Balaenoptera borealis. *IUCN Red List of Threatened Species.* Version 2010.1. Retrieved from http://www.iucnredlist.org.

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell JR, R. L., Butterworth, D. S., Clapham, P. J., Cooke, J., Donovan, G. P., Urbán, J., & Zerbini, A. N. (2008f). Balaenoptera bonaerensis. *IUCN Red List of Threatened Species.* Version 2010.1. Retrieved from http://www.iucnredlist.org.

Roeschke, J. E. (2009). Eco-terrorism and piracy on the high seas: Japanese whaling and the rights of private groups to enforce international conservation law in neutral waters. *The Villanova Environmental Law Journal, 20*(1), 99–136.

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., et al. (2009). Impacts of local human activities on the Antarctic environment. A review. *Antarctic Science, 21*(1), 3–33.

Trites, A. W., Bredesen, E. L., & Coombs, A. P. (2004). Whales, whaling and ecosystem change in the Antarctic and Eastern Bering Sea: insights from ecosystem models. In *Investigating the roles of cetaceans in marine ecosystems* (pp. 85–92). CSIEM Workshop Monographs 25. Monaco: CSIEM.

Van Waerebeek, K., Baker, A. N., Félix, F., Gedamke, J., Iñiguez, M., Sanino, G. P., et al. (2007). Vessel collisions with small cetaceans worldwide and with large whales in the Southern hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals, 6*, 43–69.

Wade, P. R. (2009). Population dynamics. In W. F. Perrin, B. Wursig., & J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals Second Edition* (pp. 913–918). San Diego, CA: Academic Press.

Williams, R., & Crosbie, K. (2007). Antarctic whales and Antarctic tourism. *Tourism in Marine Environments, 4*, 195–202.

Yasunaga, G., Fujise, Y., Zenitani, R., Tanabe, S., & Kato H. (2006). *Spatial and temporal variations in organochlorine contaminants in the Antarctic minke whale, Balaenoptera bonaerensis.* Paper SC/D06/J29 presented to the JARPA Review Workshop, Tokyo, Japan, 4–8 Dec, 2006.

Chapter 5
Global Movement and Homogenisation of Biota: Challenges to the Environmental Management of Antarctica?

Kevin A. Hughes, Peter Convey and Ad H. L. Huiskes

Abstract Globally, many thousands of species have been redistributed beyond their natural dispersal ranges as a result of human activities. The introduction of non-native species can have severe consequences for indigenous biota with changes in both ecosystem structure and function. The Antarctic region has not escaped this threat. The introduction of invasive species, including vertebrates, invertebrates and plants, has altered substantially the ecosystems of many sub-Antarctic islands. In contrast, the Antarctic continent itself currently has few confirmed non-native species, but numbers are increasing. Possible future increases in human presence in the region, either through tourism, governmental operators or other commercial activities, will increase the risk of further non-native species introductions, while climate change may enhance the likelihood of establishment and range expansion. Ensuring effective biosecurity measures are implemented throughout the Antarctic region in a timely manner is an urgent challenge for the Antarctic Treaty nations and the Antarctic community as a whole.

Keywords Alien • Antarctic • Biodiversity • Invasive species • Non-native

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5.1 Introduction

5.1.1 Global Homogenisation of Biota

Homogenisation of biota results from the replacement of native species by locally expanding non-native (synonyms: alien, exotic, non-indigenous) species (Olden et al. 2004), or genetic homogenisation within species by connecting together previously isolated populations (Chown and Convey 2007). It is one of the major ecological problems facing Planet Earth (McKinney and Lockwood 1999), the others being habitat loss, climate change and pollution. However, in contrast with pollution, the impacts of which may decrease over time as the contaminant is dispersed or degraded, a non-native species population may initially comprise of a single or low number of individuals, with little impact on the indigenous biota, but with time they may expand their distribution and alter irreversibly their host ecosystems (Fig. 5.1). Biological invasions reduce the specific distinctions between biota (Olden et al. 2004) and generally diminish biodiversity (Smart et al. 2006) leading, in turn, to changes in ecosystem structure and function (Mack et al. 2000). Three stages can be distinguished: (1) introduction, (2) naturalisation and (3) invasion (Richardson et al. 2000). Introduction means that an organism (or propagule thereof) has been transported across a geographical barrier, which separates the respective biotas. The naturalisation stage is reached when the introduced species is able to reproduce successfully and regularly. This stage comprises successful germination or hatching, establishment, growth and propagation. The invasive stage plays the most important role in homogenisation, involving the local and regional dispersal of propagules, which in turn produce successful offspring. Once the invasive stage is reached, eradications are likely to be impossible and subsequent impacts upon local biodiversity irreversible (see Fig. 5.1).

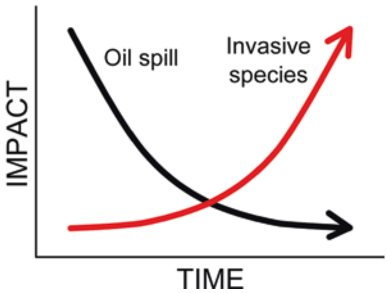

Fig. 5.1 Schematic representation of the relative impacts over time of two serious environmental incidents: marine oil spill and introduction of an invasive species. Oil spills at sea may cause substantial damage to local wildlife, but with time, the oil evaporates or dissipates and impacts generally become reduced. In contrast, the environmental impacts associated with the early stages of colonisation by a non-native species are low or non-existent, but should the organism become established and then invasive, the consequences for indigenous biological communities may be widespread and irreversible

Although natural invasions occur [e.g. the collared dove (*Streptopelia decaocto*) from Asia and the Balkans across all of Europe (Williamson 1997)], contemporary homogenisation of biotas is largely human induced. Organisms may be transported by human activities over considerable distances. Such transport may be intentional, the organism having economic, aesthetic or other values. However, inadvertently transported organisms have been a far more significant origin of invasions globally over centuries or even millennia (e.g. Crosby 1972). Accidental introductions can be numerous: 47 % of the New Zealand flora consists of non-native species (Heywood 1989). A third way to facilitate the movement of non-native species is the breach of natural dispersal barriers, for instance the construction of shipping canals such as the Panama Canal, Suez Canal or the Rhine-Main-Danube Canal. (e.g. Bij de Vaate et al. 2002).

5.1.2 Non-native Species in the Antarctic

The Antarctic[1] has to date been less affected by anthropogenic introductions of non-native organisms, because of the relatively late arrival of humans on the continent (Hughes and Convey 2010) and the location of human activity, concentrated around the sites of the research stations or sites frequently visited by tourists (Tin et al. 2009). Again, organisms have been imported both deliberately and inadvertently. Frenot et al. (2005) listed the non-native species known from the region at that stage, focusing on terrestrial biota and tabulating 108 vascular plants, 72 invertebrates and 16 vertebrate species. A small number of new records have been reported since then (e.g. Convey et al. 2010; Smith and Richardson 2011; Greenslade and Convey 2012). The number of non-native cryptogams is not known, as the Antarctic harbours many cosmopolitan cryptogam species (Øvstedal and Smith 2001; Ochyra et al. 2008). Knowledge of microbial diversity in the region is very limited (although improving), hence little is known about non-native microorganisms and diseases occurring in the Antarctic (Convey 2008; Kerry and Riddle 2009; Cowan et al. 2011). We focus in this chapter mainly on introductions in the terrestrial ecosystem, as there is more information available as compared to the Antarctic marine ecosystem (but see Lewis et al. 2003, 2005; Lee and Chown 2007), where very few introductions are currently documented (Frenot et al. 2005).

5.1.3 Vertebrate Introductions

Non-native vertebrate introductions are all confined to the sub-Antarctic islands. The two rat species (*Rattus rattus* and *R. norvegicus*) and the house mouse

[1] We use the term ‘Antarctica’ to refer to the continent in a geographical sense, and ‘the Antarctic’ in a biogeographical sense, i.e. including the sub-Antarctic islands.

(*Mus musculus*) were introduced inadvertently, escaping from visiting or shipwrecked vessels. Although three northern bird species (on Macquarie Island), *Anas platyrhynchus*, *Sturnus vulgaris* and *Carduelis flammea* are believed to have reached the island naturally from other Southern Hemisphere locations (Frenot et al. 2005; Copson and Whinam 2001), the other 10 species were introduced for human consumption, or to eradicate rats and mice (cats).

5.1.4 Invertebrate and Plant Introductions

In the sub-Antarctic and Antarctica, most of the non-native vascular plants and all invertebrate species were introduced inadvertently, with the exception of rabbit fleas carrying the myxoma virus, which were introduced to Macquarie and Kerguelen Islands as a biocontrol agent to reduce rabbit populations (Chekchak et al. 2000; Copson and Whinam 2001). At present relatively few non-native species have been reported from Antarctica, but numbers are starting to increase. In the terrestrial realm of the Antarctic Peninsula and Scotia arc region two vascular plant species (*Poa pratensis* and *P. annua*), an enchytraeid worm (*Christensenidrilus blocki*) and a chironomid midge (*Eretmoptera murphyi*) have successfully established (Smith 1996; Dózsa-Farkas and Convey 1997; Hughes and Worland 2010; Molina-Montenegro et al. 2012). There are a number of reports of Collembola (springtails) from the Antarctic Peninsula region, but their current status is unknown (Greenslade 1995; Greenslade and Wise 1984; Greenslade et al. 2012). *Poa annua* has recently been reported adjacent to two Chilean stations and one Argentine station situated in the northern Antarctic Peninsula (General Bernardo O'Higgins station, Gabriel González Videla station and Almirante Brown station) (Molina-Montenegro et al. 2010) and a currently unidentified trichocerid fly has been found in the sewage system and in the vicinity of the Uruguayan General Artigas Station on Fildes Peninsula, King George Island, South Shetland Islands (O. Volontario et al. pers. comm.). All known terrestrial introductions are found close to research stations and this pattern is likely to continue in the future as increasing numbers of research facilities are constructed. Species have also been recorded living synanthropically within research stations; Hughes et al. (2005) reported two independent introductions of the non-native dipteran *Lycoriella* sp. (black fungus midge) to the alcohol bond at the Rothera Research Station (United Kingdom), and the sewage system at Casey Station (Australia). The midges at Rothera Research Station were eradicated shortly after introduction but, despite considerable eradication attempts at Casey Station since it was first observed in 1998, it still persists within the buildings.

The green alga *Enteromorpha intestinalis* growing in the intertidal zone of Half Moon Island (South Shetland Islands) is a marine species probably introduced via vessel hulls (Clayton et al. 1997; Griffiths 2010). The issue of marine invasions has not been adequately considered by the Antarctic Treaty parties, and may not be a priority due to a combination of the likely high cost of implementing or developing technologies to reduce the risk of non-native species introductions on the hulls of tourist or National Antarctic Program (NAP) ships (Lee and Chown 2007; Aronson et al. 2011), and the practical difficulties of achieving any form of effective eradication of any species that becomes established in the marine environment.

Non-native species found in the Antarctic are often recognised only once established and are therefore past the introduction stage (for examples see Hughes and Convey 2012). Once established it can quickly become very difficult to eradicate non-native species. Eradication of, for instance, established *Sagina procumbens* on Prince Edward Island and Heard Island has only a temporary effect and needs to be repeated regularly (N. Gremmen pers. comm.; K. Kiefer pers. comm.). On the sub-Antarctic islands, several species have reached the invasive stage, such as *Agrostis stolonifera* and *Poa annua* on Marion Island, where these species show a negative influence on the natural plant species diversity (Gremmen et al. 1998), or are in the process of reaching the invasive stage [cf. *Poa annua* on King George Island, an example of such a development in the maritime Antarctic (Olech and Chwedorzewska 2011)].

The number of visitors to the region has been increasing steadily since the 1980s, which has presumably increased the propagule load accordingly. Furthermore, climate amelioration in the sub-Antarctic islands and West Antarctica will facilitate successful colonisation by non-native species, while the increasing use of aeroplanes and helicopters provides potentially rapid transport over long distances. This may cause a redistribution of native Antarctic organisms between biologically separated areas (i.e. intra-regional transfer of species) which has been highlighted as an increasing threat of homogenisation within the continent itself (Convey et al. 2000; Chown and Convey 2007; Hughes and Convey 2010).

5.1.5 Present Legislation Within the Sub-Antarctic Islands and Antarctica

Islands north of the Antarctic Treaty's area of governance include the sovereign territories of six nations (United Kingdom, Norway, South Africa, France, Australia and New Zealand) each of which enforces its own national legislation concerning conservation and biosecurity issues. Levels of protection are generally high, with most islands recognised as nature reserves at a national, and in some cases, international level (e.g. inclusion of Macquarie, Heard and McDonald Islands on the UNESCO World Heritage list; de Villiers et al. 2006). As the sub-Antarctic islands have already sustained variable, but often substantial, levels of impact from invasive species (Convey and Lebouvier 2009), biosecurity standards are now often high (Department of Environmental Affairs and Tourism 1996).

The Antarctic Treaty, which applies to the areas south of latitude 60°S, is the legal instrument used to regulate activities in Antarctica, with the Protocol on Environmental Protection to the Antarctic Treaty (signed in 1991, entered into force in 1998; also known as the Environmental Protocol or Madrid Protocol) dealing predominantly with environmental issues (ATCP 1991). All policy matters must be agreed by consensus at the, now annual, Antarctic Treaty Consultative Meeting (ATCM) and then enacted into national legislation by each Party. Legislation pertaining to the issue of non-native species is found within the Annex II (Conservation of Antarctic Fauna and Flora) and Annex V (Area Protection and Management) of the Environmental Protocol (ATCP 1991) (see Hughes and Convey 2010 for more detail). Article 4 of Annex II contains much of the legislation prohibiting the intentional introduction of non-indigenous plants and animals to the Antarctic Treaty area, which is only allowed for a defined scientific purpose and in accordance with a permit. Annex II says little about the unintentional introduction of non-native species, but specifies that precautions must be taken to prevent the introduction of microorganisms not present in the native flora and fauna. The intra-regional transfer of species may present a more significant threat than intercontinental introductions, as Antarctic species may have physiological pre-adaptation to cope with environmental conditions at other Antarctic locations (Convey et al. 2000; Convey 2008; Lee and Chown 2011). Annex II does not mention intra-regional transfer of species specifically, but does state that 'the diversity of species, as well as the habitats essential to their existence and the balance of the ecological systems existing within the Antarctic Treaty area be maintained' [Annex II Article 3(3c)]. Annex V of the Environmental Protocol deals with the Antarctic protected area system, with Antarctic Specially Protected Areas (ASPAs) generally employed to protect vulnerable, important, unusual or unique biological assemblages [Annex V Article 3(2)]. Many ASPA management plans contain text prohibiting the introduction of non-natives species, but few provide recommended biosecurity measures and advice, nor do they take into consideration the biogeography of the local area or the dispersal capacity of organisms over potentially large spatial scales (Hughes and Convey 2010).

Individual Treaty parties have responsibility for the enforcement of national laws relating to the Treaty on their citizens. No legal process exists for a nation or group of nations to penalise the citizens of another nation, or non-signatory nation, should any breaches of the Treaty and Environmental Protocol occur. In practice, prosecutions under national Antarctic legislation are rare, despite the occurrence of clear breaches of the Environmental Protocol (e.g. Hughes 2010; Braun et al. 2012).

5.1.6 Antarctic Personnel Awareness of Environmental Issues and Legislation

The work of policymakers is wasted if environmental legislation and recommendations are not translated into simple practical terms for those visiting and working in Antarctica. The Environmental Protocol with its six annexes is a lengthy document of more than 18,000 words. How well its contents are presented to and understood by the various visitors to Antarctica is not known. Many NAPs provide pre-deployment training to staff, which includes information on minimising environmental impact. However, the quality and extent of this training varies widely

Fig. 5.2 Non-native potted plant in the window of the Russian Bellingshausen Station (Fildes Peninsula, King George Island, South Shetland Islands). Importation without a permit of non-native plants and any associated non-native soil is not permitted under the Environmental Protocol. (*Photograph* K. A. Hughes)

between nations, the information may only form a small part of a much wider introduction and it may not be followed up and reiterated once the personnel arrive in Antarctica. At and near some Antarctic research stations clear breaches of the Environmental Protocol are evident (see Fig. 5.2; Braun et al. 2012). For instance, illegal behaviour by staff from all research stations on the Fildes Peninsula has included feeding of skuas and gulls with poultry products, which is a route by which pathogens could be transferred to the indigenous fauna (Bonnedahl et al. 2005; Australia 2001; Woehler et al. 2013).

5.1.7 The Propagule Load of Visitors and Imported Goods

In the austral summer of 2007/2008, using the momentum of the International Polar Year (2007–2009), an international team of ecologists assessed propagule (e.g. seeds, spores and reproductive adult organisms) pressure and the vectors (e.g. clothing, containers and fresh produce) and pathways (e.g. Australia to Antarctica via air or via sea), in as integrated a fashion across the region as possible (SCAR 2010).

5.1.7.1 Visitors and Their Clothing

A total of 850 people, travelling on 27 different ships and aircraft, making 55 different voyages, were sampled, focusing on plant seeds that may be carried

Table 5.1 Proportion of members carrying seeds in each of the visitor categories sampled (derived from Chown et al. 2012)

Category	Number	Seeds present (%)	No seeds present (%)
Ship's or aircraft crew	18	11	89
Tourists	361	21	79
Tourist support personnel	26	54	46
Field-based scientist	120	53	47
Station- or ship-based scientist	87	43	57
Field-based national programme support personnel	39	46	54
Station- or ship-based national programme support personnel	147	41	59

on clothing and baggage (Chown et al. 2012). Approximately half of those sampled were involved in NAPs (14 ships/aircraft and 18 voyages), and half from tourist operations (13 ships and 37 voyages). Additionally, 5,659 questionnaires were completed to assess patterns of travel history. Approximately 30 % of the visitors sampled carried plant seeds. Visitors carrying seeds average 9.5 seeds per person. Analyses indicated that the categories 'ship and aircraft crew' and 'tourists' had the lowest proportion of members carrying seeds, whereas 'field-based scientist' and 'tourist support personnel' had the highest proportion with seeds present (Table 5.1). The western Antarctic Peninsula was identified as currently having the highest risk for the establishment of non-native species, followed by the Ross Sea area and the East Antarctic coastal area (Chown et al. 2012).

Analyses of baggage and clothing items indicated that camera bags, back packs and footwear showed a higher frequency of harbouring seeds, than did other items of clothing or personal equipment (Chown et al. 2012). This finding was in line with previous work undertaken within the South African and Australian NAPs (Whinam et al. 2005; Lee and Chown 2009a).

Statistical analysis showed that visitors on medium-sized and large tourist vessels were relatively unlikely to carry seeds (estimated proportions of 9 and 5 %, respectively). On small tourist vessels a much larger proportion of tourists carried seeds (estimate = 37 %), while tourists travelling on NAP ships or aircraft were very likely to carry seeds (estimated proportion = 71 %). In this survey the latter all represented tourists departing from Australia or New Zealand.

These results suggest that the visitors posing the (per individual) highest risks of non-native species propagule transfer (specifically plant seeds) are those from NAPs, and tourist support personnel. This is likely to be because these categories of visitors comprise people who either professionally or recreationally spend significant time in outdoor activities, and that their personal belongings were not cleaned before going to the Antarctic.

5.1.7.2 Cargo

Cargo importation is likely to be one of the main routes for non-native species introductions because of the large volumes of material taken into the Antarctic region from ports all over the world. Cargo transported to the Brunt Ice Shelf for the construction of Halley VI Research Station likely resulted in the importation of over 5,000 seeds from 34 taxa, including several invasive species (Lee and Chown 2009b); although not a direct threat in the context of this ice-shelf-located station itself, this study provides a clear illustration of the magnitude of the risk when applied to land-based stations. Similarly, Tsujimoto and Imura (2012) report significant numbers of plant seeds, some of species already known from Arctic and other sub-Antarctic locations, associated with cargo destined for Syowa Station on the East Antarctic coast. High numbers of non-native propagules may also be introduced where cargo is contaminated with soil. In one example, over 132 kg of non-Antarctic soil was introduced accidentally to Rothera Research Station (Adelaide Island, Antarctic Peninsula) on construction vehicles (Hughes 2010). The soil contained viable non-native angiosperms, bryophytes, micro-invertebrates, nematodes, fungi, bacteria and c. 40,000 seeds and numerous moss propagules and the incident was a significant contravention of the provisions of the Environmental Protocol.

5.1.7.3 Fresh Produce

The importation of fresh produce such as eggs, fresh fruit and vegetables and meat products into Antarctica may also inadvertently permit the transport of associated non-native species including microorganisms and invertebrates. Fresh eggs and meat, and products containing them, may contain microorganisms that could cause disease in marine mammals and birds, although little conclusive evidence of this link exists (Olsen et al. 1996; Palmgren et al. 2000). Although no causal link has been made, concerns that Newcastle disease virus, avian influenza virus, avian paramyxovirus or other microbial pathogens could be transmitted to indigenous bird population via poultry products prompted the Antarctic Treaty's Committee for Environmental Protection (CEP) to restrict their use within areas established to protect bird breeding sites (Morgan and Westbury 1981; Hughes and Convey 2010).

Release of microorganisms from food into the terrestrial environment may occur. In one study, of 11,250 items of fresh fruit and vegetables imported to nine research stations in Antarctica and the sub-Antarctic region, on average, 12 % of food items had soil on their surface, 28 % showed microbial infection resulting in rot and more than 46 invertebrates were recorded, mainly from leafy produce (Hughes et al. 2011a). Thirty percent of fungi isolated from the decomposing produce were not recorded previously from Antarctica or the sub-Antarctic islands. This study also reported a close link between the numbers of introduced flying insects captured in station food storage areas and the arrival of ships and aircraft resupplying with fresh foodstuffs.

Cultivation of fruit and vegetables within artificially heated and/or illuminated glasshouses or hydroponic rooms may reduce the need for regular importation of fresh produce from outside Antarctica and also supplement the diets of over-wintering personnel who would otherwise be denied fresh foods. However, hydroponic systems are reported as a major source of successful non-native species establishment events on several sub-Antarctic islands and may also facilitate the propagation of alien microorganisms (Frenot et al. 2005; Greenslade 2006). Non-native mites, springtails and enchytraeid worms have been found in hydroponic systems at Australian Antarctic Division stations (Greenslade 1987, 2006), and more recent invertebrate infestations have occurred at McMurdo Station (USA) and Scott Base (New Zealand). Frenot et al. (2005) recommended the cessation of on station cultivation of biological material to eliminate this source of non-native species.

5.1.8 Sewage

For reasons relating to technical difficulties associated with disposal outside the Treaty area, sewage (including 'grey' water) is the only waste type, other than gases from hydrocarbon combustion, that is permitted under the Environmental Protocol to be released into the Antarctic environment on a large scale. However, it also represents the only example where the intentional release of non-native species (i.e. human-derived faecal microorganisms and microorganisms from food washings) into the environment is permitted within the Antarctic Treaty area. Within Antarctica, wastewater is generally released into station wastewater systems, which may incorporate some sewage treatment before release to sea at coastal stations, or to an ice pit for stations built on ice shelves or ice sheets (Hughes and Blenkharn 2003; Hughes 2004; Tin et al. 2009). This is a clear route for non-native microbiota release into the marine environment, although dispersal into the terrestrial and aerial environments may also be possible (Hughes 2003). The extent and effects of *in situ* sewage disposal in Antarctica have been reviewed recently (Smith and Riddle 2009; Tin et al. 2009; Aronson et al. 2011) but it is apparent that our knowledge of the impacts of sewage on indigenous biota is still scanty. Treatment of sewage waste can reduce substantially the likely impacts on local wildlife, but risks are never reduced to zero (see Fig. 5.3). While marine mammals may be vulnerable to microbial infection and disease, indigenous Antarctic microorganisms may also be vulnerable to genetic pollution from bacteria and viruses introduced to the Antarctic marine environment in sewage.

5.1.9 Science Versus Conservation: Case Studies

The protection of the Antarctic environment from the impacts of a non-native species and the desire to undertake scientific research on that species can potentially come into conflict. For example, *Poa annua* was first noted around Arctowski Station (King George Island) in 1985/86 but was not eradicated as it was deemed important

Fig. 5.3 Elephant seal (*Mirounga leonina*) resting in the drainage channel below the sewage treatment plant outfall at Rothera Research Station. Although the sewage is treated, microbial loads can still be high depending on the efficiency and performance of the sewage treatment plant. The effect of sewage ingestion by Antarctic marine mammals and avifauna is largely unknown. (*Photograph* K.A. Hughes)

for studies on colonisation by Polish researchers (Smith 1996). It has now expanded locally and become established in natural habitats on the foreground of a retreating glacier 1.5 km from the station (Olech and Chwedorzewska 2011). In a second example, on Signy Island (South Orkney Islands), a flightless midge (*Eretmoptera murphyi*) and an enchytraeid worm (*Christensenidrilus blocki*) were probably introduced in soil in the late 1960s during transplantation experiments using plants from South Georgia, although they were not discovered until the early 1980s (Block et al. 1984). Again, no attempts have been made to eradicate these non-native species (although it is debateable whether any would have been practicable given the delay between introduction and discovery). The likelihood of success should an eradication attempt be undertaken today is not considered to be great, and would have to be balanced against considerable impacts, at least at a local scale, on native biota and terrestrial habitats.

In contrast to the previous two examples, the Fuegian vascular plant (*Nassauvia magellanica*) was removed within a year of its discovery on Deception Island (although the plant removed was clearly itself several years old) (Smith and Richardson 2011; Hughes and Convey 2012). However, in this case valid doubt remains over the likely method by which the plant arrived in Antarctica, as source populations were located only c. 900 km away in Tierra del Fuego making colonisation by natural aerial dispersal or with human assistance both real possibilities.

5.1.10 Actions

Most biosecurity issues come under the responsibility and management of individual NAPs, but a forum exists for cooperation and exchange of practical experiences through the Council of Managers of National Antarctic Programs (COMNAP). Engagement of policy makers through the ATCM and CEP, scientists with experience of non-native species through the Scientific Committee on Antarctic Research (SCAR), and COMNAP will be essential if policy and science are to be translated into practical action continent-wide.

Measures have already been drawn up, with varying levels of geographical or operator-related applicability, to reduce the risk of non-natives species transfer into the Antarctic. Examples apply to several activities including scientific fieldwork (SCAR 2009), ballast water (ATS 2006), personal clothing, belongings, cargo and vehicle importation (United Kingdom 2009; IAATO 2011b; CEP 2011; COMNAP/SCAR 2010), fresh food importation and disposal (Hughes et al. 2011a; COMNAP/SCAR 2010) and/or to specific locations (e.g. Potter 2007; Potter and Maggs 2008; United Kingdom 2008; United Kingdom 2011). In the sub-Antarctic, attempts have been made, in some cases successfully, to eradicate non-native vertebrates from some islands, most obviously the eradication of cats on Marion and Macquarie Islands, although it should also be recognised that the consequences of such eradications do not always match expectations, as the targeted species in reality may have complex interactions with different elements of both the native and remaining non-native communities (Frenot et al. 2005; Bergstrom et al. 2009).

5.2 The Future

It is clear that in the future Antarctica will be influenced increasingly by global and local human impacts. Climate change will alter many of the factors that limit and facilitate life within the Antarctic marine and terrestrial environments, as is already happening on the Antarctic Peninsula (Bergstrom et al. 2006; Convey et al. 2009; Turner et al. 2009; Convey 2010). In addition, future increases in human presence in Antarctica, either through tourism, NAP activities, exploitation of mineral resources or, in the longer term future, colonisation of the region by a permanent human population, will undoubtedly increase the risk of non-native species introductions unless stringent biosecurity measures are applied and coordinated across Antarctica and the sub-Antarctic islands.

5.2.1 International Implementation of Biosecurity Measures in Antarctica

The CEP considers the issue of non-native species a high priority and has drawn up a biosecurity manual containing measures and recommendations on how to prevent, monitor sites for and respond to introductions (CEP 2011). The manual is not binding and individual nations are left to implement biosecurity measures to a level they deem appropriate, but which may be influenced largely by availability of funding, staff time and how important the issue of non-native species is considered relative to the many other demands on available resources (see Sánchez and Njaastad 2013). How effective this approach will be is not known, but given the often slow rate of progress within the Treaty System, the understandable reluctance of parties to have binding legislation placed upon them and the need for consensus across the parties, this approach may be the only practicable one available. However, one key weakness of this method is that the effectiveness of biosecurity practices are then set, to some extent, by the lowest standards employed within a geographic area. Stringent biosecurity standards set by one nation may be compromised if a second operator situated nearby applies lower standards.

Antarctic Specially Managed Areas (ASMAs) are designated to help regulate areas where activities pose a risk of mutual interference or cumulative environmental impact. However, ASMAs cover only relatively small areas of Antarctica, and more considered and site-specific biosecurity arrangements may not exist for large parts of Antarctica. In the ASMA management plans drafted to date, the issue of non-native species is either omitted or mentioned only briefly (Hughes and Convey 2010). In the future, ASMAs are potentially key management tools that may go some way to solving this dilemma, in that they permit co-ordination of biosecurity efforts to similar standards by all nations working in a given area [e.g. as could be usefully applied to ASMA No. 4 Deception Island (see Pertierra et al. 2013) or ASMA No. 6 Larsemann Hills (Australia et al. 2008)]. However, existing management plans currently fail to address this issue, while some areas which contain several stations and concentrations of activity are not managed within this framework (e.g. Fildes Peninsula, King George Island; see Braun et al. 2013).

Antarctica is already attracting increasing attention from governments in the developed and developing worlds, leading to the construction of new research stations and the accession of new states as Consultative Parties with an influence in Antarctic affairs (see www.ats.aq). Although not discussed openly, the level of importance (and funding) assigned to environmental protection inevitably will vary within the Treaty Consultative Parties (see Sánchez and Njaastad 2013). Some assessment of national engagement with environmental problems can be gleaned from the level of participation nations have with the work of the CEP, whose function is to advise the ATCM on environmental issues. Since its first meeting in 1998, almost half of the Consultative Parties have submitted fewer than 20 papers to the meeting compared with the United Kingdom, New Zealand, Australia and the USA, all of which have submitted over 100 papers (see Fig. 5.4). The need for unified, coordinated action and a modest investment of funds by all Treaty nations may be required to tackle the issues of non-native species introductions. The Treaty nations' record on attaining such levels of cooperation is variable and often slow to develop. Progress on issues is often drawn out over many years and there is some doubt over the capacity of the Treaty System to deal either responsively or strategically with the rapid and dramatic changes likely to occur in the coming decades, including an effective response to non-native species issues.

To date, the Antarctic tourism industry, which is largely regulated by the International Association of Antarctica Tour Operators (IAATO), has taken steps

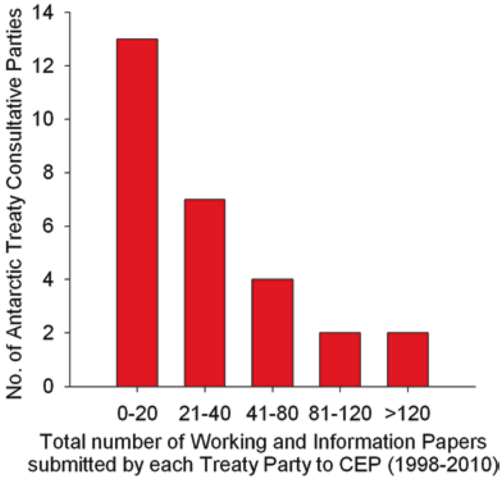

Fig. 5.4 Numbers of Working and Information Papers submitted to the Antarctic Treaty Consultative Meeting's (ATCM) Committee for Environmental Protection (CEP) by Consultative Parties between 1998 and 2010

to manage biosecurity issues, with the basic precautions applied to clothing and footwear being of a standard higher than are those employed by many national operators (IAATO 2011a). Under the scrutiny of the Treaty parties, the tourism industry would be under pressure to maintain high biosecurity standards, should development of land-based tourism infrastructure be permitted by the ATCM.

5.2.2 Potential Introductions Associated with the Antarctic Tourism Industry

Numerically, most current opportunities for tourism in Antarctica are limited to cruises where the passengers are not permitted to land, cruises which land passengers generally at a small number of popular tourist sites (Lynch et al. 2010), yacht expeditions and land-based expeditions, particularly to climb popular Antarctic peaks (e.g. Mt. Vinson). Given that tourists are currently responsible for only c. 5 % of total person days spent on land in Antarctica (with the rest attributable to national operator activities), this suggests that the tourism industry may currently contribute only a minor proportion of the risk of non-native species introductions to Antarctica (Jabour 2009; IAATO 2011b). The data presented by Chown et al. (2012) indicate that the integrated total numbers of plant seeds carried to Antarctica by personnel associated with NAPs and the tourism industry are approximately equivalent—the lower numbers typically carried by individual tourists being cancelled out by the higher number of tourists overall. It is also the case that no existing instance of a non-native species becoming established can be attributed to a tourism-associated activity (see Frenot et al. 2005; Convey and Lebouvier 2009). Nevertheless, an issue of concern is the relatively wide distribution of tourism visitation sites over the past 20 years, or so, particularly within the northern Antarctic Peninsula region, with over 350 individual locations visited (Fig. 5.5). Tourism activities are, however, concentrated on ice-free locations within relatively easy reach of South American departure ports (Lynch et al. 2010).

A new development is the increasing use of the air route from Punta Arenas to Chilean airport facilities at Fildes Peninsula, King George Island, permitting tourists to avoid the often rough seas of the Drake Passage to connect with a waiting cruise ship, or simply to visit the local area on King George Island. With flight times of less than 2 h, the potential for entrained propagules to arrive in Antarctica in a viable state is high. The general increase in reliance of several national operators on air links has already been shown to increase the number of non-native

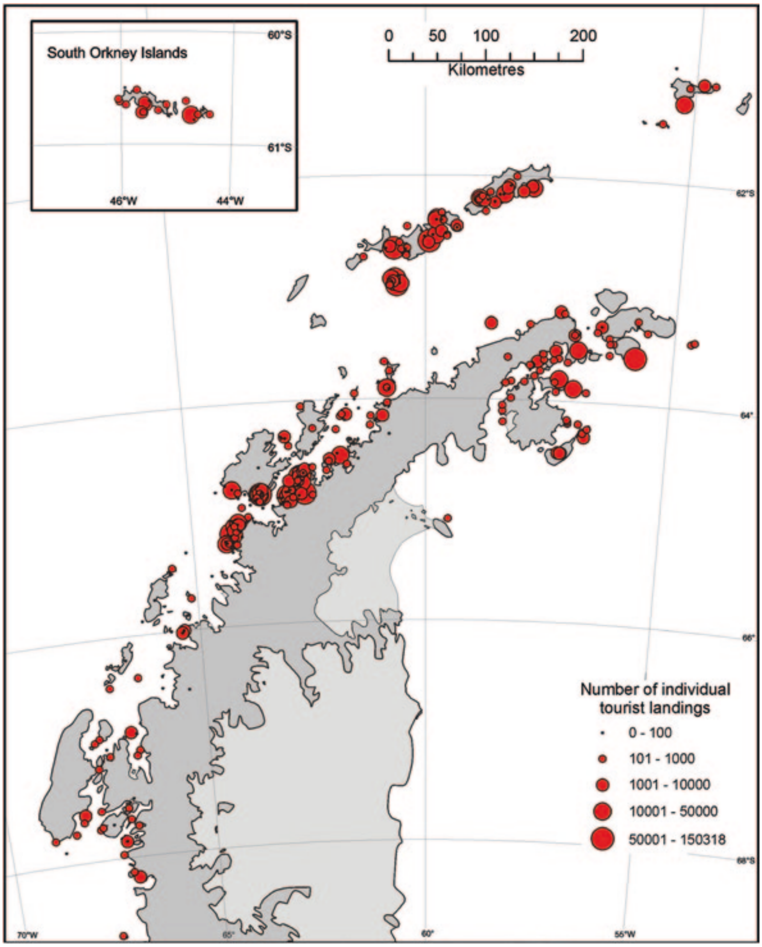

Fig. 5.5 Location of 388 recorded visitor landing sites on the Antarctic Peninsula between 1989/90 and 2008/09 (figure based on IAATO tourism statistics). Over 2 million individual tourist landings have been made since 1989

flying insects on stations (Hughes et al. 2011a). In contrast with national operator activities, the tourism industry has little land-based infrastructure, most of which is at a continental Antarctic site in the Ellsworth Mountains (80°S) and situated on permanent ice at an environmentally extreme location where the chances of establishment of non-native species are probably very low. Therefore, the quantity of cargo landed in Antarctica to facilitate tourism activities is low compared to that of national operators. Should land-based tourism expand in the future, necessitating the construction of accommodation and other 'resort' facilities, significant opportunities for non-native species introductions will occur.

As with NAP staff, a cause for concern would be an increase in tourism movement between sites in biologically distinct regions within Antarctica, including both coastal and inland locations, leading potentially to a higher risk of intra-regional transfer of non-native species than exists currently. Movement of tourists between sub-Antarctic and maritime Antarctic biogeographic zones already occurs. This scenario may arise within the maritime and continental Antarctic if the tourism industry accesses the existing air networks within Antarctica that are largely controlled by national operators, or if they develop their own networks.

5.2.3 Future Increases in Human Population and Activities Within Antarctica

Under the Environmental Protocol, any activity relating to mineral resource exploitation is prohibited for 50 years, except with consensus agreement from Treaty parties. Should this legislation be reviewed, or break down, and mineral exploitation commences within Antarctica substantial new infrastructure will be required, much in previously unimpacted areas, with a proportional increase in non-native species introduction risk. Multiple large human settlements may need large volumes of cargo for construction and on-going resupply, generate substantial quantities of sewage waste and pollution, require the importation of large quantities of fresh foods and experience regular exchange of personnel across the Antarctic Treaty area boundary (Kennicutt et al. 2010). Large settlements may also draw personnel from backgrounds that traditionally have less awareness of environmental issues.

Increases in ship traffic to remove extracted minerals, or to facilitate off-shore mineral extraction, may increase the opportunity for non-native marine species to access the Antarctic continental shelf, or for Antarctic marine species to be translocated from one Antarctic region to another (Lewis et al. 2003, 2005; Aronson et al. 2011), as well as the probability of major accidents and pollution events. Significant cargo loading will involve ballast water release in the Antarctic near-shore marine environment, something that is not currently a feature of operations, but is a major vector of marine non-native species elsewhere. Several nations have submitted data to the United Nations under Article 76 of the 1982 *UN Convention on the Law of the Sea* (UNCLOS), setting out evidence to validate claims for rights over the sea floor including the mineral resources within the Southern

Ocean, and in at least one case, within the Antarctic Treaty area (Cressey 2008; Thatje and Aronson 2009). By looking to recent events in the Arctic, we can see how rapidly political tensions can rise when access to mineral resources is at stake (Cressey 2008). Should similar or more complex events take place in Antarctica, it is unlikely that biosecurity issues will be high in the priority list for the nations involved.

5.2.4 Climate Change

Climate change is likely to have a major impact on the future colonisation of non-native species, in particular where it lowers the barriers to transport and establishment that currently protect the continent, both in terms of natural and human-assisted events. This is likely to happen in areas where environmental temperature increases occur, and where current limitations on liquid water availability are relaxed, both of which are already affecting parts of the sub- and maritime Antarctic, and whose extent is expected to expand (Convey et al. 2009; Turner et al. 2009). Table 5.2 shows the potential impacts upon Antarctica under a number of different scenarios depending upon the effectiveness with which the

Table 5.2 Potential future scenarios for non-native species dispersal and establishment depending upon the policy response to Antarctic[a] biosecurity issues and global climate change

	Global: climate warming reduced	Global: climate warming not adequately addressed
Effective Antarctic biosecurity practice implemented	*Best case scenario*. Rate of non-native species introduction will be reduced, but will not be halted completely	More rapid dispersal of existing non-native species, more natural colonisation and establishment in Antarctica. On-going dilemma of distinguishing natural from human introductions
Effective Antarctic biosecurity practice not implemented	Greater inter-continental and intra-regional dispersal of non-native species, but with current levels of subsequent establishment/invasion	*Business-As-Usual—worst case scenario*. Rapid and on-going colonisation and invasion of Antarctica, particularly in the highly visited and rapidly warming northern Peninsula region. Major habitat alteration, as already seen in some sub-Antarctic islands

[a]Most sub-Antarctic island national governments have implemented reasonably well-developed biosecurity measures. Despite this, new introductions still occur, but probably at a lower rate than would have occurred without biosecurity measures in place. Climate change probably presents a greater threat to native biodiviersity in the sub-Antarctic. Many non-native species have already been present on the islands for many decades, often in a persistent state, but are likely to be better adapted to take advantage of changes in climatic conditions than native species, with increases in reproduction rate and expansion of distribution ranges likely

international community takes step to tackle climate change and the Treaty parties implement effective biosecurity practices.

Although many native terrestrial biota are likely to benefit initially from the relaxation of thermal or hydration conditions, under the Business-As-Usual scenario, where steps are not taken to further enhance biosecurity measures applying to transport into and within Antarctica, and climate change is not tackled effectively, then Antarctica's existing biodiversity and community structures are likely to experience substantial change, and in some cases become lost forever (Convey 2010).

5.2.5 Liability Annex

At the 28th ATCM held in Stockholm in 2005 an Annex was adopted on 'Liability arising from Environmental Emergencies' (Annex VI; also known as the 'Liability Annex'). The Liability Annex appears to be aimed primarily at environmental emergencies such as major pollution incidents or oil spills at sea. Nevertheless, the introduction of a non-native species is not specifically excluded from the Annex and may be considered an environmental emergency to which the Annex may apply. In the future, if non-native species have not been eradicated by those responsible for their introduction, it may be possible for other parties or operators to undertake the eradication and use the legislation within the Annex to reclaim cost from the party or operator responsible for the introduction. However, for such a use to be tested, the Annex must become effective and this requires adoption by all parties concerned. It is also the case that the Liability Annex will not apply to operators from nations that are not signatories to the Antarctic Treaty. The Annex is clear that it cannot be applied retrospectively, and as a result, non-native species introduced before the Annex comes into effect cannot be removed and the cost charged to the operator responsible. Such hypothetical scenarios may indicate, on the one hand, a lack of recognition of some wider implications of the Annex by those drafting it or, on the other, stimulate the Treaty parties in the future to propose wording changes more tightly constraining its areas of applicability. In either case, there would seem to be no immediate prospect of the Liability Annex being used as an effective tool in enhancing biosecurity activities in Antarctica.

5.2.6 Strategic Visions of Human Activities and Their Management as Related to Biosecurity

Assuming that human activities in the Antarctic are going to increase, the need for an effective biosecurity system for the region will become all the more necessary, even in order to comply with the existing regulations laid down in the Environmental Protocol and protect Antarctic ecosystems. Humans have largely failed to control non-native species introduction and spread in the other continents, and it is unlikely that such human-mediated impacts can be successfully prevented completely in Antarctica. This may be true particularly for smaller species and microorganisms that make up the vast majority of Antarctica's biodiversity (Hughes and Convey 2010, 2012; Cowan et al. 2011; Hughes et al. 2011b). In some cases, policy makers have little understanding of the biological function and importance of Antarctic species other than some of the more charismatic birds and mammals and, as a result, few conservation measures focus on these less obvious biological groups. Implementing effective biosecurity precautions for biological groups of small size may be considered too difficult, too expensive and too abstract a concept. The interconnected nature of ecosystems is often underappreciated, and invasions by seemingly obscure/little noticed species may have indirect, but potentially highly damaging impacts upon higher species and their habitats. Added to this, policy makers may be under pressure to prioritise facilitation of the NAPs' operations over the implementation of policies that may limit non-native species introductions, particularly if individual national interests are put at risk (see Lamers et al. 2013). This may be particularly true where budgets are limited and biosecurity precautions deemed expensive and with little 'perceived' benefit. Preventing or limiting the introduction of a non-native species over the medium to long term can be seen as a mundane undertaking, yet it is vital if the Environmental Protocol is to be followed. Those seeking funds from national governments for biosecurity measures may have little hope of competing with more 'exciting' science or logistic projects. Even if money has been allocated, it may be re-allocated elsewhere once current attention to the non-native species issue within the Antarctic community shifts elsewhere. Added to this, as a consequence of the unclear and subjective nature of the environmental impacts assessment system (set out in Annex I of the Environmental Protocol), some NAPs appear to take the view that their on-going activities should proceed, with steps to mitigate environmental impacts implemented only once 'cost effective' methodologies have been developed. Such methodologies may not be developed soon and Antarctic biodiversity may be impacted as a consequence. Some national governments may struggle to afford to have both an Antarctic presence and protect the environment to the standards set out in the Environmental Protocol.

Other methods to ensure adequate protection of at least some of Antarctica's ecosystems may include setting aside unimpacted areas where either humans are not allowed to visit or areas where visitors numbers are limited and biosecurity standards are exceptionally high (Hughes et al. 2011b). More generally, the area encompassed within ASMAs and ASPAs could be increased in a systematic manner, ensuring appropriate representation of the different 'justifying values' (e.g. see Terauds et al. 2012), already recognised explicitly within the Environmental Protocol [Annex V Article 3(1)], with restrictions laid down within their management plans strengthened to give effective and enhanced protection. Given that implementing high biosecurity standards may be difficult at some locations, particularly where research stations are situated, it may be suggested that sacrificial sites are defined where, amongst other damaging activities, the possibility of introductions is accepted. We would strongly object to this scenario as, having been assisted to overcome the protective barriers surrounding Antarctica, non-native species may then use natural dispersal methods to move to other Antarctic locations.

5.3 Conclusions

The Antarctic continent remains one of the areas on Earth least impacted by human activities. Rapid advances in scientific techniques, in particular in molecular biology, along with increasingly effective levels of international scientific collaboration across the continent, will allow us to increase our knowledge of Antarctic biodiversity and the biochemical and physiological process that allow individual species, communities and entire ecosystems to exist in such a harsh environment. At present our understanding of biodiversity for many large areas of Antarctica is unsatisfactory and in some cases non-existent. Going forward, the foundations upon which our understanding lies will be weakened if we do not have appropriate measures in place to reduce the likelihood of introducing non-native species, or redistributing indigenous biota around the continent. Added to this, it could be argued that we have a moral duty defined under the founding principles of the Antarctic Treaty itself to prevent the homogenisation of Antarctic biodiversity, and preserve the many unique biological assemblages found throughout the region. The Environmental Protocol makes it clear that measures to fulfill such aims are to be implemented—the challenge lies in coordinating international action within the existing international political framework, where efforts and resources are often allocated to further individual national interests rather than the protection and conservation of biota in Antarctica as a whole. The future will tell if the ATCM, CEP, SCAR and COMNAP can work together effectively to tackle the problems posed by non-native species. Human activities and practices will change within the region in coming decades and the future security of Antarctica's existing biodiversity and ecosystems may depend upon biosecurity measures being continually reviewed and enhanced to keep pace. How well regulated such activities will be has yet to be seen, but given the poor environmental performance exhibited to date by some NAPs at some locations, where even the basic minimum standards set by the Environmental Protocol are not met 15 years after they came into force, the prognosis for the future is currently not good (Hughes 2010; Braun et al. 2012).

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References

Aronson, R. B., Thatje, S., McClintock, J. B., & Hughes, K. A. (2011). Anthropogenic impacts on marine ecosystems in Antarctica. *Annals of the New York Academy of Sciences, 1223*, 82–107.

ATCP. (1991). *Protocol on Environmental Protection to the Antarctic Treaty*. CM 1960. London: Her Majesty's Stationary Office.

ATS. (2006). Ballast water exchange in the Antarctic Treaty Area. ATCM Resolution 3 (2006). Final report of XXIX Antarctic Treaty Consultative Meeting, Edinburgh, UK, 12–23 June, 2006. Buenos Aires, Argentina: Antarctic Treaty Secretariat.

Australia. (2001). *Report on the open-ended Intersessional Contact Group on Diseases of Antarctic Wildlife, Report 1—Review and Risk Assessment*. Working Paper 10 presented at XXIV Antarctic Treaty Consultative Meeting, St. Petersburg, Russian Federation, 9–20 July 2001.

Australia, China, India, Romania, & Russian Federation. (2008). *Measures to protect the Larsemann Hills, East Antarctica, from the introduction of non-native species*. Working Paper 17 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine, 2–13 June, 2008.

Bergstrom, D. M., Hodgson, D. A., & Convey, P. (2006). The physical setting of the Antarctic. In D. M. Bergstrom, P. Convey, & A. H. L. Huiskes (Eds.), *Trends in Antarctic terrestrial and limnetic ecosystems: Antarctica as a global indicator* (pp. 15–33). Dordrecht: Springer.

Bergstrom, D. M., Lucieer, A., Kiefer, K., Wasley, J., Belbin, L., Pedersen, T. K., et al. (2009). Indirect effects of invasive species removal devastate World Heritage Island. *Journal of Applied Ecology, 46*, 73–81.

Bij de Vaate, A., Jazdzewski, K., Ketelaars, H. A. M., Gollasch, S., & Van der Velde, G. (2002). Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe. *Canadian Journal of Fisheries and Aquatic Sciences, 59*, 1159–1174.

Block, W., Burn, A. J., & Richard, K. J. (1984). An insect introduction to the maritime Antarctic. *Biological Journal of the Linnean Society, 23*, 33–39.

Bonnedahl, J., Broman, T., Waldenstrom, J., Palmgren, H., Niskanen, T., & Olsen, B. (2005). Search of human-associated bacterial pathogens in Antarctic wildlife: report from six penguin colonies regularly visited by tourists. *Ambio, 34*, 430–432.

Braun, C., Mustafa, O., Nordt, A., Pfeiffer, S., & Peter, H.-U. (2012) Environmental monitoring and management proposals for the Fildes Region (King George Island, Antarctic). Polar Research 2012, 31, 18206, http://dx.doi.org/10.3402/polar.v31i0.18206.

Braun, C., Fritz, H., Mustafa, O., Nordt, A., Pfeiffer, S., & Peter, H.-U. (2013). Environmental assessment and management challenges of the Fildes Peninsula region. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht: Springer-Verlag.

CEP. (2011). *Non-native Species Manual*. Buenos Aires: Antarctic Treaty Secretariat.

Chekchak, T., Chapuis, J.-L., Pisanu, B., & Boussès, P. (2000). Introduction of the rabbit flea, *Spilopsyllus cuniculi* (Dale), to a subantarctic island (Kerguelen Archipelago) and its assessments as a vector of myxomatosis. *Wildlife Research, 27*, 91–101.

Chown, S. L., & Convey, P. (2007). Spatial and temporal variability across life's hierarchies in the terrestrial Antarctic. *Philosophical Transactions of the Royal Society of London. Series B, 362*, 2307–2331.

Chown, S. L., Huiskes, A. H. L., Gremmen, N. J. M., Lee, J. E., Terauds, A., Crosbie, K., et al. (2012). Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. *Proceedings of the National Academy of Sciences of the USA, 109*, 4938–4943.

Clayton, M. N., Wiencke, C., & Klöser, H. (1997). New records and sub-Antarctic marine benthic macroalgae from Antarctica. *Polar Biology, 17*, 141–149.

COMNAP/SCAR. (2010). *Checklists for supply chain managers of National Antarctic Programs to reduce the risk of transfer of non-native species*. Retrieved from:

https://www.comnap.aq/Publications/Comnap%20Publications/Forms/DispForm.aspx?ID=51 (accessed 14.05.12).
Convey, P. (2008). Non-native species in Antarctic terrestrial and freshwater environments: presence, sources, impacts and predictions. In M. Rogan-Finnemore (Ed.), *Non-native Species in the Antarctic—Proceedings* (pp. 97–130). Christchurch: Gateway Antarctica.
Convey, P. (2010). Terrestrial biodiversity in Antarctica—recent advances and future challenges. *Polar Science, 4*, 135–147.
Convey, P., & Lebouvier, M. (2009). Environmental change and human impacts on terrestrial ecosystems of the sub-Antarctic islands between their discovery and the mid-twentieth century. *Papers and Proceedings of the Royal Society of Tasmania, 143*, 33–44.
Convey, P., Smith, R. I. L., Peat, H. J., & Pugh, P. J. A. (2000). The terrestrial biota of Charcot Island, eastern Bellingshausen Sea, Antarctica an example of extreme isolation. *Antarctic Science, 12*, 406–413.
Convey, P., Bindschadler, R. A., di Prisco, G., Fahrbach, E., Gutt, J., Hodgson, D. A., et al. (2009). Antarctic climate change and the environment. *Antarctic Science, 21*, 541–563.
Convey, P., Key, R. S., & Key, R. J. D. (2010). The establishment of a new ecological guild of pollinating insects on sub-Antarctic South Georgia. *Antarctic Science, 22*, 508–512.
Copson, G., & Whinam, J. (2001). Review of ecological restoration programme on subantarctic Macquarie Island: pest management progress and future directions. *Ecological Management and Restoration, 2*, 129–138.
Cowan, D. A., Chown, S. L., Convey, P., Tuffin, M., Hughes, K. A., Pointing, S., et al. (2011). Non-indigenous microorganisms in the Antarctic: assessing the risks. *Trends in Microbiology, 19*, 540–548.
Cressey, D. (2008). Geology: The next land rush. *Nature, 451*, 12.
Crosby, A. W. (1972). *The Columbian Exchange—biological and cultural consequences of 1492*. Westport: Greenwood Publishing Company.
de Villiers, M. S., Cooper, J., Carmichael, N., Glass, J. P., Liddle, G. M., McIvor, E., et al. (2006). Conservation management at Southern Ocean Islands: towards the development of best-practice guidelines. *Polarforschung, 75*, 113–131.
Department of Environmental Affairs and Tourism. (1996). *Prince Edward Islands Management Plan*. Pretoria.
Dózsa-Farkas, K., & Convey, P. (1997). *Christensenia*, a new enchytraeid genus from Antarctica. *Polar Biology*, 17, 482–486. [NB—this paper was subsequently modified—see Erratum, (1998). *Polar Biology*, 20, 292]
Frenot, Y., Chown, S. L., Whinam, J., Selkirk, P. M., Convey, P., Skotnicki, M., et al. (2005). Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews, 80*, 45–72.
Greenslade, P. (1987). Invertebrate conservation in the Antarctic and subantarctic. In J. D. Majer (Ed.), *The role of invertebrates in conservation and biological survey* (pp. 119–121). Perth: Western Australian Department of Conservation & Land Management.
Greenslade, P. (1995). Collembola from the Scotia Arc and Antarctic Peninsula including descriptions of two new species and notes on biogeography. *Polskie Pismo Entomologiczne, 64*, 305–319.
Greenslade, P. (2006). *The invertebrates of Macquarie Island*. Kingston: Department of Environment and Heritage, Australian Antarctic Division.
Greenslade, P., & Convey, P. (2012). Exotic Collembola on subantarctic islands: pathways, origins and biology. *Biological Invasions, 14*(2), 405–417.
Greenslade, P., & Wise, K. A. J. (1984). Additions to the collembolan fauna of the Antarctic. *Transactions of the Royal Society of South Australia, 108*, 203–205.
Greenslade, P., Potapov, M., Russel, D., & Convey, P. (2012). Lessons from history—global Collembola on Deception Island. *Journal of Insect Science, 12*, 111.
Gremmen, N. M. J., Chown, S. L., & Marshall, D. J. (1998). Impact of the introduced grass *Agrostis stolonifera* on vegetation and soil fauna communities at Marion Island, subantarctic. *Biological Conservation, 85*, 223–231.

Griffiths, H. J. (2010). Antarctic Marine Biodiversity—what do we know about the distribution of life in the Southern Ocean? *PLoS ONE, 5*(8), e11683. doi:10.1371/journal.pone.0011683.

Heywood, V. H. (1989). Patterns, extents, and modes of invasions by terrestrial plants. In J. A. Drake, H. A. Mooney, F. Di Castri, R. H. Groves, F. J. Kruger, M. Reymanek, & M. Williamson (Eds.), *Biological invasions: A global perspective* (pp. 31–60). Chichester: Wiley.

Hughes, K. A. (2003). Aerial dispersal and survival of sewage-derived faecal coliforms in Antarctica. *Atmospheric Environment, 37*, 3147–3155.

Hughes, K. A. (2004). Reducing sewage pollution in the Antarctic marine environment using a sewage treatment plant. *Marine Pollution Bulletin, 49*, 850–853.

Hughes, K. A. (2010). How committed are we to monitoring human impact in Antarctica? *Environmental Research Letters, 5*, 041001. doi:10.1088/1748-9326/5/4/041002.

Hughes, K. A., & Blenkharn, N. (2003). A simple method to reduce discharge of sewage microorganisms from an Antarctic research station. *Marine Pollution Bulletin, 46*, 353–357.

Hughes, K. A., & Convey, P. (2010). The protection of Antarctic terrestrial ecosystems from inter- and intra-continental transfer of non-indigenous species by human activities: A review of current systems and practices. *Global Environmental Change, 20*, 96–112.

Hughes, K. A., & Convey, P. (2012). Determining the native/non-native status of newly discovered terrestrial and freshwater species in Antarctica—current knowledge, methodology and management action. *Journal of Environmental Management, 93*, 52–66.

Hughes, K. A., & Worland, M. R. (2010). Spatial distribution, habitat preference and colonisation status of two alien terrestrial invertebrate species in Antarctica. *Antarctic Science, 22*, 221–231.

Hughes, K. A., Walsh, S., Convey, P., Richards, S., & Bergstrom, D. M. (2005). Alien fly populations established at two Antarctic research stations. *Polar Biology, 28*, 568–570.

Hughes, K. A., Lee, J. E., Tsujimoto, M., Imura, S., Bergstrom, D. M., Ware, C., et al. (2011a). Food for thought: risks of non-native species transfer to the Antarctic region with fresh produce. *Biological Conservation, 144*, 1682–1689.

Hughes, K. A., Fretwell, P., Rae, J., Holmes, K., & Fleming, A. (2011b). Untouched Antarctica: mapping a finite and diminishing environmental resource. *Antarctic Science, 23*(6), 537–548.

IAATO. (2011a). Boot, clothing and equipment decontamination guidelines for small boat operations. Retrieved from http://www.iaato.org/docs/Boot_Washing07.pdf. (accessed 04.04.11).

IAATO. (2011b). Tourism statistics. Retrieved from http://www.iaato.org/tourism_stats.html. (accessed 04.04.11).

Jabour, J. (2009). National Antarctic programs and their impact on the environment. In K. R. Kerry & M. J. Riddle (Eds.), *Health of Antarctic wildlife—a challenge for science and policy* (pp. 211–229). Heidelberg: Springer.

Kennicutt II, M. C., Klein, A. G., Montagna, P., Sweet, S. T., Wade, T. L., Palmer, T. A., Sericano, J. L., & Denoux, G. (2010). Temporal and Spatial Patterns of Anthropogenic Disturbance at McMurdo Station, Antarctica. *Environmental Research Letters*, *5*, 034010 doi: 10.1088/1748-9326/5/3/034010.

Kerry, K. R., & Riddle, M. J. (Eds.). (2009). *Health of Antarctic wildlife: A challenge for science and policy*. Heidelberg: Springer.

Lamers, M., Liggett, D., & Tin, T. (2013). Strategic thinking for the Antarctic environment: The use of assessment tools in governance. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht: Springer-Verlag.

Lee, J. E., & Chown, S. L. (2007). *Mytilus* on the move: transport of an invasive bivalve to the Antarctic. *Marine Ecology Progress Series, 339*, 307–310.

Lee, J. E., & Chown, S. L. (2009a). Breaching the dispersal barrier to invasion: quantification and management. *Ecological Applications, 19*, 1944–1959.

Lee, J. E., & Chown, S. L. (2009b). Quantifying the propagule load associated with the construction of an Antarctic research station. *Antarctic Science, 21*, 471–475.

Lee, J. E., & Chown, S. L. (2011). Quantification of intra-regional propagule movements in the Antarctic. *Antarctic Science, 23*, 337–342.

Lewis, P. N., Hewitt, C. L., Riddle, M. J., & McMinn, A. (2003). Marine introductions in the Southern Ocean: an unrecognised hazard to biodiversity. *Marine Pollution Bulletin, 46*, 213–223.

Lewis, P. N., Riddle, M. J., & Smith, S. D. A. (2005). Assisted passage or passive drift: A comparison of alternative transport mechanisms for non-indigenous coastal species into the Southern Ocean. *Antarctic Science, 17*, 183–191.

Lynch, H. J., Crosbie, K., Fagan, W. F., & Naveen, R. (2010). Spatial patterns of tour ship traffic in the Antarctic Peninsula region. *Antarctic Science, 22*, 123–130.

Mack, R. N., Simberloff, D., Lonsdale, W. M., Evans, H., Clout, M., & Bazzaz, F. A. (2000). Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications, 10*, 689–710.

McKinney, M. L., & Lockwood, J. L. (1999). Biotic homogenisation: A few winners replacing many losers in the next mass extinction. *Trends in Ecology & Evolution, 14*, 450–453.

Molina-Montenegro, M. A., Carrasco-Urra, F., Rodrigo, C., Valladares, F., & Gianoli, E. (2010). *Plant invasions in the Antarctic continent: vectors and consequences*. Poster at Scientific Committee on Antarctic Research Open Science Conference, Buenos Aires, Argentina, 3–6 August 2010. [Unpublished]

Molina-Montenegro, M. A., Carrasco-Urra, F., Rodrigo, C., Convey, P., Valladares, F., & Gianoli, E. (2012). Occurrence of the non-native annual bluegrass (*Poa annua*) on the Antarctic mainland and its negative effects on native plants. *Conservation Biology, 26*(4), 717–723.

Morgan, I. R., & Westbury, H. A. (1981). Virological studies of Adelie penguins (*Pygoscelis adeliae*) in Antarctica. *Avian Diseases, 25*, 1019–1026.

Ochyra, R., Smith, R. I. L., & Bednarek-Ochyra, H. (2008). *The Illustrated Moss Flora of Antarctica*. Cambridge: Cambridge University Press.

Olden, J. D., LeRoy Poff, N., Douglas, M. R., Douglas, M. E., & Fausch, K. D. (2004). Ecological and evolutionary consequences of biotic homogenization. *Trends in Ecology & Evolution, 19*, 18–24.

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. *Antarctic Science, 23*(2), 153–154.

Olsen, B., Bergström, S., McCafferty, D. J., Sellin, M., & Wiström, J. (1996). *Salmonella enteritidis* in Antarctica : zoonosis in man or humanosis in penguins ? *The Lancet, 348*, 1319–1320.

Øvstedal, D. O., & Smith, R. I. L. (2001). *Lichens of Antarctica and South Georgia. A guide to their identification and ecology*. Cambridge: Cambridge University Press.

Palmgren, H., McCafferty, D., Aspán, A., Broman, T., Sellin, M., Wollin, R., et al. (2000). *Salmonella* in sub-Antarctica: low heterogeneity in *Salmonella* serotypes in South Georgian seals and birds. *Epidemiology and Infection, 125*, 257–262.

Pertierra, L. R., Tejedo, P., & Benayas, J. (2013). Looking into the future of Deception Island: Current status, drivers of change and policy alternatives. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht: Springer-Verlag.

Potter, S. (2007). The quarantine protection of sub-Antarctic Australia: two islands, two regimes. *Island Studies Journal, 2*, 177–192.

Potter, S., & Maggs, T. (2008). Antarctic quarantine management: Australia's framework and practice. In M. Rogan-Finnemore (Ed.), *Non-native species in the Antarctic—proceedings* (pp. 165–182). Christchurch: Gateway Antarctica.

Richardson, D. M., Pysek, P., Rejmanek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distribution, 6*, 93–107.

Sánchez, R. A., & Njaastad, B. (2013). Future challenges in environmental management of National Antarctic Programs. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht: Springer-Verlag.

SCAR. (2009). *SCAR's environmental code of conduct for terrestrial scientific field research in Antarctica.* Information Paper 4 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, 6–17 April, 2009.

SCAR. (2010). Preliminary Results from the International Polar Year Programme: Aliens in Antarctica. Working Paper 4 presented at XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay, 3–14 May, 2010.

Smart, S. M., Thompson, K., Marrs, R. H., Le Duc, M. G., Maskell, L. C., & Firbank, L. G. (2006). Biotic homogenisation and changes in species diversity across human-modified ecosystems. *Proceedings of the Royal Society of London Series B, 273*, 2659–2665.

Smith, R. I. L. (1996). Introduced plants in Antarctica: potential impacts and conservations issues. *Biological Conservation, 76*, 135–146.

Smith, R. I. L., & Richardson, M. (2011). Fuegian plants in Antarctica: natural or anthropogenically assisted immigrants. *Biological Invasions, 13*, 1–5.

Smith, J. J., & Riddle, M. J. (2009). Sewage disposal and wildlife health in Antarctica. In K. R. Kerry & M. J. Riddle (Eds.), *Health of Antarctic wildlife: A challenge for science and policy* (pp. 271–315). London: Springer Verlag.

Terauds, A., Chown, S. L., Morgan, F., Peat, H. J., Watts, D. J., Keys, H., et al. (2012). Conservation biogeography of the Antarctic. *Diversity and Distributions, 18*(7), 726–741.

Thatje, S., & Aronson, R. B. (2009). No future for the Antarctic Treaty? *Frontiers in Ecology, 7*, 175.

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., et al. (2009). Impacts of local human activities on the Antarctic environment. *Antarctic Science, 21*, 3–33.

Tsujimoto, M., & Imura, S. (2012). Does a new transportation system increase the risk of importing non-native species to Antarctica? *Antarctic Science*. http://dx.doi.org/10.1017/S0954102012000272

Turner, J., Bindschadler, R., Convey, P., di Prisco, G., Fahrbach, E., Gutt, J., et al. (Eds.). (2009). *Antarctic Climate Change and the Environment*. Cambridge: Scientific Committee on Antarctic Research.

United Kingdom. (2008). *Antarctic Specially Protected Area (ASPA) Management Plan for Marion Nunataks, Charcot Island, Antarctic Peninsula*. Working Paper 53 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine, 2–13 June, 2008.

United Kingdom. (2009). *Procedures for vehicle cleaning to prevent transfer of non-native species into and around Antarctica.* Working Paper 32 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, 6–17 April 2009.

United Kingdom. (2011). *Proposed exploration of subglacial Lake Ellsworth Antarctica. Draft Comprehensive Environmental Evaluation.* Retrieved from http://www.antarctica.ac.uk/about_antarctica/geography/environment/eia/subglacial_lake_ellsworth_cee.pdf (accessed 04.04.11).

Whinam, J., Chilcott, N., & Bergstrom, D. M. (2005). Subantarctic hitchhikers: expeditioners as vectors for the introduction of alien organisms. *Biological Conservation, 121*, 207–219.

Williamson, M. (1997). *Biological Invasions*. London: Chapman and Hall.

Woehler, E. J., Ainley, D., & Jabour, J. (2013). Human impacts to Antarctic wildlife: predictions and speculations for 2060. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht: Springer-Verlag.

Chapter 6
Trampling the Antarctic: Consequences of Pedestrian Traffic on Antarctic Soils

Pablo Tejedo, Luis R. Pertierra and Javier Benayas

Abstract Antarctic soils provide habitat for fauna and flora which are regionally important and, in some cases, include endemic representatives. Thus, protection of this component of the ecosystem should be a priority. In this chapter, our focus is on the vulnerability of Antarctic soils to foot traffic (heretofore referred to as trampling) and possible future scenarios with regards to the conservation of Antarctic soils. We begin by briefly describing the principal abiotic and biotic features of Antarctic soils, and reviewing the limited studies that have examined the consequences of trampling. We then examine a range of drivers of change that could play a decisive role in the future conservation of Antarctic soils, such as climate change, human pressure and species introduction. Taking into consideration the current legal and management measures for Antarctic soils conservation, we propose two possible future scenarios assuming different management models: a Business-As-Usual scenario and a conservation-focused situation. The chapter ends with a small reflection centered on the difficulties in achieving a conservation-focused future, and the need to consider whether conservation of soil against trampling should be a priority on the agenda of the Antarctic Treaty nations and the international scientific community.

Keywords Human impact • Antarctic soils vulnerability • Environmental monitoring • Codes of conduct • Soil conservation

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6.1 Main Features of Antarctic Soils

Antarctica is often considered nearly pristine because levels of anthropogenic disturbance are extremely low there (Ayres et al. 2008). Nevertheless, over recent decades there has been a rapid increase in the number of people visiting it (Stewart et al. 2005). This has led to an increase in the interest in understanding the implications of human presence on the environment of this emblematic territory (Tin et al. 2009). For terrestrial ecosystems, a major abiotic component is the soil itself which has long been considered to be easily disturbed by human activities (Campbell et al. 1993). This high vulnerability is further combined with a supposed limited resilience as a consequence of low temperatures, general absence of vegetation, and scarce soil biota (Campbell and Claridge 1987). Ground disturbances resulting from foot traffic and camping usually cover a small area, but are often clearly visible. Foot tracks can be formed in a very short time in certain vulnerable soils and may remain visible for many years after the event (Campbell et al. 1998). Vehicular traffic also results in ground disturbances which are often much more extensive and persistent (e.g. Peter et al. 2008; Tin et al. 2009).

The majority of Antarctic terrestrial life is found on a small number of sites including exposed nunataks, cliffs and seasonally snow and ice-free ground areas (Bergstrom et al. 2006; Convey 2010). These areas combined cover c. 44,000 km^2 (Convey et al. 2009), and can be considered as isolated ‘islands’ separated by ice or ocean (Bergstrom and Chown 1999) within the Antarctic continent (Fig. 6.1), which has an area of c. 14,000,000 km^2. Exposed soils are characterised by limited depth, low organic matter content, low biomass and primary production, scarce nutrient availability, including nitrogen and phosphate as well as the entire range of trace elements, low availability of water reaching aridity in many cases, and slow decomposition rates (Thomas et al. 2008) (Table 6.1). In many locations permafrost is present. In summer ice-free areas, continuous stands of low-growing vegetation can be found, made up of mosaics of very simple communities that vary according to local geology, topography and hydrology. Organisms that are most able to tolerate the extreme environmental stresses include mosses, lichens, algae and cyanobacteria (among the phototrophic organisms), and mites, springtails and microfauna (among the invertebrates). The microbiota living in Antarctic soils is still poorly understood. They are likely to be limited by the availability of liquid water rather than the low temperatures (Block 1996). Terrestrial food webs present a simple trophic structure and are dominated by the detrital food chain, formed by microbivores and detritivores, lacking true grazers and with few predators, although few rigorous autecological studies have been completed (Hogg et al. 2006).

Tedrow (1977) proposed four soil zones for Polar Regions, of which only three are present in Antarctica: Sub-polar Desert, Polar Desert and Cold Desert. Sub-polar Desert zones are rarely found on the Antarctic continent and only occur in certain locations in the maritime Antarctic associated with patches of the two native vascular plants, *Deschampsia antarctica* Desvaux and *Colobanthus quitensis* (Kunth) Bartl. These soils are characterised by cushion-forming mosses and patches

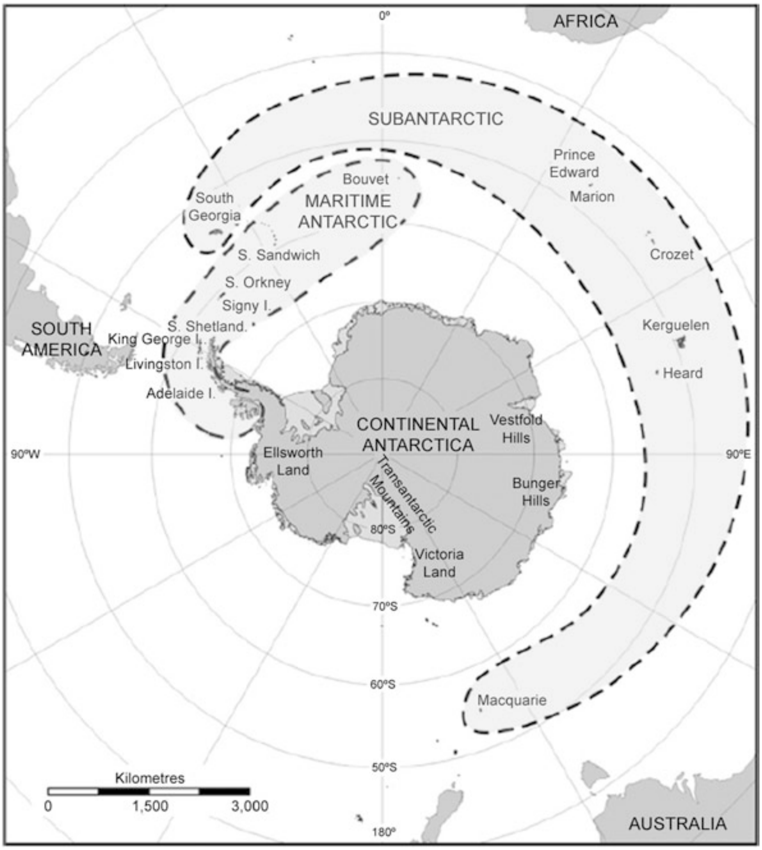

Fig. 6.1 Generally recognised biogeographical zones in the Antarctic (Thomas et al. 2008) and other selected places that are mentioned in the text and Table 6.1

of lichen interspersed with areas of bare ground (Smith 1972). There is a substantial freeze–thaw cycling, which favours the colonisation process by these organisms through vegetative propagation. When large penguin and seal colonies are present, the mechanical disturbance and the anaerobic and toxic nature of their excrement make it difficult for cryptogam or vascular plants to survive (Smith 1988), unless the plants are well established before occupation by the vertebrates. Nevertheless, nutrient transfer from bird and seal colonies can benefit adjacent vegetation.

Polar Desert zones are present on the maritime Antarctic and the coastal regions. Soils of these areas are distinguished by a lack of structural development and loose or coherent form (Campbell et al. 1998). Stones and pebbles appear at their surface, forming the so-called desert pavement. Desert pavement plays an important role in this type of system, acting as protective armour to stabilise both the slope and the soil (O'Neill and Balks 2010). Water retention is poor, at least in the surface few centimetres where permafrost does not form a barrier. Therefore, low relative

Table 6.1 Selected chemical characteristics of a range of Antarctic soils

Type of soil	Location	Region	pH	Total organic C (%)	Total N (%)	C/N ratio	P (ppm)	K (ppm)
Dry valley soils[a]	Victoria land	CA	7.4–8.9	0.02–0.09	0.004–0.085	6–13	0.03–0.27	1–245
Frost-sorted till[b]	Ellsworth land	CA	5.42	4.2×10^{-5}	5×10^{-6}	8.4	0.07	0.11
Frost-sorted till[b]	Transantarctic Mts	CA	6.82	3.7×10^{-6}	1×10^{-6}	3.7	0.05	0.3
Frost-sorted till[b]	Adelaide I	MA	5.47	2.3×10^{-4}	3.1×10^{-5}	7.4	9.2	0.27
Marble protoranker[c]	Signy I	MA	7.9	2	0.26	7.7	8	5
Peat under moss turf[c]	Signy I	MA	4.7	43.6	1.36	32	3	17
Gravel greywackes[d]	Livingston I	MA	6.4	1.1	0.1	11	0.27	104.9
Gravel mudstones[d]	Livingston I	MA	5.6	0.2	0.0	–	0.12	296.2
Greywackes[d]	Livingston I	MA	7.6	0.2	0.0	–	0.01	112
Mudstones[d]	Livingston I	MA	8.0	0.5	0.0	–	0.98	41.9
Volcanic[d]	Livingston I	MA	7.6	0.9	0.1	9	0.24	161.5
Soil under moss meadow[e]	Livingston I	MA	6.3	1.61	0.14	11.5	1.22	257.4
Patched mossy meadow[e]	Livingston I	MA	6.1	1.83	0.15	12.2	1.27	237.9
Bryolichen soil crust[e]	Livingston I	MA	7.0	2.53	0.23	11.0	0.43	136.5
Ornithogenic, penguins[c]	Signy I	MA	6.1	10	1.8	5.5	460	73
Elephant seal wallow[c]	Signy I	MA	6.7	30	3.58	8.4	66	100

Mts Mountains; *I* Island; *CA* Continental Antarctic; *MA* Maritime Antarctic

Data from [a]Cameron (1969), [b]Lawley et al. (2004), [c]Rosswall and Heal (1975), [d]Navas et al. (2008), [e]Pertierra et al. (2013a) humidity into soils is typical, resulting in rapid evaporation/ablation of water input through rain or snow. Organic content remains low but horizons are more prominent, with leached soluble minerals under moist conditions and unleached soluble minerals under less dry conditions (Thomas et al. 2008). Oxidation and salinisation are the principal weathering processes. On poorly drained sites there may be accumulation of peat-like material under moss turf, while dry conditions generate the development of pads of humus beneath the isolated plant cushions. Vegetation is dominated by mosses, liverworts, foliose and fruticose lichens and, in some regions, cushions of flowering plants. The vegetation remains very scattered, with bare areas in between. The plant cover permits the development of microbial and invertebrate communities. In areas of intense nutrient enrichment around vertebrate colonies the foliose alga *Prasiola crispa* (Kützing) Knebel dominates and provides a habitat for arthropods and nematodes (Sohlenius et al. 2004).

Finally, the Cold Desert Zone occupies the rest of the continent. In ice-free areas, Cold Desert soils are distinguished from other polar soils by the absence of distinct organic horizons, with less than 1 % of organic carbon (Barrett et al. 2005). These soils are poorly developed, strongly weathered and arid in nature. A crust is normally present at the surface and salt horizons occur within the profile. Desert biological crusts can help stabilise the soil surface and when they are lost, arid soils erode and biological activity declines (Belnap 2006). Sand predominates (>95 %) and numerous rock fragments appear at the surface (Barrett et al. 2005). These soils occupy some 4,000 km^2 of the Victoria Land Dry Valleys region (Thomas et al. 2008). They are present in smaller quantities in the Bunger Hills, Vestfold Hills and Transantarctic Mountains (Fig. 6.1), and also in small ice-free areas associated with the various nunataks and mountain ranges throughout the continent (Thomas et al. 2008). These soils present a range of habitats from sites of extreme aridity where life is scarcely sustainable, to other restricted communities where mosses, lichens and a variety of invertebrates are able to exist. Water availability leads to a patchy distribution of nematodes, rotifers, tardigrades and arthropods, with nematodes being the most widespread and abundant animals in this ecosystem (Adams et al. 2006). Endolithic communities make up a particular niche in the cold deserts. Rates of soil carbon dioxide (CO_2) efflux, an indicator of total below-ground biological activity, are lower in this ecosystem than almost anywhere in the world (Parsons et al. 2004; Barrett et al. 2006). It is suggested that less than 1 % of the gross primary production may be incorporated into the standing biomass, with the greater part of the primary production being lost either as extracellular products or specifically through investment in stress-tolerance strategies (Thomas et al. 2008).

6.2 Human Disturbance of Ground Surfaces

Trampling can affect the biological organisation within Antarctic soils at many different levels, ranging through habitats, communities to populations. It can lead to soil compaction, changes in soil surface structure, albedo alterations, visual disturbances, vegetation damage, killing of soil organisms, soil community alteration, introduction of alien species and changes in the nutrients cycles. Numerous studies quote trampling as a human impact on Antarctic terrestrial ecosystems (e.g. Headland and Keage 1985; Harris 1991; Stonehouse 1993; Olech 1996; Chen and Blume 1997; Hansom and Gordon 1998; Kriwoken and Rootes 2000; Lamers 2009), but quantitative studies are scarce (Table 6.2).

Disturbances caused by trampling range from minor and transitory to locally severe and long-term. Impacts are often concentrated at isolated locations over small areas. Human visitation and subsequent trampling are concentrated in areas where there are easy accessibility and mild climate (e.g. Antarctic Peninsula and associated archipelagos), or in areas of scientific importance (e.g. Dry Valleys), research stations (e.g. Fildes Peninsula on King George Island), historical remains (e.g. Whalers Bay on Deception Island), spectacular landscapes (e.g. Paradise Bay area), coastal wildlife colonies (e.g. Barrientos Island) and geological structures (e.g. Penguin Island). Moreover, certain Antarctic soils seem to be very vulnerable to even very low levels of disturbance (e.g. Beyer and Bölter 2002; Tin et al. 2009). The Antarctic Cold Desert is particularly sensitive to anthropogenic changes because it has little resilience (Ayres et al. 2008). Non-cohesive soils with sandy pebble-gravel textures are also very vulnerable to trampling, and damage is immediate (Fig. 6.2). In contrast, soils with a high surface-boulder cover and/or a big particle-size fraction are the least susceptible (Campbell et al. 1998). However, for most Antarctic soils an exceedingly low level of trampling—i.e. 20–100 pedestrian transits depending on the soil characteristics—is sufficient to result in very obvious and probably permanent damage (Table 6.2). This high fragility and susceptibility to damage requires a set of management measures that will be described later.

Available studies generally agree on the persistence of disturbances to Antarctic soils. In the McMurdo Dry Valleys, footprints and surface stone disturbances can still be visually identified up to 30 years after the last human visit (Campbell and Claridge 1987; Campbell et al. 1998), as a result of the high fragility of the desert pavement and the absence of significant natural rehabilitation processes. In other areas with volcanic soils dominated by lapillus—volcanic material ranging in size from 2 to 64 mm in diameter—the ground surface is less sensitive to trampling, and physical effects of regular human foot traffic can disappear after 1 year due to the freeze–thaw activity and wind action (Tejedo et al. unpublished data, Deception Island). Experimental manipulations of certain soils demonstrate that in areas that have been subjected to an intermediate level of trampling, i.e. of around 2,000 pedestrian transits, the effects of soil compaction could be completely reversed within 2–3 years if the area remains closed to any human traffic during this period (Tejedo et al. 2012). The same interval of time was necessary for bryophyte and associated invertebrate communities to develop on previously bare soil (Convey 2003). Therefore, the recovery capacity of Antarctic soils is variable and depends on soil properties and environmental conditions.

Table 6.2 Summary of known consequences of trampling on Antarctic soils based on existing studies

Type of impact	Observed changes
Alteration of soil structure and surface properties	*Resistance to compression:* even a low level of trampling on vegetation-free soils, around 100 pedestrian transits, increases significantly resistance to compression. A higher compaction reduces infiltration rate and macroporosity, making this habitat less suitable for certain soil organisms[a, b, c]
	Bulk density: values measured on a walking track were 10 % higher than those values measured on adjacent untrampled soil[d]. The correlation between bulk density and trampling has been observed in other studies[b]
	Micro-relief changes: cobbles and boulders are steadily removed from paths, largely by being kicked and flicked aside by passing boots, but most of the smaller clasts become pressed into the soil surface. Paths are quickly formed in more vulnerable soils, with as few as 20 pedestrian transits[d]
	Track width: shows a progressive increase with increasing traffic density[d]
	Visual changes: paths are easily produced in certain fragile substrates, such as pavement surfaces, and can remain for a long time[d, e]. Randomly dispersed footprints associated with a campsite can be undetectable within 5 years, meanwhile heavily disturbed areas can be remediated to re-contour pedestrian tracks, getting a visual full recovery of the desert pavement within 10 years[e]
	Soil moisture: human trampling intensity does not have a clear influence on this parameter[c, f]
	Albedo: reflection of sunlight is higher on tracks due to exposure of the light-coloured subsurface material and compaction[f]
	Carbon cycling: high levels of trampling reduce soil CO_2 fluxes, which are related to total biological activity in the ground. Disturbance of the soil respiration rate may be site specific[g]. Trampling could affect other nutrient cycles in soils
Damage to soil biota	*Biomass*: total biomass on the land surface suffers a clear loss with increasing trampling: over 50 % with only 600 pedestrian transits[c]
	Vegetation coverage: vegetation coverage is quickly reduced by trampling, although vulnerability varies according to the plant community. Moss meadows lose over 95 % of their initial cover with 300–600 pedestrian transits, meanwhile bryolichenic crusts are more sensitive and fewer than 200 pedestrian transits are enough to reach this state[c]. Usually, recovery is not possible during the same growing season[h]
	Invertebrate abundance: trampling reduces Collembola presence. The abundance of *Cryptopygus antarcticus* Willem, the most studied Antarctic collembolan, was correlated to trampling intensity under experimental conditions[b]. Some Antarctic nematodes (*Scottnema lindsayae* Timm and *Eudorylaimus* sp.) are also sensitive to trampling, showing a decrease in heavily disturbed areas[g] and an increase in the relative abundance of dead individuals in the top soil layer[i]. All these changes on soil populations could alter ecosystem functioning and food web structure, and favours species replacement
	Microbiota: the effect of trampling on the microbial community remains unknown. It is proposed that medium levels of trampling may increase the availability of previously protected soil carbon to microbes as a result of the physical disturbance of the soil, thus stimulating their activity, meanwhile high levels of disturbance could directly kill a large proportion of the microbial community[g]. But both issues still need to be demonstrated
	Alien species: there is considerable concern about the possibility of introduced species establishment as a direct result of human presence and foot traffic, although there is still little evidence that this is a real problem[c, j]

Data from [a]Tejedo et al. (2005), [b]Tejedo et al. (2009), [c]Pertierra et al. (2013a), [d]Campbell et al. (1998), [e]O'Neill et al. (2010), [f]Campbell et al. (1994), [g]Ayres et al. (2008), [h]de Leeuw (1994), [i]Ayres et al. (2007), [j]Frenot et al. (2005)

Fig. 6.2 Compaction of the ground surface as a result of foot traffic is clearly visible in this picture thanks to the snow (photograph by Pablo Tejedo)

It is also advisable to put in context the ecological importance of trampling. One way to assess the scope of this impact is to compare the effects of human traffic with those produced by the movements of vertebrates that inhabit many of the ice-free areas in Antarctica. Numerous studies quoted the damages on soils and vegetation produced by the presence and movement of wildlife. On Signy

Island in maritime Antarctic, Tilbrook (1967) observed large areas reduced to barren, muddy ground, with large populations of the green alga *Prasiola crispa*, an indicator of eutrophication, present on the periphery of coastal colonies of vertebrates. In this location, Smith (1988) also noticed that the dramatic increase in the number of Antarctic fur seals *Arctocephalus gazella* Peters coming ashore on the island during the short summers was devastating certain terrestrial environments, in which the fragile cryptogam-dominated vegetation was physically damaged and removed in many cases. On King George Island, trampling by seabirds caused fast changes in vegetation (Kanda and Inoue 1994). On Sub-Antarctic Islands similar changes have been observed. For example on South Georgia Island, the impact of fur seal trampling on typical sub-Antarctic terrestrial vegetation is evident. At heavily impacted areas, tussock grass has been displaced and the dead tussock stools colonised by the moss *Polytrichum strictum* Brid. (Convey and Lebouvier 2009). Until now, there have been few studies comparing the impacts of trampling by wildlife with those by humans. Tejedo et al. (unpublished data) compared two parallel paths on Barrientos Island. One path was created by humans and the other was created by penguins. Resistance to compression was the selected indicator used for the comparison. Results showed that in flat areas the physical degradation of the soil surface was greater in the path created by the penguins. However, in those areas with a pronounced slope, 18° on average, results were reversed with a greater compaction in the path used by tourists. These and similar experiments can help us identify the conditions under which human presence can cause greater disturbance over those produced naturally by the indigenous fauna.

6.3 Drivers of Change

In order to construct future scenarios, we need to have a knowledge of vulnerabilities and drivers of change. In our opinion, the main drivers of change for Antarctic soils are (a) climate change, (b) human pressure and (c) the potential consequences of the introduction of alien species. In the following sections, these drivers are briefly reviewed and their possible future trends are identified.

6.3.1 Climate Change

Over the last 50 years, rapid warming has been documented along the western Antarctic Peninsula. The largest warming has been measured at Vernadsky/Faraday Station, at a rate of 0.53 °C per decade for the period 1951–2006 (Turner et al. 2009), seven times faster than the average rate of global warming (IPCC 2007). Climate models project significant warming over the Antarctic continent over the twenty-first century. It is expected that, in a warmer world, there will be less ice and higher sea level and the most likely regions of near-future change are those that are changing most today, such as the Antarctic Peninsula (IPCC 2007). Antarctic terrestrial ecosystems are expected to show particular sensitivity and rapid responses under climate change (Quayle et al. 2002, 2003). Antarctic summer temperatures are very low, with levels often near the minimum threshold for many physiological processes (Convey 2006). Therefore, small temperature increases could produce a greater effect than in temperate regions. Multiple biological processes involved in growth, metabolism and maintenance have different optimal temperatures. As a result it is difficult to predict the response of an organism as a whole under climate change. Soil life may undergo several changes under warmer conditions. For some invertebrate species, microhabitat warming may exceed their upper thermal limits (Van der Merwe et al. 1997; Convey 2001), and brief exposures to high temperatures could produce high mortality rates among these organisms (Convey 2010).

Under climate change, it is expected that the winter period will be shorter, hence lengthening the active season for terrestrial biota, at least in the maritime Antarctic archipelagos. This would allow liquid water in soils to be maintained or even released through earlier spring thaws and later autumn freezing (Convey 2006). Higher water availability, both precipitation and melt, could also contribute to increases in the processes of colonisation (Hawes 2011) and the abundance of certain species of flora and invertebrates. The abundance and distribution of the only two species of Antarctic native flowering plants, Antarctic pearlwort *Colobanthus quitensis* and Antarctic hair grass *Deschampsia antarctica*, have increased in different sites (Fowbert and Smith 1994; Grobe et al. 1997; Gerighausen et al. 2003; Convey 2006; Block et al. 2009; Smith and Richardson 2010). Long-term studies have shown that some populations have increased by one to two orders of magnitude in as little as 30 years (Convey 2006). Other populations have colonised new areas of ice-free ground. These increases have been attributed both to extended growing seasons (Smith and Richardson 2010) and warmer summer temperatures that, in turn, enhanced seed production, maturation, germination and seedling survival (Convey 2003, 2006). A four-year experiment carried out on vegetation near Palmer Station on the western Antarctic Peninsula, showed that higher water availability increased soil microarthropod abundance (Convey et al. 2002). Similar experiments have demonstrated that abiotic factors, precipitation regime principally, play a dominant role in controlling plants and microarthropod abundance (Day et al. 2009). Schulte et al. (2008) observed extremely large aggregations of collembolan eggs on Humble Island, which could be attributed to spring warming which occurred seven weeks earlier than the previous year. Over the long term, an extension of the growing season could change the life cycle of some Antarctic organisms, such as biennial and perennial plant species, and animals with multi-year development. In the case where higher temperatures are combined with strong winds, plants and invertebrates could experience desiccation stress where soils have a low capacity to retain water. Under these conditions, some plant and invertebrate species could be favoured. The springtail *Cryptopygus antarcticus* Willem or the mite *Alaskozetes antarcticus* Michael have significant resistance to desiccation and can survive a reduction in total body water from 60 to 40 % of fresh weight (Elnitsky et al. 2008; Thomas et al. 2008). Other less hardy organisms could migrate deeper into the soil, where the environmental conditions are more stable.

Nutrient cycles and food webs could also be modified in more vulnerable soils. Freckman and Viginia (1997) demonstrated that an increase in soil water, carbon and temperature could modify the food web in the soils of the Dry Valley region, decreasing the abundance of the single omnivore-predator species and increasing the abundance of microbivorous prey species. With a greater availability of nutrients, plant communities that thrive in Antarctic soils, such as *Polytrichum alpestre* Hoppe and *Drepanocladus uncinatus* (Hedw.) Warnst are expected to expand. Collembola and acari could also increase their diversity or abundance under these favourable conditions. As they play a key role in nutrient cycling in the soil ecosystem, the expansion of these species may significantly alter the rate at which soil organic material can be broken down. However, some experiments based on warming treatments suggest that immediate effects within the decomposer cycle would be small (Bokhorst et al. 2008). Because variables are interlinked, these changes could have consequences that cascade throughout the environment and biological systems. The typical succession of soil communities would certainly be altered. In most of the habitats of the maritime Antarctic, communities could either not develop to a climax state, or follow a form of circular succession or auto succession, with pioneer and climax species occurring together (Smith 1972; Convey 1996). This succession is extremely slow due to conditions that are inimical to plant growth. Under more favourable conditions, biotic controls could dominate plant growth and favour the progress towards a climax community, probably dominated by vascular plants in soils with enough available nutrients and good drainage. However, the real importance of these changes remains uncertain due to the complexity in the relationship between atmospheric climatic conditions and soil microclimate.

6.3.2 Human Pressure

According to the Council of Managers of National Antarctic Programs (COMNAP 2012), there are approximately 100 active stations, refuges and camps, across Antarctica, with simultaneous capacity for 4,397 and 1,085 people during the summer and winter seasons respectively. The operation of these facilities has produced several impacts on Antarctic soils, such as the deposition of chemical and organic pollutants (e.g. polychlorinated biphenyls, heavy metals, polycyclic aromatic hydrocarbons, faecal wastes) and disturbance of terrestrial ecosystems (Tin et al. 2009 and references therein). In fact, areas around these facilities are usually considered as sacrificial zones where impacts are concentrated, leaving the areas further away from the facilities as nearly pristine for research purposes. The number of Antarctic stations that are in active use is constantly changing, with some countries temporarily closing some of their facilities and others opening new stations. A significant increase is not expected in the future due to the foreseeable lack of funding. However, abandoned facilities are rarely removed (Tin et al. 2009). Some stations are visited by tourists during their stay in Antarctica, and some stations are also used to support tourist activities, such as the blue ice airstrip near Novolazarevskaya Station in Queen Maud Land (Russian Federation 2010; Japan 2011) and a hangar at Artigas Base (Bastmeijer and Roura 2008; ASOC 2008). Terrestrial tourist facilities are scarce. They include temporary camps, such as the facility White Desert, which is dismantled every season (ASOC 2009) and permanent tourism facilities, such as the camp established near the Union Glacier by Antarctic Logistics and Expeditions LLC. This infrastructure replaces Patriot Hills Camp which operated for two decades and was designed to accommodate up to 80 people (ASOC 2011). Scientific and tourist expeditions also take place far away from research stations and established infrastructure, exerting pressure on Antarctic soils further afield (Fig. 6.3). In the case of scientific expeditions, most of the field research initially takes place in the vicinity of a newly built station. As this area becomes well-studied, research teams expand their work to other distant areas through the installation of temporary camps and the use of vessels as mobile logistic bases.

Most commercial tourists travel to Antarctica onboard cruise ships with the majority of cruises taking place around the Antarctic Peninsula region and its associated archipelagos. While tourists spend most of their time onboard, they have the opportunity to make shore visits on the ice-free coastal zones of 2 to 3 h each,

Fig. 6.3 Tourists following an official walking route marked with flags by guides in Barrientos Island, South Shetland Islands (photograph by Javier Benayas)

one to three times daily (Bertram 2007). During the 2010–2011 seasons, over 150 sites were visited by a total of over 150,000 visitors. The four most visited sites (all in the Peninsula region) each received a total of 10,000–15,000 visitors between November and March, which accounted for over 30 % of the total number of visitors at sites (IAATO 2011a). In contrast, some sites, especially those that are far from the Peninsula, are only visited once or twice per year. Tourists undertake a wide range of activities on land, including camping, hiking and climbing (International Association of Antarctica Tour Operators 2011b). The number of visitors to Antarctica has been increasing over recent decades. While visitor numbers have decreased in recent years as a result of a global economic crisis, the decades-long trend of growth in Antarctic tourism is expected to resume (IAATO 2011c).

Climate change could also have an influence on human pressure in the near future. Sea ice cover along the Western Antarctic Peninsula has decreased by 40 % between 1979 and 2004 (Ducklow et al. 2007; Stammerjohn et al. 2008). A shorter sea ice season has been observed (Parkinson 2002). Annual average total sea ice area is expected to decrease under climate change (Turner et al. 2009). Less sea ice could make some locations more accessible and a shorter sea ice season would lengthen the tourist season and the summer campaign for researchers. All of these changes could increase the human pressure on Antarctic soils.

6.3.3 Species Introduction

Antarctic terrestrial ecosystems are limited in species diversity and are characterised by the absence of many taxonomic groups. These simplified systems are more vulnerable to colonisation by alien species (Convey 2006). Climate change and human pressure are likely to act synergistically by reducing the barriers to establishment and increasing import of alien species (Convey 2010). This would subsequently increase the likelihood of establishment of alien species on Antarctic soils which could impact native ecosystems and alter soil characteristics. To date, only five alien species have established on the Antarctic continent, although there are at least three others unconfirmed (Frenot et al. 2005; Hughes and Convey 2010; Hughes et al. 2013). The established species are three grasses (*Poa annua* L., *P. pratensis* L. and *P. trivialis* L., with the latter species eradicated in 2007), an enchytraeidae worm (*Christensenidrilus blocki* Dózsa-Farka and Convey), and a brachypterous and parthenogenetic chironomid midge (*Eretmoptera murphyi* Schaeffer). All of these species were first observed in the vicinity of scientific stations. In fact, it is believed that invertebrates were introduced accidentally during transplantation experiments performed in the late 1960s (Dózsa-Farkas and Convey 1997, 1998). Regarding alien microbiota, several authors have identified that there is a critical gap in current knowledge (Frenot et al. 2005; Hughes and Convey 2010; Cowan et al. 2011).

None of the above mentioned species seem to have become invasive, although in certain locations such as Arctowski Station, King George Island, these grasses are locally abundant (Frenot et al. 2005). In this place, *Poa annua* has extended into the surrounding native vegetation and was recently observed 1.5 km away from the station, on the deglaciated moraines of the retreating Ecology Glacier (Olech and Chwedorzewska 2011). There are other observations of exotic springtails (Convey 2008; Hughes and Worland 2009; Greenslade 2010) and plants in the maritime Antarctic, although the current status of these populations is unknown. In 2009, four individuals of the flowering plants *Nassauvia magellanica* JF Gmelin and one of *Gamochaeta nivalis* Cabrera were found at Whalers Bay, Deception Island. This site is frequently visited by large numbers of tourists and researchers, therefore an anthropogenically mediated establishment cannot be dismissed (Smith and Richardson 2010). The specimens were removed in January 2010 by a representative of the Deception Island Management Group to preserve the integrity of the island's native terrestrial ecosystem.

6.4 How Are Antarctic Soils Protected?

The Protocol on Environmental Protection to the Antarctic Treaty (also called the Environmental Protocol) is the main regulatory document regarding environmental protection in Antarctica. Article 3(2)(b)(iii) requires that 'activities in the Antarctic Treaty area shall be planned and conducted so as to avoid: significant changes in the… terrestrial… environment'. However, the Protocol and its Annexes do not identify any specific measures with respect to the minimisation of trampling effects. Annex V of the Protocol sets out provisions for the establishment of Antarctic Specially Protected Areas (ASPAs) and Antarctic Specially Managed Areas (ASMAs). Management plans guide the regulation of human activities within ASPAs and ASMAs with the goal of protecting the special values of these areas. These documents establish, among others, the conditions under which permits may be granted for access to the areas, activities which may be conducted including restrictions on time and place, location of field camps, or requirements for waste disposal. Annex I of the Protocol sets out the requirements for the undertaking of Environmental Impact Assessments (EIAs) prior to the start of all activities to be conducted in Antarctica, whether government, private or commercial. EIAs should analyse the possible consequences of all activities, including foot traffic, on the different elements of the environment, including soils.

Apart from these legal instruments, a number of non-binding codes of conduct developed by different organisations are also relevant to the conservation of Antarctic soils. For specific locations, site-specific guidelines have been developed by the International Association of Antarctica Tour Operators (IAATO) in conjunction with the Antarctic Treaty parties. These guidelines provide practical guidance for tour operators and guides on how tourist visits should be conducted at these sites, taking into account local environmental values and sensitivities. Some measures for controlling the effects of trampling are included, such as closing areas from visitation and establishing walking routes in order to protect vulnerable features or fragile surfaces such as desert pavement and avoid disturbance to vegetation (ATS 2012).

The 'Environmental Code of Conduct for Terrestrial Scientific Field Research in Antarctica' of the Scientific Committee on Antarctic Research (SCAR 2009) provides recommendations on how scientists and associated personnel can undertake scientific field activities while minimising their environmental impact. All countries involved in Antarctic field research are encouraged to include this code of conduct within their operational procedures. Regarding trampling, three measures are proposed: (a) stay on established trails when available, (b) avoid walking on areas that are especially vulnerable to disturbance and (c) re-use existing sites wherever possible. Guidelines are important contributions towards the minimisation of human impacts and they need to be supported by targeted research. At present, the effect of cumulative impacts is poorly known. It is uncertain if repeated use of one area or spreading the activity across a larger area would lead to lower impacts on soils (see Tejedo et al. 2009; O'Neill and Balks 2010). At Southern Beaches Camp on Livingston Island, Tejedo et al. (unpublished data) measured the physical properties of the top centimetres of the soil profile to examine how the soils' resistance to compression changed following the establishment and use of a tent camp. The presence of the camp initially led to soil compression which was followed by good recovery from season to season. However, previously impacted soils had a higher vulnerability to disturbances which favoured the rapid appearance of significant changes in the physical properties of the soil surface. The freeze–thaw cycle that is present in most maritime Antarctic soils could favour recovery (Tejedo et al. 2005, 2009), but continued use of the same area for several seasons may excessively degrade the soil, making recovery more difficult. This and similar research is necessary to help design effective future guidelines.

Finally, IAATO applies a version of the Recommendation XXVIII-1 Guidance for Visitors to the Antarctic as guidelines for visitors to Antarctica (IAATO 2012). There are no explicit guidelines for soil conservation and trampling. Expedition leaders and guides are left to interpret these general recommendations in terms of appropriate visitor behaviour for the minimisation of soil disturbances during visits ashore.

6.5 Future Scenarios Regarding Soil Conservation

Integrating the discussions of soil vulnerability, drivers of change and existing conservation measures in earlier sections, we analyse two possible future scenarios for the conservation of Antarctic soil in this section. The first scenario assumes a continuation of the current situation, which will be characterised by a limited knowledge of soil degradation processes and a lack of concern for the environmental impacts of human presence in the medium and long-term. The second scenario assumes a change from the current mentality towards one which favours an integral conservation of Antarctic resources, including soils.

6.5.1 Business-As-Usual Scenario

Under this scenario, trampling would not become a widespread impact on terrestrial Antarctic ecosystems, but certain sites with high levels of use will be severely impacted. This is the case of Fildes Peninsula, King George Island, where numerous stations are concentrated (Peter et al. 2008; Braun et al. 2013), or Barrientos Island, a popular tourist visitation site, where unofficial paths have been created outside authorised walking routes (Ecuador and Spain 2012). Under this scenario, little research on soil properties and human impacts is conducted, hence our understanding of the factors that govern degradation of ground surfaces will not be greatly improved, hampering our ability to establish effective protocols for soil conservation and the consideration of cumulative impacts in EIAs. Management decisions will continue to be made based on large uncertainties surrounding the resilience, response and early detection of impacts of Antarctic soils. The current trend would continue, where more effort is spent on documenting impacts than in mitigating them.

6.5.2 Conservation-Focused Scenario

This scenario would reflect a clear commitment of Antarctic Treaty parties to prioritise the conservation of all natural resources in Antarctica, including soils. Current knowledge about the characteristics and operation of Antarctic soils would be improved, including the establishment of monitoring protocols based on specific and sound physical, chemical and biological indicators. Although at present different research teams are working on these indicators (see references in this chapter), there are still certain gaps in knowledge on specific issues, including the effects of trampling at the level of nutrient cycles, the impact on soil microbiota functionality, or vulnerability and resilience against trampling in the medium- to long-term for different Antarctic soils, making it difficult to make sound science-based management decisions with respects to soil conservation. The establishment of a monitoring network will fill this gap by providing information on spatial patterns and temporal trends (see Klein et al. 2013; Sánchez and Njaastad 2013). This network would include areas subject to intense human activity, such as at research stations and popular tourist visitation sites (Fig. 6.4), and complementary control sites with little human activity. Data could be represented in a geographic information system (GIS) with free access to researchers worldwide. Availability of such data will be invaluable for assessing the effectiveness of codes of conduct, mitigation measures and restoration activities and would help to create a catalogue of best practices regarding soil conservation (see Pertierra et al. 2013b). National Antarctic Programs can use this data to monitor their own environmental impacts. The data can also be used to help with the management of tourist visitation sites, such as highlighting best practices and identifying impacted areas which may need to be closed to allow recovery. At a broader scale, this data can be useful for the purposes of strategic environmental assessments. The Antarctic Treaty System's Committee for Environmental

Fig. 6.4 Environmental monitoring plot on Whalers Bay, Deception Island. In the background, both the remains of the Norwegian whaling station and a tourist vessel can be observed (photograph by Pablo Tejedo)

Protection could lead this process, while SCAR could collaborate in providing scientific advice. In line with the commitment to the conservation of all natural resources in Antarctica, under this scenario, remediation and restoration of abandoned sites will also be prioritised. The legacy of contaminated soils and sediments in Antarctica is estimated to be of the order of 1–10 million m^3 (Snape et al. 2001). While a number of clean-ups have taken place, site remediation has generally been given low priority (Tin et al. 2009). In addition, site restoration can facilitate the recovery of Antarctic soils that have been impacted by the formation of walking tracks and use of campsites. O'Neill and Balks (2010) demonstrated that raking to recontour tracked areas led to recovery of surface pavements in the Ross Sea Region. All of these measures would help to preserve the intrinsic physical attributes of Antarctic soils.

6.6 Conclusions

In this chapter, we have reviewed the major impacts of trampling and proposed a conservation-focused future scenario which gives higher priority to soil conservation than current practices or in a Business-As-Usual future. Under the Antarctic Treaty System, environmental monitoring is a legal obligation for signatory nations and an essential tool for managers attempting to minimise local human impacts, yet implementation is sparse (Hughes 2010). Perhaps this is linked to the difficulty that Antarctic Treaty nations may have in firmly prioritising conservation and monitoring over other issues, such as historical land claims or the pursuit of international prestige associated with presence in Antarctica. Secondly, material, human and monetary resources are all needed to carry out environmental monitoring in an effective way. These resources are often limited, especially around times of economic recession, and gives rise to a fundamental question: should the minimisation of trampling impacts be considered as a priority in Antarctic environmental management? Surely many people would suggest that there are other bigger problems with greater negative consequences for the environment, such as climate change, alien species, the risk of an oil spill, or long-range transboundary air pollution. And most likely they are right. Nevertheless, in our opinion, conservation of Antarctic soils should be a priority as they provide habitats for a regionally important and, in some groups, highly endemic edaphic fauna and flora (Hughes and Convey 2010). Moreover, Antarctica should be preserved in its best possible condition to allow scientists to continue using it as a reference area for analysing certain processes, such as global changes, and to give future generations the chance to inherit a wilderness that is in as pristine a condition as possible. Therefore, we recommend further work to improve the current knowledge about soil degradation processes in Antarctica and what measures could be used to prevent the long-term impacts of trampling. This would allow us to identify the best strategies to improve the conservation of this important resource, which is crucial for the conservation of some of the most vulnerable Antarctic terrestrial ecosystems against the impacts of human activities.

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References

Adams, B. J., Bardgett, R. D., Ayres, E., Wall, D. H., Aislabie, J., Bamforth, S., et al. (2006). Diversity and distribution of Victoria Land biota. *Soil Biology and Biochemistry, 38*, 3003–3018.

ASOC. (2008). *A decade of Antarctic tourism: Status, change, and actions needed.* Information Paper 41 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine.

ASOC. (2009). *Tourism and land-based facilities in Antarctica.* Information Paper 23 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA.

ASOC. (2011). *Land-based tourism in Antarctica.* Information Paper 87 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina.

ATS. (2012). *Site Guidelines for visitors*. Retrieved from: http://www.ats.aq/e/ats_other_siteguidelines.htm.

Ayres, E., Nkem, J. N., Wall, D. H., Simmons, B. L., Adams, B. J., Barreto, J. E., & Virginia, R. A. (2007). *Human trampling reduces soil faunal populations and soil respiration in the McMurdo Dry Valleys, Antarctica*. Paper presented at the ESA/SER Joint Meeting, San José, California.

Ayres, E., Nkem, J. N., Wall, D. H., Adams, B. J., Barrett, J. E., Bross, E. J., et al. (2008). Effects of human trampling on populations of soil fauna in the McMurdo Dry Valleys, Antarctica. *Conservation Biology, 22*, 1544–1551.

Barrett, J. E., Virginia, R. A., Parsons, A. N., & Wall, D. H. (2005). Potential carbon and nitrogen turnover in soils of the McMurdo Dry Valleys, Antarctica. *Arctic, Antarctic, and Alpine Research, 37*, 107–116.

Barrett, J. E., Virginia, R. A., Hopkins, D. W., Aislabie, J., Bargagli, R., Bockheim, J. G., et al. (2006). Terrestrial ecosystem processes of Victoria Land, Antarctica. *Soil Biology and Biochemistry, 38*, 3019–3034.

Bastmeijer, K., & Roura, R. (2008). Environmental impact assessment in Antarctica. In K. Bastmeijer & T. Koivurova (Eds.), *Theory and practice of transboundary environmental impact assessment* (pp. 175–219). Monographs Series on Legal aspects of sustainable development. Leiden, Netherlands: Brill/Martinus Nijhof Publishers.

Belnap, J. (2006). The potential roles of biological soil crusts in dryland hydrologic cycles. *Hydrological Processes, 20*, 3159–3178.

Bergstrom, D. M., & Chown, S. L. (1999). Life at the front: History, ecology and change on Southern Ocean Islands. *Trends in Ecology and Evolution, 14*, 472–476.

Bergstrom, D. M., Hodgson, D. A., & Convey, P. (2006). The physical setting of the Antarctic. In D. M. Bergstrom, P. Convey & A. H. L. Huiskes (Eds.), *Trends in Antarctic terrestrial and limnetic ecosystems. Antarctica as a global indicator* (pp. 15–34). Berlin, Germany: Springer.

Bertram, E. (2007). Antarctic shipborne tourism: an expanding industry. In J. M. Snyder & B. Stonehouse (Eds.), *Prospects for polar tourism* (pp. 149–169). Wallingford: CABI Publishers.

Beyer, L., & Bölter, M. (Eds.). (2002). *Geoecology of Antarctic ice-free coastal landscapes. Ecological studies (Vol. 154)*. Berlin, Germany: Springer.

Block, W. (1996). Cold or drought: The lesser of two evils for terrestrial arthropods? *European Journal of Entomology, 93*, 325–339.

Block, W., Lewis-Smith, R. I., & Kennedy, A. D. (2009). Strategies of survival and resource exploitation in the Antarctic fellfield ecosystem. *Biological Reviews, 84*, 449–484.

Bokhorst, S., Huiskes, A. H. L., Convey, P., van Bodegom, P. M., & Aerts, R. (2008). Climate change effects on soil arthropod communities from the Falkland Islands and the Maritime Antarctic. *Soil Biology and Biochemistry, 40*, 1547–1556.

Braun, C., Fritz, H., Mustafa, O., Nordt, A., Pfeiffer, S., & Peter H.-U. (2013). Environmental assessment and management challenges of the Fildes Peninsula region. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

Cameron, R. E. (1969). *Abundance of microflora in soils of desert regions. Technical Report* (Vol. 32–1378). Pasadena, CA: Jet Propulsion Laboratory.

Campbell, I. B., & Claridge, G. G. C. (1987). *Antarctica: Soils, weathering processes and environment*. Amsterdam: Elsevier.

Campbell, I. B., Balks, M. R., & Claridge, G. G. C. (1993). A simple visual technique for estimating the effects of fieldwork on the terrestrial environment in an ice-free area of Antarctica. *Polar Record, 29*, 321–328.

Campbell, I. B., Claridge, G. G. C., & Balks, M. R. (1994). The effects of human activities on moisture content of soils and underlying permafrost from the McMurdo Sound region, Antarctica. *Antarctic Science, 6*, 307–314.

Campbell, I. B., Claridge, G. G. C., & Balks, M. R. (1998). Short and long-term impacts of human disturbance on snow-free surfaces in Antarctica. *Polar Record, 34*, 15–24.

Chen, J., & Blume, H. P. (1997). Impact of human activities on the terrestrial ecosystem of Antarctica: A review. *Polarforschung, 65*, 83–92.

COMNAP. (2012). *Antarctic Facilities.* Retrieved from: https://www.comnap.aq/Members/Shared%20Documents/Antarctic_Facilities_List_3Feb2012.xls.

Convey, P. (1996). The influence of environmental characteristics on the life history attributes of Antarctic terrestrial biota. *Biological Reviews, 71*, 191–225.

Convey, P. (2001). Terrestrial ecosystem response to climate changes in the Antarctic. In G. R. Walther, C. A. Burga, & P. J. Edwards (Eds.), *"Fingerprints" of climate change: Adapted behaviour and shifting species ranges* (pp. 17–42). New York: Kluwer.

Convey, P. (2003). Maritime Antarctic climate change: signals from terrestrial biology. In E. Domack, A. Burnett, A. Leventer, P. Convey, M. Kirby & R. Bindschadler (Eds.), *Antarctic Peninsula climate variability: Historical and palaeoenvironmental perspectives,* (pp. 145–158). Antarctic research series (Vol. 79). Washington, D.C.: American Geophysical Union.

Convey, P. (2006). Antarctic climate change and its influences on terrestrial ecosystems. In D. M. Bergstrom, P. Convey, & A. H. L. Huiskes (Eds.), *Trends in Antarctic terrestrial and limnetic ecosystems: Antarctica as a global indicator* (pp. 253–272). Dordrecht: Springer.

Convey, P. (2008). Non-native species in Antarctic terrestrial and freshwater environments: Presence, sources, impacts and predictions. In M. Rogan-Finnemore (Ed.), *Non-native Species in the Antarctic: Proceedings* (pp. 97–130). Christchurch: Gateway Antarctica.

Convey, P. (2010). Terrestrial biodiversity in Antarctica: Recent advances and future challenges. *Polar Science, 4*, 135–147.

Convey, P., & Lebouvier, M. (2009). Environmental change and human impacts on terrestrial ecosystems of the sub-Antarctic islands between their discovery and the mid-twentieth century. *Papers and Proceedings of the Royal Society of Tasmania, 143*, 33–44.

Convey, P., Pugh, P. J. A., Jackson, C., Murray, A. W., Ruhland, C. T., Xiong, F. S., et al. (2002). Response of Antarctic terrestrial arthropods to multifactorial climate manipulation over a four year period. *Ecology, 83*, 3130–3140.

Convey, P., Stevens, M. I., Hodgson, D. A., Smellie, J. L., Hillenbrand, C.-D., Barnes, D. K. A., et al. (2009). Exploring biological constraints on the glacial history of Antarctica. *Quaternary Science Reviews, 27–28*, 3035–3048.

Cowan, D. A., Chown, S. L., Convey, P., Tuffin, M., Hughes, K. A., Pointing, S., et al. (2011). Non-indigenous microorganisms in the Antarctic: Assessing the risks. *Trends in Microbiology, 19*, 540–548.

Day, T. A., Ruhland, C. T., Strauss, S. L., Park, J. H., Krieg, M. L., Krna, M. A., et al. (2009). Response of plants and the dominant microarthropod, *Cryptopygus antarcticus*, to warming and contrasting precipitation regimes in Antarctic tundra. *Global Change Biology, 15*, 1640–1651.

De Leeuw, C. (1994). *Tourism in Antarctica and its impact on vegetation*. PhD thesis. Groningen: Arctic Centre, University of Groningen.

Dózsa-Farkas, K., & Convey, P. (1997). *Christensenia*, a new terrestrial enchytraeid genus from Antarctica. *Polar Biology, 17*, 482–486.

Dózsa-Farkas, K., & Convey, P. (1998). Erratum; *Christensenia*, a new terrestrial enchytraeid genus from Antarctica. *Polar Biology, 20*, 292.

Ducklow, H. W., Baker, K., Martinson, D. G., Quetin, L. B., Ross, R. M., Smith, R. C., et al. (2007). Marine pelagic ecosystems: The West Antarctic Peninsula. *Philosophical Transactions of the Royal Society Series B, 362*, 67–94.

Ecuador & Spain. (2012). Revised Visited Site Guidelines: Aitcho Islands. Working Paper 59 presented at XXXV Antarctic Treaty Consultative Meeting, Hobart, Australia.

Elnitsky, M. A., Benoit, J. B., Denlinger, D. L., & Lee, R. E. J. (2008). Desiccation tolerance and drought acclimation in the Antarctic collembolan *Cryptopygus antarcticus*. *Journal of Insect Physiology, 54*, 1432–1439.

Fowbert, J. A., & Smith, R. I. L. (1994). Rapid population increases in native vascular plants in the Argentine Islands, Antarctic Peninsula. *Arctic and Alpine Research, 26*, 290–296.

Freckman, D. W., & Viginia, R. A. (1997). Low-diversity Antarctic soil nematode communities: distribution and response to disturbance. *Ecology, 78*, 363–369.

Frenot, Y., Chown, S. L., Whinam, J., Selkirk, P., Convey, P., Skotnicki, M., et al. (2005). Biological invasions in the Antarctic: Extent, impacts and implications. *Biological Reviews, 80*, 45–72.

Gerighausen, U., Bräutigam, K., Mustafa, O., & Peter, H. U. (2003). Expansion of vascular plants on an Antarctic island: A consequence of climate change? In A. H. L. Huiskes, W. W. C. Gieskes, J. Rozema, R. M. L. Schorno, S. M. van der Vies, & W. J. Wolff (Eds.), *Antarctic biology in a global context* (pp. 79–83). Leiden: Backhuys.

Greenslade, P. (2010). Collembola fauna of the South Shetland Islands revisited. *Antarctic Science, 22*, 233–242.

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

Hansom, J. D., & Gordon, J. E. (1998). *Antarctic environments and resources*. Harlow: Longman.

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

Hawes, T. C. (2011). Rafting in the Antarctic springtail, *Gomphiocephalus hodgsoni*. *Antarctic Science, 23*, 456–460.

Headland, R. K., & Keage, P. L. (1985). Activities on the King George Island group, South Shetland Islands, Antarctica. *Polar Record, 22*, 475–484.

Hogg, I. D., Cary, S. C., Convey, P., Newsham, K. K., O'Donnell, T., Adams, B. J., et al. (2006). Biotic interactions in Antarctic terrestrial ecosystems: Are they a factor? *Soil Biology and Biochemistry, 38*, 3035–3040.

Hughes, K. A. (2010). How committed are we to monitoring human impacts in Antarctica? *Environmental Research Letters, 5*, 041001. doi:10.1088/1748-9326/5/4/041001.

Hughes, K. A., & Convey, P. (2010). The protection of Antarctic terrestrial ecosystems from inter- and intra-continental transfer of non-indigenous species by human activities: a review of current systems and practices. *Global Environmental Change, 20*, 96–112.

Hughes, K. A., & Worland, M. R. (2009). Spatial distribution, habitat preference and colonization status of two alien terrestrial invertebrate species in Antarctica. *Antarctic Science, 22*, 221–231.

Hughes, K. A., Convey, P., & Huiskes, A. H. L. (2013). Global movement and homogenisation of biota: challenges to the environmental management of Antarctica? In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment.* Dordrecht: Springer.

IAATO. (2011a). *2010–2011 Number of Visitors (tourists, staff and crew) per Site per Vessel*: *All Antarctic Sites (6 Sheets Total)*. Retrieved from: http://iaato.org/tourism-statistics.

IAATO. (2011b). *2010–2011 Number of Visits per Site/per Activity (6 Sheets*: *Sorted by All sites, Continental and Peninsula)*. Retrieved from: http://iaato.org/tourism-statistics.

IAATO. (2011c). *IAATO Overview of Antarctic Tourism: 2010–2011 Season and Preliminary Estimates for 2011-2012 Antarctic Season.* Information Paper 106. Rev 1 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina.

IAATO. (2012). *Guidance for visitors to the Antarctic*. Retrieved from: http://iaato.org/visitor-guidelines.

IPCC. (2007). *Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the IPCC.* Cambridge: Cambridge University Press.

Japan. (2011). *Inspection undertaken by Japan in accordance with Article VII of the Antarctic Treaty and Article XIV of the protocol on environmental protection*. Working Paper 1 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina.

Kanda, H., & Inoue, M. (1994). Activities on the King George Island group, South Shetland Islands, Antarctica. *Polar Biology, 7*, 221–231.

Klein, A. G., Sweet, S. T., Kennicutt II, M. C., Wade, T. L., Palmer, T. A., & Montagna, P. (2013). Long term monitoring of human impacts to the terrestrial environment at McMurdo station. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht: Springer.

Kriwoken, L. K., & Rootes, D. (2000). Tourism on ice: Environmental impact assessment of Antarctic tourism. *Impact Assessment and Project Appraisal, 18*(2), 138–150.

Lamers, M. (2009). *The future of tourism in Antarctica. Challenges for sustainability*. PhD Thesis. Maastricht: Universitaire Pers Maastricht.

Lawley, B., Ripley, S., Bridge, P., & Convey, P. (2004). Molecular analysis of geographic patterns of eukaryotic diversity in Antarctic soils. *Applied and Environmental Microbiology, 70*, 5963–5972.

Navas, A., López-Martínez, J., Casas, J., Machín, J., Durán, J. J., Serrano, E., et al. (2008). Soil characteristics on varying lithological substrates in the South Shetland Islands, maritime Antarctica. *Geoderma, 144*, 123–139.

O'Neill, T. A., & Balks, M. R. (2010). *A provisional method for assessing the impact on, and recovery of, Antarctic Desert Pavements from human-induced disturbances*. Paper presented at the 19th World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, Australia.

O'Neill, T. A., Balks, M. R., & López-Martínez, J. (2010). *Soil surface recovery from foot traffic in the Ross Sea Region of Antarctica*. Paper presented at IPY Oslo Science Conference, Oslo, Norway.

Olech, M. (1996). Human impact on terrestrial ecosystems in West Antarctica. *Polar Biology, 9*, 299–306.

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. *Antarctic Science, 23*, 153–154.

Parkinson, C. L. (2002). Trends in the length of the Southern Ocean sea ice season, 1979–1999. *Annals of Glaciology, 34*, 435–440.

Parsons, P. N., Barrett, J. E., Wall, D. H., & Virginia, R. A. (2004). Soil carbon dioxide flux in Antarctic dry valley ecosystems. *Ecosystems, 7*, 286–295.

Pertierra, L. R., Lara, F., Tejedo, P., Quesada, A. & Benayas, J. (2013a). Rapid denudation processes in cryptogamic communities from Maritime Antarctica subjected to human trampling. *Antarctic Science*, *25*, 318–328.

Pertierra, L. R., Tejedo, P., & Benayas, J. (2013b). Looking into the future of Deception Island: Current status, drivers of change and policy alternatives. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment.* Dordrecht: Springer.

Peter, H.-U., Buesser, C., Mustafa, O., & Pfeiffer, S. (2008). *Risk assessment for the Fildes Peninsula and Ardley Island, and development of management plans for their designation as Specially Protected or Specially Managed Areas*. Dessau: German Environmental Agency. Retrieved from: http://www.umweltdaten.de/publikationen/fpdf-l/3478.pdf.

Quayle, W. C., Peck, L. S., Peat, H., Ellis-Evans, J. C., & Harrigan, P. R. (2002). Extreme responses to climate change in Antarctic lakes. *Science, 295*, 645.

Quayle, W. C., Convey, P., Peck, L. S., Ellis-Evans, J. C., Butler, H. G., & Peat, H. J. (2003). Ecological responses of maritime Antarctic lakes to regional climate change. In E. Domack, A. Burnett, A. Leventer, P. Convey, M. Kirby & R. Bindschadler (Eds.), *Antarctic Peninsula climate variability: Historical and palaeoenvironmental perspectives* (pp. 159–170). Antarctic Research Series (Vol. 79). Washington, D.C.: American Geophysical Union.

Rosswall, T., & Heal, O. W. (Eds.). (1975). *Structure and function of Tundra Ecosystems*. Stockholm: Swedish Natural Science Research Council.

Russian Federation (2010). *Queen Maud Land—a new center of non-governmental activity in the Antarctic*. Working Paper 61 presented at XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay.

Sánchez, R.A., & Njaastad, B. (2013). Future challenges in environmental management of National Antarctic Programs. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht: Springer.

SCAR (2009). *SCAR's environmental code of conduct for terrestrial scientific field research in Antarctica.* Information Paper 4 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA.

Schulte, G. G., Elnitsky, M. A., Benoit, J. B., Denlinger, D. L., & Lee, R. E. J. (2008). Extremely large aggregations of collembolan eggs on Humble Island, Antarctica: A response to early seasonal warming? *Polar Biology, 31*, 889–892.

Smith, R.I.L. (1972). *Vegetation of the South Orkney Islands with particular reference to Signy Island*. BAS Scientific Reports, 68. Cambridge: British Antarctic Survey.

Smith, R. I. L. (1988). Destruction of Antarctic terrestrial ecosystems by a rapidly increasing fur seal population. *Biological Conservation, 45*, 55–72.

Smith, R. I. L., & Richardson, M. (2010). Fuegian plants in Antarctica: natural or anthropogenically assisted immigrants? *Biological Invasions, 13*, 1–5.

Snape, I., Stark, J. S., Cole, C. M., Gore, D. G., Duquesne, S., & Riddle, M. J. (2001). Management and remediation of contaminated sites at Casey Station, Antarctica. *Polar Record, 37*, 199–214.

Sohlenius, B., Boström, S., & Jönsson, I. (2004). Occurrence of nematodes, tardigrades and rotifers on ice-free areas in East Antarctica. *Pedobiologia, 48*, 395–408.

Stammerjohn, S. E., Martinson, D. G., Smith, R. C., Yuan, X., & Rind, D. (2008). Trends in Antarctic annual sea ice retreat and advance and their relation to El Niño-Southern Oscillation and Southern Annular Mode variability. *Journal of Geophysical Research*, *113*, C03S90. doi 10.1029/2007JC004269.

Stewart, E., Draper, D., & Johnston, M. (2005). A review of tourism research in the Polar Regions. *Arctic, 58*, 383–394.

Stonehouse, B. (1993). Shipborne tourism in Antarctica: Project Antarctic Conservation studies 1992/93. *Polar Record, 29*, 330–332.

Tedrow, J. C. F. (1977). *Soils of the Polar Landscapes*. New Brunswick: Rutgers University Press.

Tejedo, P., Justel, A., Rico, E., Benayas, J., & Quesada, A. (2005). Measuring impacts on soils by human activity in an Antarctic special protected area. *Terra Antarctica Reports, 11*, 57–62.

Tejedo, P., Justel, A., Benayas, J., Rico, E., Convey, P., & Quesada, A. (2009). Human impact on soils in an Antarctic specially protected areas: Tools to evaluate SCAR recommendations. *Antarctic Science, 21*, 229–236.

Tejedo, P., Pertierra, L. R., Benayas, J., Convey, P., Justel, A. & Quesada, A. (2012). Trampling on maritime Antarctica: can soil ecosystems be effectively protected through existing codes of conduct? Polar Research, 31, 10888, http://dx.doi.org/10.3402/polar.v31i0.10888.

Thomas, D. N., Fogg, G. E., Convey, P., Fritsen, C. H., Gili, J. M, Gradinger, R., Laybourn-Parry, J., Reid, K., & Walton, D. W. H. (2008). *The Biology of Polar Regions* (2nd ed.). *Biology of Habitats Series*. Oxford: Oxford University Press.

Tilbrook, P. J. (1967). Arthropod ecology in the Maritime Antarctic. In J. L. Gressitt. (Ed.), *Entomology of Antarctica. Antarctic Research Series* (Vol. 10, pp. 331–356). Washington D.C.: National Research Council, U.S.

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., et al. (2009). Impacts of local human activities on the Antarctic environment. *Antarctic Science, 21*, 3–33.

Turner, J., Bindschadler, R. A., Convey, P., Di Prisco, G., Fahrbach, E., Gutt, J., et al. (Eds.). (2009). *Antarctic climate change and the environment*. Cambridge: Scientific Committee on Antarctic Research.

Van der Merwe, M., Chown, S. L., & Smith, V. R. (1997). Thermal tolerance limits in six weevil species (Coleoptera, Curculionidae) from sub-Antarctic Marion Island. *Polar Biology, 18*, 331–336.

Part I
Species and Ecosystems

Summary

Chapters 2–6 examine possible futures of different components of Antarctic marine and terrestrial ecosystems. In Chap. 2, Woehler et al. examine threats to Antarctic wildlife that could lead to significant decrease or loss in the quality and quantity of habitat, disrupt ecosystem services and functions, or result in a significant decrease in population sizes. They speculate that there will be an expansion of virtually all anthropogenic activities in the Antarctic over the next 50 years. Under a Business-As-Usual scenario, in which the current trajectory is extrapolated into the future, human activities (primarily research, fisheries and tourism) are expected to pose increasing threats to Antarctic marine and terrestrial wildlife and ecosystems. Climate change will act synergistically with existing anthropogenic threats. Threats to Antarctic ecosystems will increase in their intensity, frequency and spatial extents into the future. The authors confidently predict that synergistic and cumulative impacts will exacerbate existing threats and reduce the resilience of ecosystems to further anthropogenic threats, placing greater stress on ecosystem functions, tropho-dynamics and ecosystem services than at present. They conclude that management of the Antarctic and its wildlife needs to adopt a holistic and pro-active approach. Failure to address environmental threats now is indefensible and may result in a future Antarctica with degraded environment values and ecosystem functions, more typical of the rest of the planet.

In Chap. 3, Miller examines potential future trends for the exploitation of Antarctic marine living resources in general and the krill fishery in particular. He contends that both the present and the future are very different from the past largely due to the existence of the Convention on the Conservation of Antarctic Marine Living Resources, the impending scope of the krill fishery and the likely domination of physico-biological impacts of climate change in the determination of the ecosystem's future. He acknowledges that harvesting and unsustainable fishing, along with associated cumulative impacts from climate change and pollution, remain the most dominant future threats to the Southern Ocean marine

ecosystem. Effective governance and cost-efficient environmental management are at the center of sustainable management of Antarctic marine living resources, while protecting their associated ecosystems is an equally important consideration. He concludes that increased ecological uncertainty will further complexify the task of ameliorating human impacts. Therefore, the future of sustainable fishing in the Southern Ocean is critically dependent on the effective implementation of, and compliance with, creative governance solutions that are applied with the necessary political will. He proposes a systematic risk-based approach to identify impacts, address performance breakdowns and improve any attached impact mitigation strategies.

In Chap. 4, Leaper and Childerhouse discuss a number of future management scenarios of whale conservation in the Southern Ocean, from the perspective of baleen whales being an important component of the Antarctic marine ecosystem. While the likelihood for the Antarctic to be reopened for large-scale whaling appears to be very low, the authors assert that the best possible future scenario in terms of whale conservation would be one where scientific 'Special Permit' whaling within the Southern Ocean Sanctuary is halted, protective measures to allow for the full recovery of whale populations are supported, alternative and non-lethal uses of whales are developed, while baleen whales quietly get on with their business of recovering. The authors also contend that, in the mean time, the possible consequences of non-whaling threats associated with growing levels of commercial, governmental and private human activity are highly uncertain. Threats such as marine pollution, fisheries and climate change, may not only impact whales but Antarctica as a whole.

In Chap. 5, Hughes et al. explore potential future scenarios for the dispersal and establishment of non-native species in the Antarctic. Non-native species are considered to be threats to Antarctica's existing biodiversity, unique biological assemblages, ecosystem structures and functions and scientific value. The authors argue that a Business-As-Usual future in which climate warming is not adequately addressed globally and in which biosecurity measures are not implemented effectively for Antarctica represents a worst case scenario that results in rapid colonisation of non-native species in Antarctic ecosystems and major habitat alteration. They contend that an effective biosecurity system for the region will become all the more necessary, assuming that human activities in the Antarctic are going to increase, even in order to comply with the existing regulations laid down in the Madrid Protocol. Other methods to ensure adequate protection of at least some of Antarctica's ecosystems may include setting aside unimpacted areas where either humans are not allowed to visit or where visitors numbers are limited and biosecurity standards are exceptionally high. More generally, the area encompassed within Antarctic Specially Managed Areas and Antarctic Specially Protected Areas could be increased in a systematic manner, and their management plans could be strengthened to give effective and enhanced protection.

In Chap. 6, Tejedo et al. propose two possible future scenarios with respect to the management of human traffic on Antarctic soils. Under a Business-As-Usual future, soil impacts will not become widespread but impacts would be concentrated at certain sites with high levels of use. Antarctica is valued as a scientific reference area and pristine wilderness for future generations. Antarctic soils are also important habitats for regionally important as habitats for regionally important and highly endemic edaphic fauna and flora. Therefore, they also depict a conservation-focused scenario which reflects a clear commitment of Antarctic Treaty parties to prioritise the conservation of all natural resources in Antarctica, including soils. Under this scenario, knowledge of Antarctic soils will be improved, through targeted research and the establishment of systematic monitoring networks. This information would be used for assessing the effectiveness of codes of conduct, mitigation measures and restoration activities and would help to create a catalogue of best practices regarding soil conservation. Remediation and restoration of abandoned sites will also be prioritised, helping to preserve the intrinsic physical attributes of Antarctic soils.

For many of the human activities discussed in Part I, regulations were introduced after significant impacts on species and ecosystems were reported. At one end of the spectrum, nearly all present and future activities related to commercial whaling were banned after a near annihilation of most whale populations (Chap. 4). Less drastic is the case of scientific research and associated logistics, which have resulted in significant impacts on Antarctic wildlife in the past. These activities are now regulated through the Madrid Protocol, and environmental impacts reported in conjunction with these activities are not considered to be extreme (Chap. 2). In the case of krill harvesting, human activities have not yet led to proven significant impacts (Chap. 3). The same can be said for the introduction of non-native species (Chap. 5). However, it is acknowledged that in both cases future impacts can have far-reaching consequences. Therefore, authors of both Chaps. 3 and 5 maintain that activities should only be allowed, and be regulated, with the intention of maintaining ecological sustainability and avoiding significant impacts. As such, regulation of these activities and impacts should be proactive, precautionary and strategic. By comparison, the regulation of certain aspects of shipping, tourism and human traffic on soils is seen as weak and not regarded as long-term, precautionary or strategic (Chaps. 2 and 6).

Since commercial whaling is a human activity that is currently subject to strongest regulation (i.e. no activity is allowed with exception being whaling for scientific purposes), it is the only case where a Business-As-Usual scenario would allow species to recover or ecosystem health to improve (Chap. 4). In the consideration of Antarctic wildlife, krill, non-native species and soil ecosystems (Chaps. 2, 3, 5 and 6), authors postulate that a Business-As-Usual scenario would entail increased human activity and, taking into consideration the effects of climate change, current regulations would not be able to ensure ecological sustainability.

Part II
Regional Case Studies

Chapter 7
Environmental Assessment and Management Challenges of the Fildes Peninsula Region

Christina Braun, Fritz Hertel, Osama Mustafa, Anja Nordt, Simone Pfeiffer and Hans-Ulrich Peter

Abstract Since the inception of the Antarctic Treaty, numerous regulations for environmental protection were adopted by the Treaty parties to minimise negative environmental impacts of human activity. Nevertheless, the concentration of a variety of human activities in some Antarctic regions leads to a conflict of interest. The Fildes Peninsula on King George Island, in the Antarctic Peninsula, represents a unique example of increasing human pressure due to multiple human uses. Scientific research, station operations, transport logistics, tourism, nature conservation and protection of geological and historical values regularly overlap in space and time. A standardised assessment of fauna, flora and impact of human activities on the terrestrial ecosystem was conducted between 2003–2006 and 2008–2011 to provide a comprehensive dataset that documents the environmental state of the

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Fildes Peninsula. Management measures are suggested to mitigate these impacts, such as the designation of an Antarctic Specially Managed Area. The political debate amongst the Treaty parties about regulatory measures is on-going, but we strongly recommend immediate action.

Keywords Antarctica • Antarctic Specially Protected Area • Environmental management • Fildes Peninsula Region • Human impact

7.1 Introduction

Fildes Peninsula, Ardley Island and adjacent small islands within half a kilometre off the coast (hereafter 'Fildes Peninsula Region', 62°08′–62°14′S, 59°02′–58°51′W) are located in the south-western part of King George Island, South Shetland Islands, Antarctic Peninsula. This region represents one of the largest ice-free areas in the maritime Antarctic. As a consequence of its high biodiversity and rich fossil deposits two Antarctic Specially Protected Areas (ASPAs) have been designated: ASPA No. 125 Fildes Peninsula and No. 150 Ardley Island, Maxwell Bay, King George Island (ATS 2010). At present Fildes Peninsula hosts six permanent Antarctic stations, built between 1968 and 1994 (COMNAP 2010; Fig. 7.1). Due to the proximity to South America and the construction of the Chilean airport in 1980, the area represents a major logistical hub for the South Shetland Islands and the Antarctic Peninsula. Consequently, the area is intensively used for scientific, logistic and tourism-related activities which frequently overlap in space and time. This often leads to conflicts of interests between the different human activities and the legally agreed standards of environmental protection provided by the Protocol on Environmental Protection to the Antarctic Treaty (hereafter 'Protocol'; ATS 1991).

In various reports of inspections carried out under Article 7 of the Antarctic Treaty and Article 14 of the Protocol, together with non-governmental reports, a variety of shortcomings were stated (Australia et al. 2005; United Kingdom and Germany 1999; United States 2001, 2007; Tin and Roura 2004). This included regular duplication of scientific projects and station operations. Recommendations were made by the inspection teams, amongst other things, regarding fuel handling and storage, waste management and sewage treatment, but have been implemented only partially by the National Antarctic Programs (NAPs).

As a result of the persistent concern about the environmental situation, there has been an ongoing discussion over the last decades about how to reduce negative impacts by supplementing the existing ASPAs with additional management measures. In this context, the German Federal Environment Agency (Umweltbundesamt) commissioned a research project (2003–2006) to provide a substantial data set that enables a full evaluation of the environmental risks in this area (Germany 2004). To this end, a multitude of relevant biotic and abiotic parameters were assessed during the summer seasons (December–March). This included

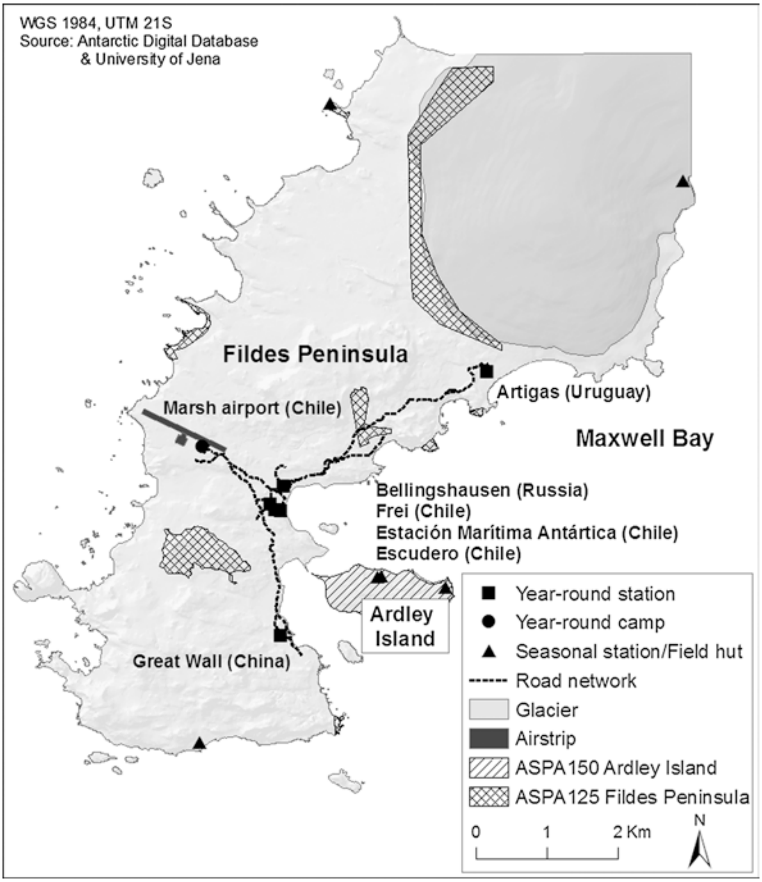

Fig. 7.1 Overview of the Fildes region (modified after Braun et al. 2012)

standardised monitoring of the distribution of bird and seal breeding sites, the occurrence of non-native species and the recording of human activities, with special attention to their associated environmental impacts and obvious infringements of ASPA management plan regulations. The methods applied are described in detail in Peter et al. (2008). Data has been collected within station boundaries of several countries, with the permission of those responsible for the station concerned. Our data was supplemented by information provided by personnel from stations in the Fildes Peninsula Region. For the sake of confidentiality no names of informants will be given. Based on the findings, the implementation of an Antarctic Specially Managed Area (ASMA) was proposed and a management plan was drafted for this purpose (Germany 2004; Peter et al. 2008). A second monitoring period was initiated between 2008 and 2011 to provide an updated database for the international debate within the Antarctic Treaty Consultative Meeting's (ATCM) Committee for Environmental Protection (CEP) (Germany 2009).

Here, the main results of the standardised assessment of fauna and flora related to changes in human activities are presented. Predictions for future developments in the Fildes Peninsula Region are made, which strongly support the need for effective management measures to reduce negative impacts of human activities on the ecosystem. It is argued that the implementation of a legally binding ASMA is the only option that will effectively control future impacts. So far, there is no consensus between the stakeholders about the appropriate management measures.

7.2 Current Environmental Situation

7.2.1 Avifauna

The Fildes Peninsula is an important breeding ground for four seal species and thirteen seabird species (Table 7.1). In addition, a new breeding colony of the light-mantled sooty albatross was detected recently (Lisovski et al. 2009). The highest breeding pair density of seabirds was found on Ardley Island, one of the main reasons for its designation as ASPA No. 150. Skuas (*Catharacta antarctica lonnbergi*, *C. maccormicki*), Antarctic terns (*Sterna vittata*) and storm petrels (*Oceanites oceanicus*, *Fregetta tropica*) also breed in areas of high human activity like the immediate vicinity of the stations, roads and the airstrip. This indicates a habituation behaviour leading

Table 7.1 Observed range of breeding pair numbers in the Fildes Region in seasons 2003/2004–2005/2006 and 2008/2009–2010/2011

Species	Breeding pair numbers
Chinstrap penguin (*Pygoscelis antarctica*)	8–29 (Ardley island)
Gentoo penguin (*Pygoscelis papua*)	4,957–5,665
Adélie penguin (*Pygoscelis adeliae*)	307–559
Southern giant petrel (*Macronectes giganteus*)	225–407
Light-mantled sooty albatross (*Phoebetria palpebrata*)	0–5
Cape petrel (*Daption capense*)	>300
Wilson's storm petrel (*Oceanites oceanicus*)	~3,500–5,000
Black-bellied storm petrel (*Fregetta tropica*)	~500–1,000
Brown skua (*Catharacta antarctica lonnbergi*)	27–85
South polar skua (*Catharacta maccormicki*)	132–254
Mixed skua pairs (*C. a. lonnbergi x C. maccormicki*)	9–32
Kelp gull (*Larus dominicanus*)	50–142
Antarctic tern (*Sterna vittata*)	<100–900[a]
Snowy sheathbill (*Chionis alba*)	0–2

[a]total number during the whole season

to a lower sensitivity to permanent or frequent stressors like visitors and noise (e.g. Cobley and Shears 1999; Fraser and Patterson 1997; Nimon et al. 1995; Young 1990).

Results of more than 30 years of continuous monitoring of penguin breeding pair numbers on Ardley Island show significantly diverging trends for the three

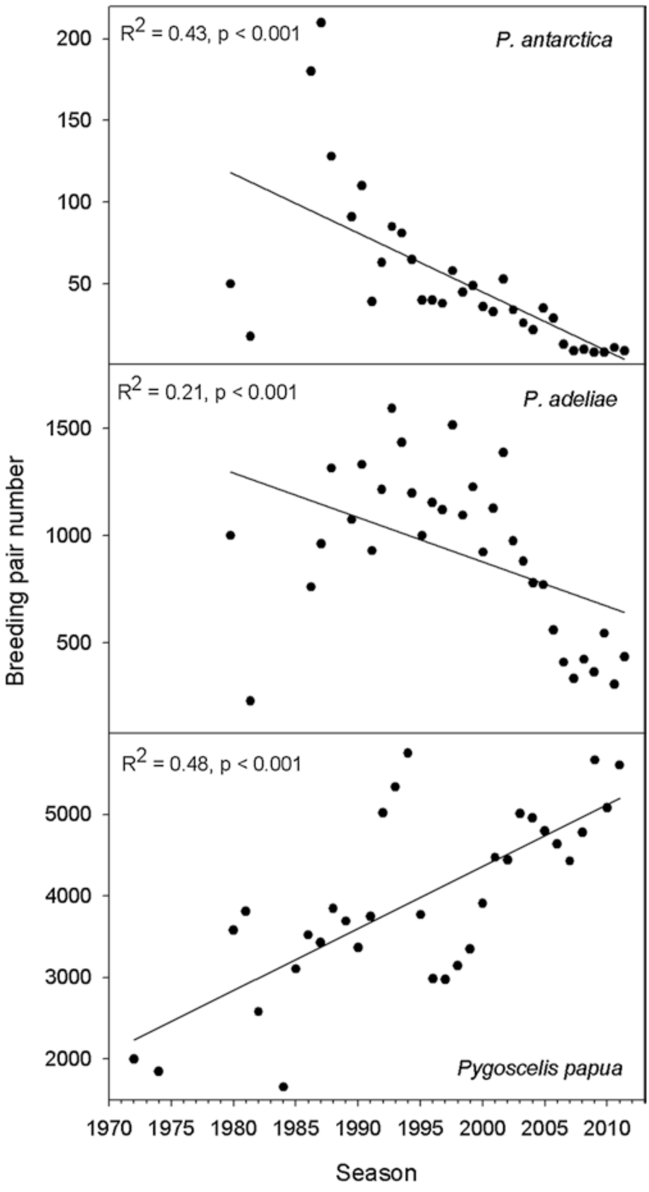

Fig. 7.2 Numbers of breeding pairs of gentoo, chinstrap and Adélie penguins on Ardley Island over the last 40 years

penguin species (Fig. 7.2). The total number of breeding pairs (BP) of gentoo penguins (*Pygoscelis papua*) increased from 1,656 in 1983/1984–5,603 in 2010/2011 with a maximum of 5,746 in 1993/1994. The numbers of Adélie penguins (*P. adeliae*) breeding on Ardley Island have shown a strong decline from 1,516 BP in 1993/1994 to a minimum of 307 BP in 2009/2010. The chinstrap penguin (*P. antarctica*) population decreased from over 200 BP in the 1970s to only 9 BP in 2010/2011. This decline is amplified by climate change effects (Peter et al. 2008).

The most plausible explanation for the diverging population trends of Adélie, chinstrap and gentoo penguins on Ardley Island could be related to different survival rates during winter, as the breeding success did not differ between the species (unpublished data). Results obtained in several studies support this (Carlini et al. 2009; Hinke et al. 2007; Lynch et al. 2010). Thus, the observations on Ardley Island coincide with the general trend in the Antarctic Peninsula of penguin populations responding to increasing average winter temperatures (e.g. Carlini et al. 2009; Chwedorzewska and Korczak 2010; Forcada et al. 2006; Hinke et al. 2007; Lynch et al. 2008; Trivelpiece and Fraser 1996; Woehler et al. 2001).

Southern giant petrels (*Macronectes giganteus*) are considered to be highly sensitive to human disturbance (e.g. Gonzalez-Solis et al. 2000; Micol and Jouventin 2001; Pfeiffer and Peter 2004) and show a global decreasing population trend

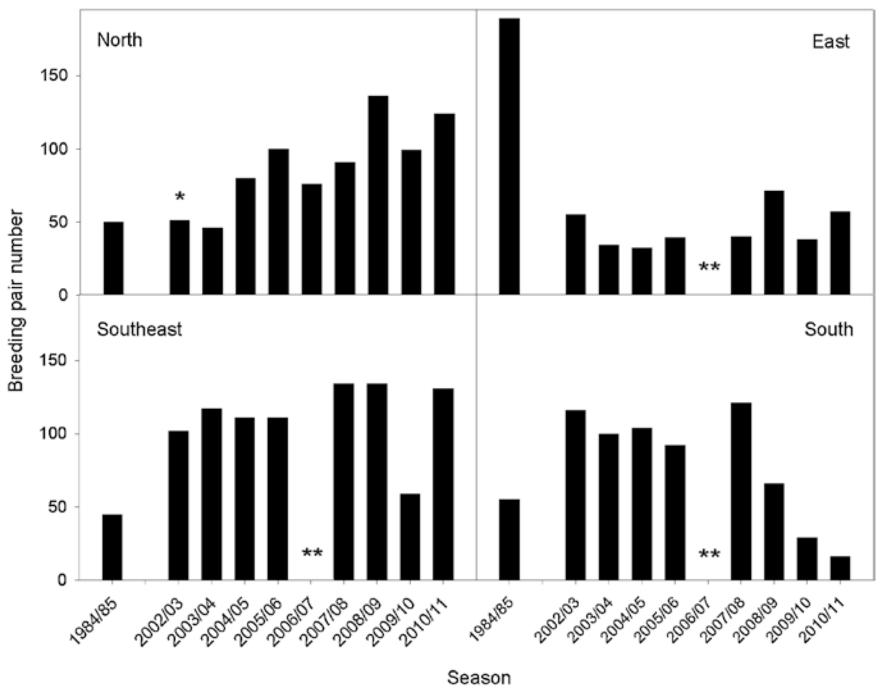

Fig. 7.3 Number of breeding pairs of southern giant petrels in different zones of the Fildes Region, (* data incomplete, ** no data)

(IUCN 2010). Pfeiffer (2005) has demonstrated that southern giant petrels in the Fildes Peninsula Region may habituate to human impact if the disturbance is regular and predictable. Since 1984/1985, the total number of breeding pairs of southern giant petrels in the Fildes Peninsula Region did not show significant changes ($R^2 = 0.00$, $p \leq 0.001$, Fig. 7.2). This is consistent with other studies reporting stable or increasing populations (Lynch et al. 2008; Woehler 1997). However, BP numbers and breeding success (raised chicks per BP) decreased rapidly in some colonies, whereas nearby colonies either showed a slight increase or no change (Fig. 7.3). Natural factors (e.g. food availability, predation, climatic conditions) are unlikely to explain these findings, as they should have the same influence on adjacent colonies. The observed different level of human activity is considered to have a strong impact on the number of BP and the breeding success (Braun et al. 2012; Peter et al. 2008), as only colonies that are frequently visited during summer by station personnel in their leisure time (see also Sect. 7.2.9) showed a population decline. The slight increases in other colonies indicate nest site shifts, which have been shown earlier for the Fildes Peninsula Region (Chupin 1997; Peter et al. 1991, 2008; Pfeiffer 2005). Our results suggest that leisure visits are a major threat to southern giant petrels.

7.2.2 Non-indigenous Species

Antarctic ecosystems are highly vulnerable to the introduction of non-indigenous species, as favourable environmental conditions can lead to distribution of these species and even suppression of endemic species (Frenot et al. 2005; Hughes and Convey 2010; Hughes et al. 2013). Results from recent studies suggest that personnel of NAPs throughout Antarctica carry a higher propagule load than tourists (SCAR 2010). Hence, there is a major threat of the introduction of non-indigenous species by transporting people, cargo, food and construction material to the stations (Barnes and Convey 2005; Osyczka 2010), especially in areas with intensive station and visitor activity like the Fildes Peninsula Region. While crews and tourists of vessels operating within the guidelines of the International Association of Antarctica Tour Operators (IAATO) apply some measures to minimise the risk of introduction of seeds and other propagules, no systematic efforts are known from the NAPs present in the Fildes Peninsula. In contrast, the use of untreated Siberian moss as sealing material has been documented and houseplants are still present in some of the stations (Peter et al. 2008). In the 2003/2004 season at least one rat was transferred to Fildes Peninsula during unloading of a ship, but was found dead after a few weeks (Peter et al. 2008). The repeated occurrence of moths and fruit flies in storage buildings was reported (pers. comm. station personnel). Individual specimens of several introduced grass species were detected in two station areas and subsequently removed by the authors as recommended in Article 4, Annex II of the Protocol (Peter et al. 2008; New Zealand 2006). However, due to the size of the plants and the existence of flowers further colonisation cannot be excluded.

7.2.3 Air Traffic

The construction of the Chilean airport turned the area into a logistic center resulting in extensive air traffic. The survey of local flight activity during the summer months revealed a constant and high proportion of days with aircraft operations throughout the summer. Flight activity was observed on average on ~70 % of days of the study period (10 December–26 February 2003/2004–2005/2006 and 2008/2009–2010/2011). The use of smaller aircraft (e.g. King Air, BAE-146, Twin Otter), mainly used for tourism purposes, exceeded logistic flights of Hercules C-130 by far (Braun et al. 2012). The slight decrease of helicopter flight days does not indicate reduced helicopter use but a general higher concentration on certain days during logistic operations. Concerning the overflight exclusion zone for Ardley Island [below the vertical distance of 610 m and the horizontal distance of 460 m; ATCM recommendations (ATS 2004, 2009b), the number of observed flights into the zone decreased considerably over time. This could be attributed to the increasing acceptance and implementation of the above-mentioned guidelines.

7.2.4 Ship Traffic

Ship traffic in the Maxwell Bay increased significantly, for example in terms of the number of ship arrivals over the six studied seasons ($R^2 = 0.71$, $p < 0.05$). This was mainly caused by supply (40 % of all observed ship arrivals), patrol (18 %) and research vessels (9 %). Despite regular tourist activity and growing levels of passenger exchange via air-cruise programmes (IAATO 2010a) in the Fildes Peninsula, cruise ship accounted for only 25 % of all observed ship arrivals. This underlines the low attractiveness of the Fildes Peninsula for cruise tourism (Lynch et al. 2010). A number of cruise vessel approaches were due to other purposes, e.g. medical evacuation of passengers or transport of scientists (Braun et al. 2012).

After a strong increase between 2003 and 2006 (Peter et al. 2008), the number of days with at least one ship present in Maxwell Bay (ship days) remained on a high level. On average, ships were observed at 73 % of days during the study period. The findings indicate a growing accumulation of ships with an observed peak of seven ships simultaneously present in Maxwell Bay (Peter et al. 2008). Most accumulations took place during logistical operations and often entailed extensive air traffic (primarily helicopter), cargo transport with inflatable boats and heavy vehicles, as well as station visits of ship crews or tourists. Cumulative environmental impacts, caused by these peaks in human activity, can affect the station areas and their vicinity, for example by increased noise and disturbance of breeding or resting seabirds and seals.

7.2.5 Land Traffic

Land traffic occurs mainly along the existing network of gravel roads connecting all stations in the Fildes Peninsula Region. Each NAP holds a vehicle fleet to transport people and cargo. The assessment of vehicle tracks beyond the road network revealed an increasing number of off-road tracks compared to data from 2003–2006 (Braun et al. 2012; Peter et al. 2008; unpubl. data). Many of these tracks deeply carved into the soil, which often resulted in physical destruction of vegetation. Moreover, we have documented vehicle use within the two ASPAs No. 125 and 150 (Fig. 7.4a), which represents a clear infringement of the regulations set out in the ASPA's management plans (ATS 2009b, c).

A high proportion of off-road vehicle tracks were caused by four-wheel motorbikes. This vehicle type has been introduced recently in several stations, allowing access to regions which have never been visited with vehicles before. Apparently vehicle use beyond the road network was in a few cases related to scientific activities, but mostly for leisure purposes (pers. obs., see below; Braun et al. 2012).

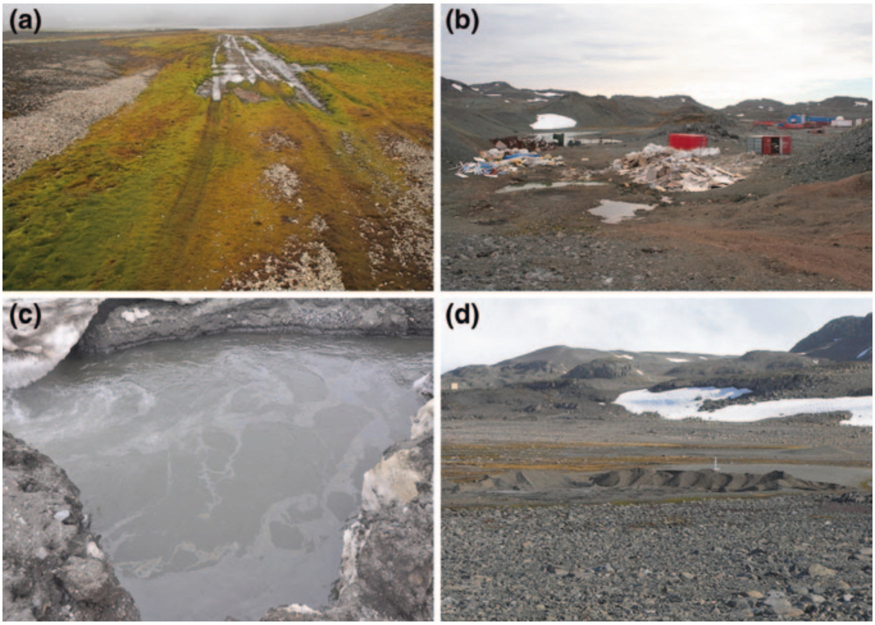

Fig. 7.4 Examples of environmental impacts in the Fildes region: **a** vegetation damage in ASPA No. 150 caused by land traffic, **b** open waste deposit, **c** diesel plume on the stream discharging into the Maxwell Bay, **d** beach ridge, damaged by quarrying

7.2.6 Waste and Sewage Management

As a consequence of the relatively long human presence in the Fildes Peninsula Region, waste in many different forms is present across the entire region. By means of waste mapping we showed the broad distribution of waste objects (Peter et al. 2008). Besides large amounts of marine debris washed ashore, a large variety of objects originated from the local stations. Waste that was buried in the past near the station becomes visible as a consequence of solifluction processes. In some cases, remains of installations of scientific experiments still contribute to the ongoing waste entry into the region.

Various efforts to improve waste management in the stations were made, for example the dismantling of unused and demolished buildings or the removal of large amounts of historical waste from the Antarctic Treaty area. Nevertheless, several decayed field huts and installations still remain, and certain banned practices for dealing with waste (see Annex II and III of the Protocol) do still occur (Braun et al. 2012; Peter et al. 2008). These include the open burning of waste, the active feeding of birds and the existence of open waste dumps containing hazardous items (Peter et al. 2008).

In the 2008/2009 season, waste was openly stored in one of the stations for at least 4 months. A wide variety of unsorted materials like insulation material, cardboard, construction waste, paint buckets, batteries and fire extinguishers were continuously deposited (Fig. 7.4b; Braun et al. 2012). As no measures were applied to prevent distribution by wind drift, a large amount of lighter weight waste materials were spread throughout the southern part of the Fildes Peninsula Region and into the Maxwell Bay, also affecting the ASPA No. 150 Ardley Island (Braun et al. 2012).

Despite the elimination of access for skuas and gulls to anthropogenic organic material, the banned practice of active feeding, including with poultry products, has been reported at all stations in the Fildes Peninsula Region (Peter et al. 2008). This represents a high risk of introduction and spread of diseases in Antarctica (Australia 2001; Bonnedahl et al. 2005; Gardner et al. 1997; Hemmings 1990; Parmelee et al. 1979; Woehler et al. 2013).

Regarding sewage treatment, growing efforts have been made in the Fildes Peninsula to fulfil the guidelines of the Protocol. Since the 2008/2009 season, all stations run sewage treatment plants of different levels of sophistication (Braun et al. 2012). Until then, the waste water of one of the stations was discharged untreated when the number of resident summer station personnel exceeded the recommended maximum of 30 persons. This practice was in conflict with the requirements of the Protocol (see Annex II). After treatment, the water is typically discharged into the sea, except in one case where the effluent is drained into a stream approximately 1 km from the coast (Braun et al. 2012). The effectiveness of the applied sewage treatment could not be monitored by the authors, but pungent smells and high turbidity at some sewage outfalls indicate a poor quality of sewage treatment. This was underlined by reports of marine biologists about the condition of the sea floor off the coast of the central Fildes Peninsula, which is covered with a remarkable layer of organic material of anthropogenic origin and shows a very low biodiversity of marine organisms (ASOC 2007; Braun et al. 2012; pers. comm.).

7.2.7 Oil Contamination

Hydrocarbon contamination is a widespread environmental threat resulting from human activity in Antarctica, in particular because of the low degradation rate due to the generally cold climate conditions (Filler et al. 2008; Tin et al. 2009). For the Fildes Peninsula, chronic oil contamination and the urgent need of upgrading and improving the infrastructure have been repeatedly reported (Australia et al. 2005; United States 2007; Tin and Roura 2004). Leaking station tanks and pipelines, spillages during fuel transfer and from poorly maintained vehicles, and the remobilisation of formerly contaminated soil were identified as the main contamination sources (Braun et al. 2012; Peter et al. 2008). Some efforts are being made to replace old single-walled fuel tanks and improve fuel handling and transfer following the recommendations of the Council of Managers of National Antarctic Programs (COMNAP 2008). In contrast, contingency plans and resources required to contain an oil spill are not available at all stations (pers. comm. station personnel), which became evident during a recent oil spill. Major oil spills of several thousand litres of fuel are known to occur in the Fildes Peninsula every few years.

The most recent incident was an oil spill at a fuel tank, which started leaking during winter 2009 and caused a major oil spill of diesel fuel in the following summer (Braun et al. 2012). An unknown amount of diesel fuel was released into the snow and with onset of snowmelt discharged via an adjacent stream into the Maxwell Bay (Fig. 7.4c). The pollution continued throughout the summer, visible by the broad oily sheen covering the western part of the Maxwell Bay. In cooperation with neighbouring stations some mitigation measures were taken, in particular the removal and burning of contaminated snow, the application of absorbent oil booms in the stream, as well as the use of inflatable boats in Maxwell Bay in order to increase fuel evaporation. However, the applied containment and remediation measures were very limited in their extent and effectiveness. They failed to prevent widespread pollution of the marine environment. Penguins were observed regularly diving through the dense diesel plume, as the oil spill occurred in close proximity to the penguin colony on Ardley Island (ASPA No. 150). Thus, negative impacts on penguins, for example in terms of the effects on energy metabolism, physiology or immunosuppressive mechanisms, are very likely (e.g. Briggs et al. 1996, 1997; Culik et al. 1991; Eppley and Rubega 1990).

7.2.8 Construction Activities

In recent years, a clear trend in extending station facilities on the Fildes Peninsula has become evident, as five out of six stations have been extended since 2006.

The achieved improvements refer to scientific facilities as well as to operational constructions, for example the replacement of corroded single-walled fuel tanks.

Construction activities in and around stations are considered to be the main potential threat to the environment in the Fildes Peninsula. A variety of environmental impacts of construction activities in and around the stations have been reported, including the extraction of material and quarrying for building material (Braun et al. 2012; Peter et al. 2008). The observed impacts ranged from an increased level of oil pollution by leaking vehicles and major waste entry into the environment. Quarrying sand and gravel for building purposes has not only resulted in change of the landscape structure but also in heavy disturbance or even destruction of vegetation and breeding sites of skuas, gulls, terns and storm petrels. Several fossil beach ridges were quarried (Fig. 7.4d) regardless of their high scientific value for regional and global palaeoclimate research (Berkman et al. 1998; Mäusbacher 1991). Between 2008 and 2011, the total area affected by the extraction of material covered more than 60,000 m^2.

Despite these impacts, the commensurate level of Environmental Impact Assessment (EIA) has obviously not always been applied. The Protocol requires that projects with an impact considered greater than ‘minor or transitory’ be subject to the highest level of EIA, known as a Comprehensive Environmental Evaluation (CEE), which subjects the project to international scrutiny. For example, the destruction of beach ridges represents a case of long-lasting environmental damage, and should have merited a CEE. Similar conclusions were made by the Antarctic and Southern Ocean Coalition (ASOC 2007) and Bastmeijer and Roura (2008). As a consequence of the station extensions between 2006 and 2011, the area consumption by station buildings increased by 24 %, and the number of station personnel by 23 and 34 % during summer and winter, respectively.

According to the Protocol, station extension processes should be accompanied by monitoring procedures to assess and verify the impact of the associated environmental impacts (Hughes 2010; Klein et al. 2013). It is not known if and to what extent such monitoring efforts have been put in place in the Fildes Peninsula.

7.2.9 Scientific, Leisure and Tourism Activities

7.2.9.1 Scientific Research

The potential environmental impact of scientific activities is widely recognised. The demand for co-ordination of, and cooperation between, station personnel and scientists on King George Island has been repeatedly stressed (ASOC 2007; SCAR 2001, 2009a). In particular, the high concentration of stations in the Fildes Peninsula enlarges the chance of duplication of research projects. This may cause unnecessary negative environmental impacts as well as detrimental effects on the quality of the obtained data (Peter et al. 2008). Nevertheless, all NAPs have recently increased their scientific activities in the Fildes Peninsula Region without any appropriate co-ordination. Due to the often limited access to information about ongoing projects, the environmental impact of scientific field work is hard to verify. However, it is expected that the associated impacts will increase further if no effective measures to reduce research duplication are duly applied (Braun et al. 2012).

Attention should also be paid to the methods applied in the execution of field work, as a variety of broken installations and remains of field experiments can be found in the Fildes Peninsula (Braun et al. 2012). Unnecessary vehicle use, also by scientists, beyond the road network has led to extensive damage of vegetation and disturbance of birds and seals. The application of the recently published environmental code of conduct for terrestrial scientific field research in Antarctica could contribute to the avoidance of these impacts (SCAR 2009b).

7.2.9.2 Station Personnel Recreational Activities

Due to high numbers of station personnel and the length of their stay in the region, their leisure activities play a significant role with regard to disturbance of fauna and flora (Haase 2005; Headland 1994; Riddle 2010). Proven damage on the environment includes population declines and shifts in breeding areas of birds and seals (Chwedorzewska and Korczak 2010; Peter et al. 2008; Pfeiffer 2005).

Station personnel in the Fildes Peninsula are known to spend a considerable part of their leisure time outside the stations, roaming almost freely over the whole area (Peter et al. 2008). Of particular interest in this context are sensitive and/or protected areas. These areas are mainly accessed by vehicles or boat, for example for taking pictures or fishing. We personally observed that local station personnel occasionally collected fossils and minerals or approached, touched or caught animals in order to take pictures. Such leisure activities are conflicting with the regulations of the Protocol (Annex II, Article 3), as well as the management plans of the affected ASPA No. 125 and ASPA No. 150 (ATS 2009b, c). The lack of an appropriate environmental briefing in some of the stations (pers. obs.) contributes to a disregardful attitude of some of the station personnel (Braun et al. 2012). In addition, neither of the management plans for both ASPAs in the region, nor information about existing guidelines (e.g. those recommended by IAATO and the Antarctic Treaty Consultative Meetings) were available to all station members.

7.2.9.3 Tourism Industry

Tourism activities in the Fildes Peninsula take place on a regular basis, such as sea-borne, air-borne and combined air-cruise tourism. While the sea-borne tourism (landings of passengers of cruise vessels) did not increase (IAATO 2010a), the number of tourist flights, related to one- or two-day programmes involving guided walks (air-borne tourism), have increased (Braun et al. 2012). The transfer of passengers between cruise vessels and the Chilean airport on Fildes Peninsula represents the relatively new practice of air-cruise tourism, which allows tourists to avoid the potentially rough crossing of the Drake Passage by ship. Although the numbers of transported passengers between 2003 and 2010 increased almost tenfold (IAATO 2004, 2010b), no direct negative impacts have been associated with these various types of tourism.

A marathon is organised almost yearly on Fildes Peninsula, with participants arriving by ship. The event was observed by the authors in 2005, 2009 and 2011, and the landings of passengers were considered in line with the accepted IAATO guidelines (ATS 2009a). The environmental impact was considered to be low, as the track almost exclusively followed the existing road network and took place at the very end or after the bird breeding season (Braun et al. 2012; Peter et al. 2008).

In contrast to the station personnel, most tourists are strictly guided, limited to certain routes and briefed about existing regulations and guidelines.

7.2.9.4 Government-Supported Tourism

A small number of tourists travel with ships of NAPs to the Antarctic (Hall 1992; Riffenburgh 1998). During landings on Fildes Peninsula we observed several instances of passengers without guides closely approaching penguins and seals (Braun et al. 2012). Some of these passengers stated that they had no knowledge of the existing visitor guidelines of IAATO and the Antarctic Treaty System (ATS 1994). In order to avoid negative impacts on fauna and flora by these visitors, an appropriate environmental briefing and guidance during landings should be obligatory.

7.2.9.5 Official Delegations, Media and Educational Visits

Due to the relatively easy access, the Fildes Peninsula is often visited by a variety of other people, for example official delegations and media teams. There is an increasing trend in educational programmes conducted by all NAPs present in the area. The execution of some of these programmes revealed scarce preparation, for instance, an ASPA was entered for scientific sampling without an appropriate permit.

In summary, despite the fact that the number of tourists arriving in the Fildes Peninsula far exceeds the number of station personnel, tourism is considered to have a comparatively low environmental impact. Due to the much longer presence of station personnel within the area, expressed in person-days ashore (Riddle 2010), station personnel is likely to have a much higher local environmental impact than tourists (Braun et al. 2012; Haase 2005; Headland 1994).

7.3 Political Debate

Parallel to the German research activities, Treaty parties have been involved in a discussion process on environmental management at an early stage, especially those which run stations or huts in the Fildes Peninsula Region (Germany 2004, 2005).

The results of a workshop on King George Island organised by Germany were presented at the 29th ATCM in 2006 and led to the establishment of the International Working Group on Fildes Peninsula (IWG Fildes) convened by Chile and Germany (Brazil et al. 2006). This IWG aims to develop a management plan for the Fildes Peninsula. Another 13 Antarctic Treaty parties joined the IWG: i.e. Argentina, Australia, Brazil, China, France, Japan, Korea (ROK), Peru, Poland, Russia, Spain, United Kingdom and Uruguay. IAATO and ASOC joined as advisory members. Since 2006, different management proposals and their necessity have been discussed mainly on the basis of the research results achieved by the German research project (Peter et al. 2008). The aim of the IWG is to improve the co-ordination of all human activities in the Fildes Peninsula to minimise the environmental impacts. To achieve this aim, the majority of the involved IWG members favoured the designation of the region as an ASMA (Brazil et al. 2006). However, Chile and Uruguay did not approve this proposal.

Chile initially took an active part in the discussion on possible management proposals for the Fildes Peninsula Region and organised a workshop in Punta Arenas in 2007 to discuss feasible alternatives to an ASMA designation (Germany 2007; Germany and Chile 2007). They proposed a legally non-binding approach with codes of conduct for different kinds of activities (like tourism, scientific research, etc.).

During the 30th ATCM, the conveners of the IWG reported on the results achieved so far, in particular results of the German research project (Peter et al. 2008; Germany and Chile 2007). Additionally, Germany introduced the paper 'Possible Modules of a 'Fildes Peninsula Region' ASMA Management Plan', which included a spatial zoning system for different kinds of activities, as well as different codes of conduct (Germany 2007). These proposals were approved by the IWG Fildes as a basis for further work and discussion. During the IWG meeting in New Delhi in 2007, the members agreed on a working plan and a respective timetable. Accordingly, it was agreed that the Draft Management Plan, developed by Germany, should be revised to include all available information provided by the other IWG members, such as codes of conduct for facility zones, scientific research and visitors. Due to little participation of IWG members within the web-based discussion forum set up by the CEP, the work has stagnated and a working plan could not be finalised. At the 31st ATCM, Germany presented and distributed the final report of the first research project on environmental management (Germany 2008).

At the IWG Fildes meeting in August 2009 in Punta Arenas, Chile pointed out that it would no longer aspire to the proposed long-term objective of designating a 'Maxwell Bay ASMA', expressed earlier that year at the 32nd ATCM (Chile 2009). Instead, Chile would rather concentrate on a smaller area comprising the Fildes Peninsula and Ardley Island territories. Further, Chile preferred the establishment of a zoning system. Stepping stones for the set-up of a facility zone and the visitor zone were agreed upon (Germany and Chile 2010). Chile, Argentina and Uruguay disapproved the proposal to designate Fildes Peninsula as an ASMA. However, Germany still holds the view that the designation of an ASMA, either in a small scale (Fildes Peninsula Region) or in a wider scale version (Maxwell Bay), is the only effective option to get the environmental challenges under control in a sustainable manner (e.g. Peter et al. 2008).

Since 2009, discussions within the IWG have moved forward in small steps, without considering the ASMA option. The Draft Management Plan elaborated by Germany has been revised several times. Recently, all parties running stations in the area agreed on the spatial extension of a potential facility zone (Germany and Chile 2010). Currently, the proposed code of conduct for the facility zone is under further discussion.

7.4 Future Challenges for the Fildes Peninsula Region

The Antarctic is an important part of the Earth's ecosystem. The climatic, physical and biological properties of the continent and the surrounding ocean are closely connected to other parts of the global environment through both oceanic and atmospheric circulation (SCAR 2009c). Over the next 50 years, based on our area of expertise, we are expecting a continuation of the current trends of increasing human activities and further anthropogenic influences affecting Fildes Peninsula on different scales. The most important external factor is climate change. Strong increases of air and water temperatures have already resulted in a large regional decrease of sea ice, as well as of ice shelves, at the Antarctic Peninsula, but not in East Antarctica (SCAR 2009c). This development will presumably continue in the future.

Components of the marine ecosystem linked to sea ice, such as krill and penguin abundances, show a clear response to climate change (e.g. Smith et al. 2003; Atkinson et al. 2004; Forcada et al. 2006). Due to the loss of sea ice, significant changes in algal growth and krill densities are observed (e.g. Atkinson et al. 2004; Ducklow et al. 2007). Many populations of Adélie penguins at the northern Antarctic Peninsula currently decline due to a loss of sea-ice and food availability (Ducklow et al. 2007). In contrast, populations of Adélie penguins in the southern part of the Antarctic Peninsula are generally stable or increasing as a result of more moderate ice conditions (Carlini et al. 2009; Chwedorzewska and Korczak 2010; Forcada et al. 2006; Hinke et al. 2007; Lynch et al. 2008; Smith et al. 2003; Trivelpiece and Fraser 1996; Woehler et al. 2001). Thus, the observed development of the penguin population on Ardley Island coincides with the general trend in the Antarctic Peninsula. Assuming the continuation of the present trend, the extinction of the Adélie penguin population in the Fildes Peninsula is a possible scenario. In contrast, the more sub-Antarctic gentoo penguins seem to benefit from persistent sea ice reductions by an increase of their available niche (Forcada et al. 2006; Ducklow et al. 2007; Lynch et al. 2008).

A second important feature in this area is the rapid expansion of plant communities and the colonisation of newly available land by both plants and animals (Hughes and Convey 2010). The inadvertent introduction of non-indigenous or alien organisms (plants, animals, microorganisms) represents a major, large-scale threat to Antarctic ecosystems. In addition, alien species may benefit from more hospitable habitats caused by global warming, especially in the western Antarctic Peninsula Region. A warmer climate will probably result in an increasing introduction of alien species (Australia 2005), mainly caused by national programme personnel travelling and working throughout Antarctica (SCAR 2010). Thus, due to the high number of both station personnel and tourists, the Fildes Peninsula particularly is subject to a high risk of introduction of non-indigenous organisms.

In the future, the Fildes Peninsula will face further challenges from internal pressures. On King George Island, in the presence of ten permanent and one seasonal station and various field huts (COMNAP 2010), the ongoing logistical and scientific cooperation and co-ordination has to be considerably improved to further minimise environmental damage and to safeguard the scientific value of the area. International panels like the Cross-Standing Scientific Group (SSG) King George Island Science co-ordination Action Group (SCAR 2009a; see also http://www.scar.org) should guarantee the co-ordination of all active researchers on this island, providing information about their field work and promoting exchange of results in order to minimise the adverse effects of duplication of research projects. In particular, the increasing number of people working and staying in the area, connected with the increasing area consumption (e.g. buildings, roads or scientific field work) emphasises the importance of effective cooperation and co-ordination. Furthermore, future technological developments can help to reduce negative impacts by providing less invasive scientific methods and more ‘gentle’ logistics.

In the Antarctic, scientific and touristic activities are closely related to seaborne and air-borne transport systems. With regard to the Fildes Peninsula, the construction of a parking zone for large aircrafts next to the runway in 2004/2005 (Peter et al. 2008), and the installation of a Transponder Landing system in the 2009/2010 season, allow flight operations even under conditions of low visibility. These technological advances will expectedly result in increasing flight activity in the area, in particular tourist flights (Braun et al. 2012).

It is also assumed that ship traffic in the Antarctic, and around the Fildes Peninsula in particular, will remain at high levels or continue to increase. The implementation of the heavy fuel ban in the Antarctic by the International Maritime Organization (IMO), in August 2011 (IMO 2010), will mainly affect large vessels with more than 500 passengers, which usually do not head for the Fildes Peninsula. Therefore, the ban will presumably not lead to a long-term reduction in the number and frequency of ship traffic vessels approaching the Fildes Peninsula (Braun et al. 2012). However, the combination of the airstrip with the planned construction of docking facilities at two stations in the next few years (CAA 2007; La Estrella 2010) will facilitate easier passenger landings and cargo operations.

The establishment of more extensive facility zones, proposed by the NAPs and currently discussed within the IWG Fildes, suggests a further increase of the total area affected by station facilities and operations. As a consequence of the station extensions, we expect a higher number of station personnel working in the Fildes Peninsula resulting in additional human impacts due to science and leisure related activities.

Environmental damage of the Fildes Peninsula Region is more directly linked with activities of NAPs and much less with tourism activities. Obviously, the existing formal protection measures (Protocol, ASPA, Historic Sites and Monuments) are not sufficient in some areas to safeguard the existing values effectively. Proper and consistent enforcement of these measures will provide a start. We further argue that an effective management system should be implemented soon, otherwise environmental impacts and habitat degradation will increase further and possibly contribute to extensive and irretrievable damage to the local ecosystem.

Altogether, the long-term efforts to implement a legally binding management system for the Fildes Peninsula could be considered as preliminarily failed. So far, the response of the Antarctic Treaty parties has been quite hesitant and the development of alternative management systems has developed slowly. The environmental situation in the Fildes Peninsula has the potential to become a famous negative example for the treatment of the Antarctic environment by humans. The main future challenge is to prevent this from coming true.

7.5 Conclusions

Our comprehensive assessment of human impacts in the Fildes Peninsula region during six field seasons revealed increasing human pressure affecting the local environment. This included increasing ship traffic, constant high-levels of air traffic and prevailing frequent vehicle use beyond the existing road network. Despite some improvements in station operations, various shortcomings in waste and sewage management as well as smaller oil contaminations and some larger oil spills were documented. The extension of stations seems to be a conspicuous trend in the Fildes Peninsula and has already led to extensive environmental impacts. A wide variety of tourist and other visitor activities were described, but the leisure behaviour of station personnel was observed to have a much stronger effect.

Lack of knowledge and awareness of the sensitivity of Antarctic ecosystems, the values that need protection and the international obligations aiming to protect it are presumably the main reasons for the depraved state of the environment in the Fildes Peninsula region as presented in this chapter. Each year, visitors continue to arrive at Fildes Peninsula without prior briefing of environmental vulnerability and international obligations.

We authors believe that designating the Fildes Peninsula region as an ASMA is an effective instrument for dealing with current and future challenges. The following criteria are fulfilled in the region in order to be designated as an ASMA: high level of human activity by several Antarctic Treaty parties, insufficient co-ordination between the parties on site, doubled scientific work resulting in unnecessary environmental impacts. Compared to voluntary and non-binding agreements, like bilateral arrangements between parties on management zones or codes of conduct, the ASMA presents the advantage that all regulations stated in the corresponding management plan are legally binding for all activities of parties, non-Treaty parties, tour operators, non-governmental organisations, independent people working in or visiting the area. ASMAs have been successfully established in other parts of the Antarctic with high levels of human activity (see Pertierra et al. 2013). The experience gathered during the establishment and implementation processes should be used for the Fildes Region.

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References

ASOC. (2007). *Implementing the Madrid protocol: a case study of Fildes peninsula, king George Island*. Information paper 136 presented at XXX Antarctic Treaty Consultative Meeting, New Delhi, April 30–May 11, 2007.

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. (1991). *The protocol on environmental protection to the antarctic treaty*. Buenos Aires: Secretariat of the Antarctic Treaty. Retrieved from: http://www.ats.aq/e/ep.htm.

ATS. (1994). *Guidance for visitors to the antarctic*. Attachment to recommendation XVIII–1. Adopted at XVIII Antarctic Treaty Consultative Meeting, Kyoto, April 11–22, 1994.

ATS. (2004). *Guidelines for Aircraft near concentrations of birds. Resolution 2* (*2004*). Adopted at XXVII Antarctic Treaty Consultative Meeting, Cape Town, 24 May–04 June, 2004.

ATS. (2009a). *Landing of persons from passenger vessels. Measure 15* (*2009*). Adopted at XXXII Antarctic Treaty Consultative Meeting, Baltimore, 06–17 April, 2009.

ATS. (2009b). *Revised management plan for antarctic specially protected area no. 150 Ardley Island, Maxwell Bay, King George Island* (*25 de Mayo*) Adopted at XXII Antarctic Treaty Consultative Meeting, Baltimore, 06–17 April, 2009.

ATS. (2009c). *Revised management plan for antarctic specially protected area no. 125 Fildes Peninsula, King George Island* (*25 de Mayo*). Adopted at XXII Antarctic Treaty Consultative Meeting, Baltimore, 06–17 April, 2009.

ATS. (2010a). *Status of antarctic specially protected area and Antarctic specially managed area management plans*. Adopted at XXIII Antarctic Treaty Consultative Meeting, Punte del Este, 06–17 April, 2009.

Australia. (2001). *Report on the open-ended intersessional contact group on diseases of Antarctic Wildlife, report 1—review and risk assessment*. Paper presented at the ATCM XXIV.

Australia. (2005). *Measures to address the unintentional introduction and spread of non-native biota and disease to the Antarctic Treaty Area*. Working paper 28 presented at XXVIII Antarctic Treaty Consultative Meeting, Stockholm, Sweden, 6–17 June, 2005.

Australia., Peru., & United Kingdom. (2005). *Report of joint inspections under article VII of the Antarctic Treaty and article 14 of the environmental protocol*. Working paper 32 presented at the XXVIII Antarctic Treaty Consultative Meeting, Stockholm, 6–17 June, 2005.

Barnes, D. K. A., & Convey, P. (2005). Odyssey of stow-away noctuid moths to southern polar islands. *Antarctic Science, 17*(3), 307–311.

Bastmeijer, K., & Roura, R. (2008). Environmental impact assessment in Antarctica. In K. Bastmeijer, T. Koivurova (Eds.), *Theory and Practice of Transboundary Environmental Impact Assessment* (pp. 175–219). Leiden: Brill/Martinus Nijhoff.

Berkman, P. A., Andrews, J. T., Bjorck, S., Colhoun, E. A., Emslie, S. D., Goodwin, I. D., et al. (1998). Circum-Antarctic coastal environmental shifts during the Late Quaternary reflected by emerged marine deposits. *Antarctic Science, 10*(3), 345–362.

Bonnedahl, J., Broman, T., Waldenstroem, J., Palmgren, H., Niskanen, T., & Olsen, B. (2005). In search of human-associated bacterial pathogens in antarctic wildlife: report from six penguin colonies regularly visited by tourists. *Ambio, 34*(6), 430–432.

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 Research*, 2012, *31*, 18206, http://dx.doi.org/10.3402/polar.v31i0.18206.

Brazil., China., Germany., South Korea., & Russian Federation. (2006). *'Possibilities for environmental management of Fildes Peninsula and Ardley Island'. Proposal to establish an intersessional contact group*. Working paper 22 presented at the XXIX Antarctic Treaty Consultative Meeting, 12–23 June, 2006.

Briggs, K. T., Yoshida, S. H., & Gershwin, M. E. (1996). The influence of petrochemicals and stress on the immune system of seabirds. *Regulatory Toxicology and Pharmacology, 23*.

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

CAA. (2007). *National annual report on polar program of China 2006*. Beijing: Chinese Arctic and Antarctic Administration. Retrieved from: http://polar.chinare.gov.cn/times/affix_data/chinare2006en.pdf.

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 Biology, 32*, 1427–1433.

Chile. (2009). *Notes on a multiple protection system for some areas of King George Island: Zones under Annex V and their relevance to Fildes Peninsula and adjacent areas*. Information paper 81 presented at the XXXII Antarctic Treaty Consultative Meeting, Baltimore, 6–17 April, 2009.

Chupin, I. (1997). Human impact and breeding success in southern giant petrel *Macronectes giganteus* on King George Island (South Shetland Islands). *Korean Journal of Polar Research, 8*(1,2), 113–116.

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*(1), 45–60.

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 Biology, 21*, 355–360.

COMNAP. (2008). *COMNAP fuel manual (operation manual)*. Hobart: Council of Managers of National Antarctic Programs.

COMNAP. (2010). Main antarctic facilities operated by national antarctic programs in the antarctic treaty area (South of 60° latitude South). Retrieved from: https://www.comnap.aq/facilities.

Culik, B. M., Wilson, R. P., Woakes, A. J., & Sanudo, F. W. (1991). Oil pollution of Antarctic penguins: effects on energy metabolism and physiology. *Marine Pollution Bulletin, 22*(8), 388–391.

Ducklow, H. W., Baker, K., Fraser, W. R., Martinson, D. G., Quetin, L. B., Ross, R. M., et al. (2007). Marine pelagic ecosystems: the West Antarctic Peninsula. *Philosophical Transactions of the Royal Society, London B, 362*(1477), 67–94.

Eppley, Z. A., & Rubega, M. A. (1990). Indirect effects of an oil-spill—reproductive failure in a population of south polar skuas following the bahia paraiso oil-spill in Antarctica. *Marine Ecology-Progress Series, 67*(1), 1–6.

Filler, D. M., Snape, I., & Barnes, D. L. (2008). *Bioremediation of petroleum hydrocarbons in cold regions*. Cambridge: Cambridge University Press.

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 Biology, 12*(3), 411–423.

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 B. Battaglia (Ed.), *Antarctic communities, species, structure and survival* (pp. 445–452). Cambridge: University Press.

Frenot, Y., Chown, S. L., Whinam, J., Selkirk, P. M., Convey, P., Skotnicki, M., et al. (2005). Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews, 80*, 45–72.

Gardner, H., Kerry, K., & Riddle, M. (1997). Poultry virus infection in Antarctic penguins. *Nature, 387*, 245.

Germany. (2004). *Research project 'risk assessment for the Fildes Peninsula and Ardley Island and the development of management plans for designation as Antarctic specially protected or managed areas'*. Information paper 5 presented at the XXVII Antarctic Treaty Consultative Meeting, Capetown, 24 May–4 June, 2004.

Germany. (2005). *Progress report on the research project 'risk assessment for Fildes Peninsula and Ardley Island and the development of management plans for designation as Antarctic specially protected or managed areas'*. Information paper 16 presented at the XXVIII Antarctic Treaty Consultative Meeting, Stockholm, Sweden, 6–17 June, 2005.

Germany (2007). *Possible modules of a 'Fildes peninsula region' ASMA management plan*. Information paper 112 presented at the XXX Antarctic Treaty Consultative Meeting, New Dehli, 30 April–11 May, 2007.

Germany. (2008). *Final report on the research project 'risk assessment for Fildes Peninsula and Ardley Island and the development of management plans for designation as Antarctic specially protected or managed areas'*. Information paper 30 presented at the XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine, 2–13 June, 2008.

Germany (2009). *Research project 'current environmental situation and management proposals for the Fildes region* (*Antarctic*)*'*. Information paper 50 presented at the XXXII Antarctic Treaty Consultative Meeting, Baltimore, 6–17 April, 2009.

Germany., & Chile. (2007). *Progress report on the discussion of the international working group about possibilities for environmental management of Fildes Peninsula and Ardley Island*. Information paper 22 (rev.1) presented at the XXX Antarctic Treaty Consultative Meeting, New Dehli, 30 April–11 May, 2007.

Germany., & Chile. (2010). *Third progress report on the discussion of the international working group about possibilities for environmental management of Fildes Peninsula and Ardley Island*. Working paper 40 presented at the XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay, 3–14 May, 2010.

Gonzalez-Solis, 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. *Marine Ecology Progress Series, 204*, 279–288.

Haase, D. (2005). Too much pressure on thin ice? *Antarctic Tourism and Regulatory Considerations. Polarforschung, 75*(1), 21–27.

Hall, C. M. (1992). Tourism in Antarctica: activities, impacts and management. *Journal of Travel Research, 30*(4), 2–10.

Headland, R. K. (1994). Historical development of Antarctic tourism. *Annals of Tourism Research, 21*(2), 269–280.

Hemmings, A. D. (1990). Human impacts and ecological constraints on skuas. In K. R. Kerry & G. Hempel (Eds.), *Antarctic ecosystems—ecological change and conservation* (pp. 224–230). Berlin: Springer.

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.

Hughes, K. A. (2010). How committed are we to monitoring human impacts in Antarctica? *Environmental Research Letter, 5*(4), 1–3.

Hughes, K. A., & Convey, P. (2010). The protection of Antarctic terrestrial ecosystems from inter- and intra-continental transfer of non-indigenous species by human activities: a review of current systems and practices. *Global Environmental Change, 20*(1), 96–112.

Hughes, K.A., Convey, P., & Huiskes, A.H.L. (2013). Global movement and homogenisation of biota: challenges to the environmental management of Antarctica? In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. (pp. 113–137) Dordrecht, Netherlands: Springer-Verlag.

IAATO. (2004). *IAATO Overview of Antarctic tourism 2003–2004 Antarctic season*. Information paper 63 presented at the XXVII Antarctic Treaty Consultative Meeting, Capetown, South Africa, 24 May–4 June, 2004.

IAATO. (2010a). Tourism statistics. Retrieved from: http://www.iaato.org/tourism_stats.html.

IAATO. (2010b). *IAATO Overview of Antarctic tourism: 2009–2010 season and preliminary estimates for 2010–2011 and beyond*. Information paper 113 presented at the XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay, 3–14 May, 2010.

IMO. (2010). *Amendments to MARPOL annex I on special requirements for the use or carriage of oils in the Antarctic Area.* Information Paper 94 presented at the XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay, 3–14 May, 2010.

IUCN. (2010). The IUCN red list of threatened species. From http://www.iucnredlist.org/apps/redlist/details/144819/0.

Klein, A.G., Sweet, S.T., Kennicutt II, M.C., Wade, T.L., Palmer, T.A., & Montagna, P. (2013). Long term monitoring of human impacts ot the terrestrial environment at McMurdo Station. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. (pp. 213–227) Dordrecht: Springer.

La Estrella (2010). *Ministerio des Obras Públicas presentó plan Antártico.* Retrieved from the internet on 27.04.2010. at http://www.cronica.cl/noticias/site/artic/20100210/pags/20100210164655.php.

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 Biology, 32*, 1811–1813.

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. *Marine Ornithology, 36*, 83–97.

Lynch, H. J., Crosbie, K., Fagan, W. F., & Naveen, R. (2010). Spatial patterns of tour ship traffic in the Antarctic Peninsula region. *Antarctic Science, 22*(2), 123–130.

Mäusbacher, R. (1991). *Die jungquartäre Relief-und Klimageschichte im Bereich der Fildeshalbinsel Süd-Shetland-Inseln, Antarktis* (Vol. 89). Heidelberg: Geographisches Institut der Universität Heidelberg.

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

New Zealand (2006). *Non-native species in the Antarctic. Report of a workshop*. Working paper 13 presented at the XXIX Antarctic Treaty Consultative Meeting, Edinburgh, UK, 12–23 June, 2006.

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

Osyczka, P. (2010). Alien lichens unintentionally transported to the 'Arctowski' station (South Shetlands, Antarctica). *Polar Biology, 33*(8), 1067–1073.

Parmelee, D. F., Maxson, S. J., & Bernstein, N. P. (1979). Fowl cholera outbreak among Brown skuas (*Catharaca skua lonnbergi*) at Palmer station. *Antarctic Journal of the United States, 14*(5), 168–169.

Pertierra, L. R., Tejedo, P. & Benayas, J. (2013). Looking into the future of Deception Island: current status, drivers of change and policy alternatives. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht: Springer.

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 designation as Antarctic Specially Protected or Managed Areas.* Dessau: German Federal Environment Agency. Retrieved from: http://www.umweltdaten.de/publikationen/fpdf-l/3478.pdf.

Pfeiffer, S. (2005). *Effects of human activities of southern giant petrels and skuas in the Antarctic.* Unpublished PhD thesis, University of Jena, Jena.

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

Riddle, M. J. (2010). *Environmental governance a world apart: the view from the south*. Oslo: Paper presented at the presented at International Polar Year Oslo Science Conference.

Riffenburgh, B. (1998). Impacts on the Antarctic environment: tourism vs government programmes. *Polar Record, 34*(190), 193–196.

SCAR. (2001). Recommendation SCAR XXVI-6: Concerning rationalization of scientific activities on King George Island. (S. S. C. o. A. Research).

SCAR. (2009a). *Report on SCAR's 3rd cross-linkages workshop*. Modena. S. C. o. A. Research.

SCAR. (2009b). *SCAR's environmental code of conduct for terrestrial scientific field research in Antarctica*. Information paper 4 presented at the XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, 6–17 April, 2009.

SCAR. (2009b). *Antarctic climate change and the environment*. Cambridge: SCAR.

SCAR. (2010). *Preliminary results from the international polar year programme: Aliens in Antarctica*. Working paper 4 presented at the XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay, 3–14 May, 2010.

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 D. Greenland, D. G. Goodin, & R. C. Smith (Eds.), *Climatic variability and ecosystem response at long-term ecological research sites* (pp. 158–173). Oxford: Oxford University Press.

Tin, T., & Roura, R. (2004). *environmental reports of Fildes peninsula, 1988–1997: benchmarks for environmental management*: Antarctic and Southern Ocean Coalition.

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., et al. (2009). Impacts of local human activities on the Antarctic environment. *Antarctic Science, 21*(1), 3–33.

Trivelpiece, W. Z., & Fraser, W. R. (1996). The breeding biology and distribution of Adélie penguins: adaptations to environmental variability. In R. M. Ross, E. E. Hofmann & L. B. Quetin (Eds.), *Antarctic Research Series. Foundations for Ecological Research West of the Antarctic Peninsula* (Vol. 70, pp. 273–285).

United Kingdom., & Germany. (1999). *Report of a joint inspection under article VII of the Antarctic Treaty, Antarctic Treaty Inspection Programme: January 1999*. Working paper 23 presented at the XXIII Antarctic Treaty Consultative Meeting, Lima, Peru, 24 May–4 June, 1999.

United States. (2001). *The inspection conducted in accordance with article vii of the antarctic treaty and article xiv of the protocol under auspices of the united states department of state*. Information paper 17 presented at the XXIV Antarctic Treaty Consultative Meeting, St. Petersburg, Russia, 9–20 July, 2001.

United States. (2007). *United states report of inspections*. Information paper 10 presented at the XXX Antarctic Treaty Consultative Meeting, New Dehli, 30 April–11 May, 2007.

Woehler, E. J. (1997). Seabird abundance, biomass and prey consumption within Prydz Bay, Antarctica, 1980/1981–1992/1993. *Polar Biology, 17*, 371–383.

Woehler, E. J., Cooper, J., Croxall, J. P., Fraser, W. R., Kooyman, G. L., Miller, G. D., et al. (2001). A statistical assessment of the status and trends of Antarctic and Subantarctic seabirds (Report on SCAR BBS Workshop on Southern Ocean seabird populations): SCAR BBS.

Woehler, E.J., Ainley, D. & Jabour, J. (2013). Human impacts to Antarctic wildlife: predictions and speculations for 2060. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. (pp. 27–60). Dordrecht: Springer.

Young, E. C. (1990). Long-term stability and human impact in antarctic skuas and adelie penguins. In K. R. Kerry & G. Hempel (Eds.), *Antarctic Ecosystems. Ecological Change and Conservation* (pp. 231–236). Heidelberg: Springer.

Chapter 8
Historical Developments, Drivers of Change and Future Scenarios for Human Activities on Deception Island

Luis R. Pertierra, Pablo Tejedo and Javier Benayas

Abstract Deception Island is an active volcano with a flooded caldera and numerous glaciers, providing a unique habitat to very rare biological assemblies. Deception Island has a long history of human activity and is currently one of the most visited locations in the Antarctic. Natural, scientific and tourism values coexist in a small area. Some activities may interfere with others and can potentially compromise the future conservation of the island and its unique values. Under the Antarctic Treaty System (ATS), regulatory mechanisms have been developed to provide different levels of protection to the island in order to minimise the inevitable environmental impacts and cumulative effects arising from existing human activities. Six Treaty parties manage Deception Island collectively as Antarctic Specially Managed Area (ASMA) No. 4 which has been identified as an exemplar of strategic environmental management. However, under the ATS the success of policies is highly dependent on the level of stakeholder acceptance. In this chapter, through a review of the environmental impacts, regulatory mechanisms, current trends and drivers for change we examine a range of possible management scenarios that combine different levels of environmental standards with varying likelihoods of stakeholder acceptance. Success of any of these policies will rely on information provided by monitoring programmes.

Keywords Antarctic specially protected area • Environment • Management • Conservation

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8.1 Introduction

Deception is a volcanic island within the South Shetland Islands at approximately 70 km from the Antarctic Peninsula. Its volcanic caldera is flooded and is connected to the Southern Ocean via a narrow channel, thus allowing marine access into the caldera/bay, known as Port Foster (Fig. 8.1). It has had a long history of human activity associated with sealing, whaling and scientific research and is currently one of the most visited tourist locations in Antarctica. With a surface area

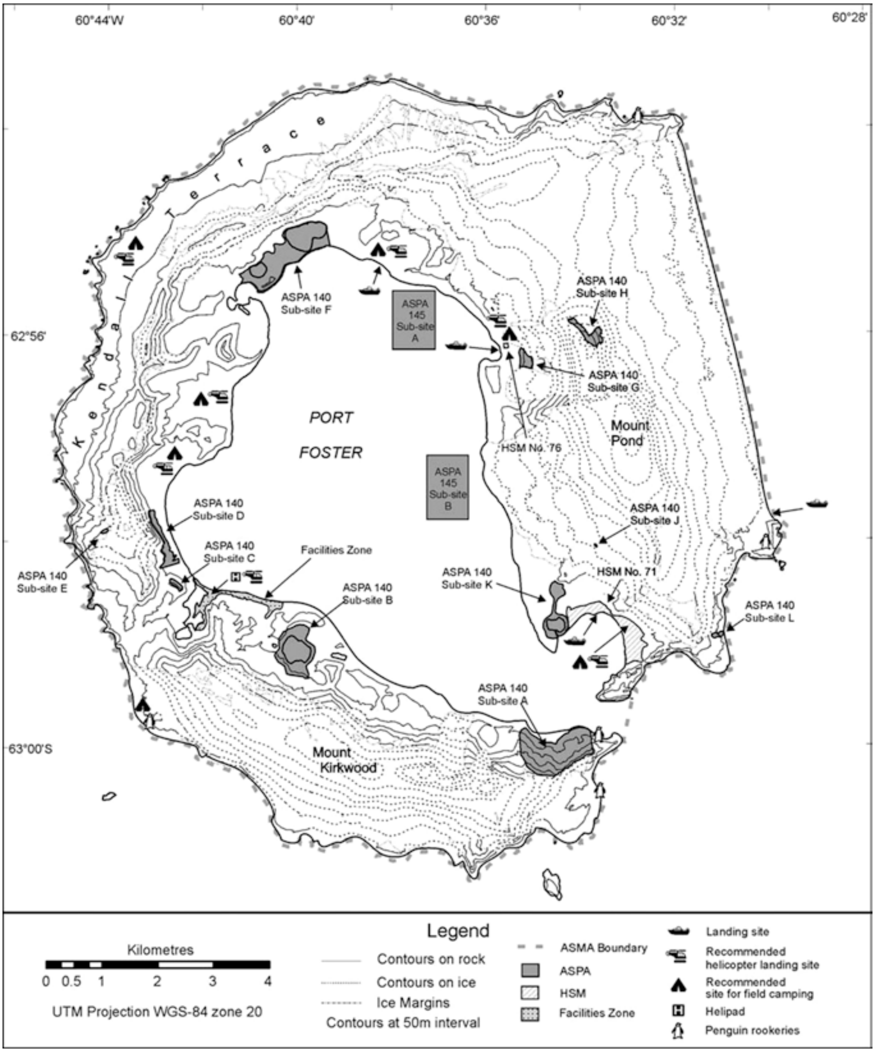


Fig. 8.1 Map of Deception Island. *Source* British Antarctic Survey

of 98.5 km^2, Deception Island has unique and outstanding environmental, historic and scientific values. There are two active research stations and several monitoring stations. It is managed by the Antarctic Treaty parties under the Antarctic Treaty System (ATS). A Deception Island Antarctic Specially Managed Area (ASMA) Management Group, which comprises of six Antarctic Treaty parties, assumes the task of co-ordination of activities and facilitation of communication. The diversity of human activities taking place can result in potential conflicts between stakeholders and can also lead to pressures on the unique values of Deception Island. In this sense, Deception Island can be considered as a microcosm of the Antarctic where strategic management decisions need to be taken in order to accommodate competing priorities through consensus (Roura and Hemmings 2011; Roura and Tin 2013). In this chapter, we start by summarising the present situation of the island: its human activities, regulatory mechanisms, values that are protected and environmental impacts. We then explore possible drivers of change and future regulatory scenarios. This roughly follows some of the components of the Millennium Ecosystem Assessment (MA). For the MA, a comprehensive framework was developed to analyse the effects of environmental change on ecosystems and human well-being at multiple geographic and time scales, while considering the interactions among individual natural resources and the consequences of the tradeoffs that are made in the decision-making process (Carpenter et al. 2009; Mooney et al. 2004). While Deception Island is a much simpler system than the global and sub-global regions where MA has been applied to, we believe that selected components of the MA framework can serve as a useful guide in an exploration of the future of Deception Island.

8.2 Current Status

8.2.1 Historical Development of Human Activities

The first humans to occupy the island were American and British fur sealers that arrived around 1820. Several Antarctic explorers, including Charcot and Bellingshausen also passed through on their expeditions (Martin 1996). Norwegian whalers arrived at the start of the twentieth century, first basing their operations out of floating factory ships and later on from a land-based complex, of which remains still stands today at Whalers Bay (Dibbern 2010).

In the 1940s, as nations began to take interest in territorial claims in Antarctica, Argentina, Chile and UK respectively put in claims for Deception Island. UK founded Base B in Whalers Bay. Argentina established what is known today as Deception station. In 1955, Chile founded the station Pedro Aguirre Cerda and the refuge Gutierrez Vargas (Joyner and Ewing 1991). Many buildings, including the Chilean and British stations and the abandoned whaling station were partially destroyed by volcanic eruptions in 1967 (Smellie 2001). Argentina's Deception

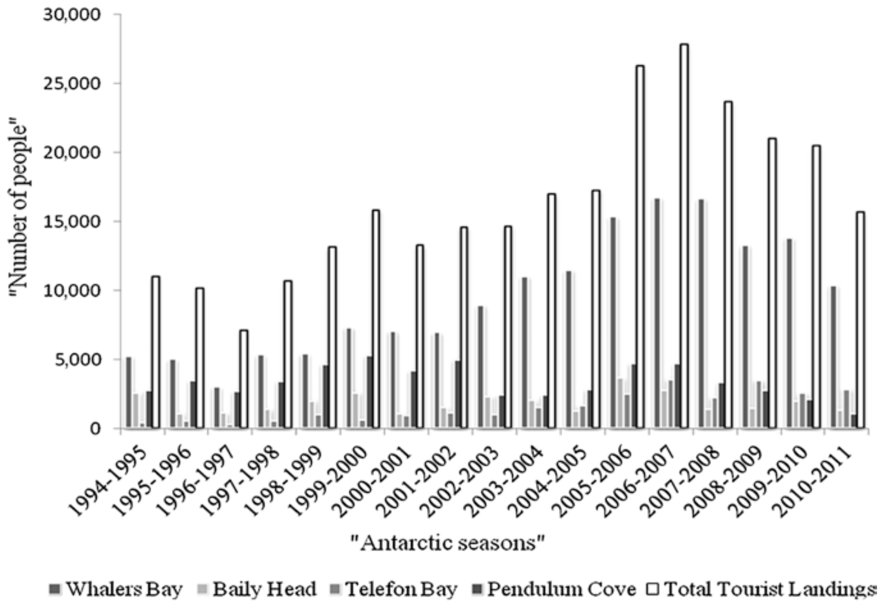


Fig. 8.2 Tourist landings on Deception Island (1994–2010). *Data source* IAATO (2001a, b, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011b)

and Spain's Gabriel de Castilla stations are the two active research stations on the island today. Over the past five decades, nations including Argentina, Spain, UK, Brazil, Chile and USA have conducted scientific research in many areas of natural sciences, such as biological, oceanographic, geological and physical studies, operating out of land-based stations, field camps and vessels.

Since the end of the twentieth century, Deception Island has become one of the most visited tourist destinations in the Antarctic. By mid 1990s, over 10,000 tourist landings[1] were made on Deception Island, at the four main sites of Whalers Bay, Telefon Bay, Baily Head and Pendulum Cove (Fig. 8.2). The sustained growth peaked in the 2007–2008 seasons, with a record of over 25,000 tourist landings on the island. Sailing yachts, carrying 1–12 passengers, are also commonly seen on the island. Unlike larger cruise ships, the presence of sailing yachts is not regularly recorded and there is no clear information of non-IAATO cruises

[1] The International Association of Antarctica Tour Operators (IAATO) publishes statistics on tourist visits to Antarctica under its member companies. IAATO has over 100 member companies that cover around 97 % of the Antarctic tourism market. According to IAATO's statistics, a tourist landing is counted when a paying passenger gets off a ship and makes a visit at a land location. One passenger usually makes only one landing at each location but can make landings at several locations.

and private small yachts activities (Murray and Jabour 2004; Enzenbacher 2007). Casual observations suggest that the number of yachts visiting Deception Island is in the order of ten's of yachts per year (Pertierra, pers. obs.).

8.2.2 Regulatory Mechanisms

Like the rest of the Antarctic Treaty Area, human activities on Deception Island are managed under the provisions laid out under (see Tin et al. 2013):

- The legal instruments of the ATS, among them the Convention for the Conservation of Antarctic Seals (CCAS), Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) and the Protocol on Environmental Protection to the Antarctic Treaty (also known as the Environment Protocol);
- Other relevant international agreements, e.g. the International Convention for the Regulation of Whaling (ICRW) and the Agreement on the Conservation of Albatrosses and Petrels (ACAP); and
- Specific Measures, Decisions and Resolutions adopted at Antarctic Treaty Consultative Meetings (ATCMs).

Of specific relevance to Deception Island is the Deception Island Management Package adopted by the ATCM in 2005. This integrated management plan replaced piecemeal proposals for legal protection of different parts of the island with a coherent island-wide strategy to manage human activities (ATS 2005). Deception Island was formally adopted as Antarctic Specially Managed Area (ASMA) 4 in 2005 under ATCM XXVIII Measure 3. It includes:

- Several Antarctic Specially Protected Areas (ASPAs), where entry is by permit only;
- Several Historic Sites and Monuments (HSMs), where artefacts shall not be damaged, removed or destroyed;
- A facilities zone encompassing the two research stations, where human activities are subject to a code of conduct (Table 8.1);
- A series of general visitor guidelines and site-specific visitors' guidelines (Table 8.2).

A management group, comprising of Argentina, Spain (countries occupying research stations on Deception Island), Chile, Norway, UK (countries at the origin of the historic sites) and US (conducting field research regularly on the island), was established to coordinate, facilitate communication, maintain a record of activities and inspect and monitor for cumulative environmental impacts (Argentina et al. 2006). The management plan has the advantage of short-term adaptability as it is revised every 5 years and can thus take into consideration new issues as they arise. In contrast the current management arrangements have difficulties in managing long-term issues, including systematic monitoring, identifying cumulative impacts and establishing higher standards of protection, due to lack of agreement and conflicts of interest among stakeholders on these issues.

Table 8.1 Elements of the Deception Island management package (ATS 2005)

Instruments	Management objectives	Selected management measures
Management plans for protected areas		
ASPA Nº 140—Sites of unique botanical importance, Deception Island	Preserve sites, avoid degradation to rare terrestrial flora and minimise the possibility of the introduction of alien plants and other biota while allowing scientific research to take place	Entry by permit only, for compelling scientific reasons which cannot be served elsewhere or for essential management actions. Access to sites is by foot or small boat. Land vehicles, helicopter landings and camping are prohibited
ASPA Nº 145—Port Foster	Avoid degradation to diverse marine benthic system while allowing scientific research to take place	Entry by permit only, for compelling scientific reasons which cannot be served elsewhere or for essential management actions
Conservation strategies for historic sites and monuments		
HSM Nº 71—Whalers Bay	Preserve historic values of one of the most visited sites in Antarctica—remains of Norwegian Hector whaling station and British Base B	No new buildings to be erected. Limited use of motorised vehicles. Recommended helicopter landing and camping locations. Site specific visitor guidelines
HSM Nº 76—Pedro Aguirre Cerda Station	Acknowledging the historic significance of Antarctic cultural and natural history	Shall not be damaged, removed or destroyed
Codes of conduct		
General Code of Conduct for entire island	Conserve and protect unique and outstanding environment of Deception Island, whilst managing the variety of competing demands placed upon it, including science, tourism and the conservation of its natural and historic values	All activities should take into account volcanic risk. Field camps should be located on non-vegetated sites, avoid areas of geothermally heated ground or fumaroles, dry lake or stream beds. All wastes other than human wastes and domestic liquid waste shall be removed
Code of Conduct for Facilities Zone, Deception and Gabriel de Castilla stations	Preserving natural, scientific and cultural values while encouraging scientific research in the area	Consideration given to reusing existing sites when practicable, in order to minimise disturbance. Vehicles only used when necessary, on established tracks and away from flora or fauna areas
Code of Conduct for Visitors to Deception Island	Preserving natural, scientific and cultural values while allowing education and tourism in the area	<100 passengers ashore at any time. 1 guide for every 20 passengers. Do not walk on vegetation. Maintain 5–15 m from wildlife. Maintain at least 20 m from scientific equipment. Do not litter, graffiti or take souvenirs

Table 8.2 Visitor Site Guidelines for the Deception Island landing sites (ATS 2005, 2011)

Landing site	Visitor guidelines
Pendulum Cove	Safety requirements during use of bathing pits
Whalers Bay	One ship <500 passengers at a time. Recommended landing, guided walking and free roaming areas. Identification of closed areas. Bathing pits should not be dug. Hiking between Whalers Bay and Baily Head strongly discouraged
Telefon Bay	One ship <500 passengers at a time. Recommended landing, guided walking and free roaming areas
Baily Head	Maximum two ships each <200 passengers per day. <350 visitors ashore per day. No visitors between 22:00 p.m. and 4:00 a.m. Visits to colony should be in closely supervised groups of <20 visitors, well-spaced, one guide per group

8.2.3 Values to Be Protected

Under the Deception Island Management Package, the island is protected for its 'important natural, scientific, historic, educational, aesthetic and wilderness values' (ATS 2005). It is one of only two volcanoes in the Antarctic that has erupted in modern times. It contains a caldera with active geothermal processes and is likely to erupt again in the future. The area also has an exceptionally important flora, including very rare species of mosses associated with these geothermal areas and which have not been recorded elsewhere in the Antarctic (Smith 2005). There are numerous birds on the island with nine breeding species (Bó and Copello 2001), including the world's largest colony of chinstrap penguins *Pygoscelis antarctica* Forster 1781. The benthic habitat in Port Foster is also of ecological interest because of the perturbations caused by volcanic activity.

In terms of scientific values, Deception Island holds outstanding interest for studies in geoscience and biological science. It is a unique natural laboratory where the effects of natural and human perturbations can be studied directly. Historically, Deception Island has played a significant role in the history of human's involvement in Antarctica, acting as the stage for exploration, sealing, whaling and scientific research for two centuries. The aesthetic value of Deception Island is given by its unique landscape of a flooded caldera, linear glaciated coastline, barren volcanic slopes with fumaroles on steaming beaches, ash-layered glaciers, old and modern stations and a massive penguin rookery in the form of an amphitheatre at Baily Head (Downie 2007).

Deception Island's natural and scientific values together with its rich historic and aesthetic values provide significant educational values on geophysics, marine and terrestrial biology and exploration heritage. Its volcanic landscape strongly contrasts with nearby locations. For all these reasons, Deception Island is one of the most visited tourism sites, and is part of the main tourist corridor to the Antarctic Peninsula (Lynch et al. 2010).

8.2.4 Known Human Impacts

Few of the effects of human activity on the environment of Deception Island have been examined in detail. The presence of infrastructure and footpaths is the most obvious evidence of human presence on Deception Island. Several footpaths have developed around heavily studied locations such as the chinstrap penguin rookery located in Vapour Col and at tourism sites, such as at Neptune's Window at Whalers Bay (Spain 2010a). The impacts of foot traffic on Deception Island's soil fauna are being studied (Tejedo et al. 2012, 2013). Rubbish has been found on beaches and along footpaths. Organic waste was found at Telefon Bay while plastic was the most common type of rubbish found at Pendulum Cove. Abandoned buildings at Whalers Bay are likely to be the source of wood, glass and metal waste materials found in nearby beaches (Spain 2010a; Benayas, pers. obs.). Vandalism, including graffiti and damage of historical artefacts have taken place at historic sites (Roura et al. 2008). At Pendulum Cove, pools were dug in the sand to allow tourists to bathe in the geothermal water. The pools were rarely filled in after use, leaving obvious evidence of human presence. This practice has now largely been abandoned (Spain 2010a).

8.3 Looking into the Future

8.3.1 Drivers of Change

8.3.1.1 Research and Technology

Two research stations, several monitoring stations and two historic sites form the bulk of the long-term infrastructure found on Deception Island. Occupation of Deception station has remained below full capacity (65 people) in recent years, and has remained closed in some years. Gabriel de Castilla station has been operating at full capacity. Renovation works were completed in the 2009–2010 season which extended the available living and research space inside the station to 36 people. Both research stations are expected to continue operating in coming years. It is unlikely that Deception station will need to be expanded in the near future due to the low occupation rates in recent years. Gabriel de Castilla station has seen a steady growth in occupation rates in the last 20 years (Fig. 8.3). Existing research projects focus on long-term volcanic and seismic monitoring, which are likely to continue operating. New technologies and research interests may attract more researchers to the station and/or use of field camps and establishment of instruments in more locations. Extrapolating from the trends of the last 20 years, we expect the capacity for Gabriel de Castilla station to increase to between 50 and 100 people in the next decades. Of course, there may be many kinds of constraints, e.g. economic, logistical, technological, that may limit this

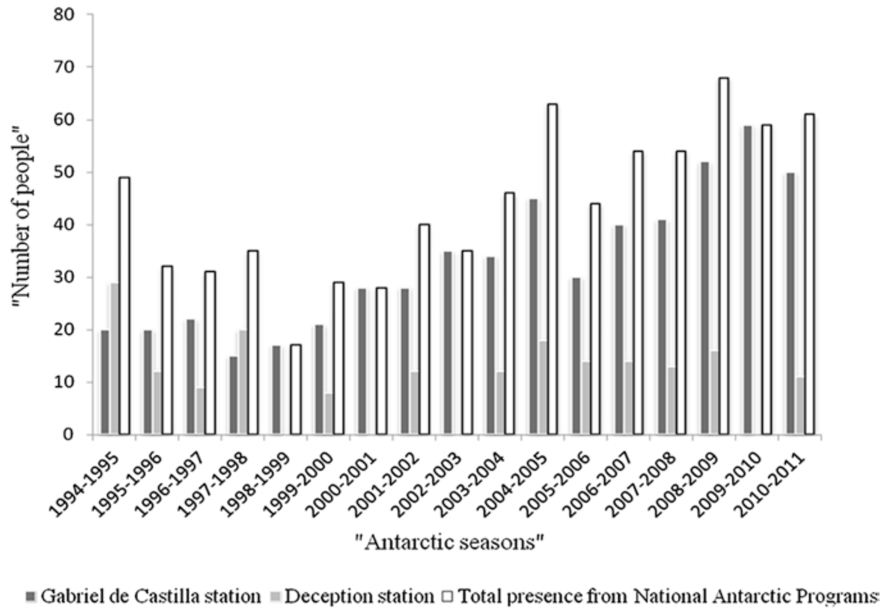


Fig. 8.3 Evolution of personnel at the two operating stations on Deception Island (1994–2011). Data for Gabriel de Castilla station obtained from Commander Francisco Lupiani (pers. comm.). Data for Deception station obtained from Commander Cristian Carrizo (pers. comm.)

steady growth. New research technologies and interests may involve remote sensing techniques that require no visits to Deception Island (e.g. Fretwell et al. 2011; LaRue et al. 2011). Environmental monitoring and human impacts research may lead to management decisions that restrict certain human activities at certain locations or during certain times. Research activities can be affected by fluctuations in research budgets, and stations could be temporarily closed or expanded.

Continuous use of machines and infrastructure could potentially lead to leaks of heavy metals and hydrocarbons into the local environment. These parameters are currently not monitored regularly on Deception Island, and only a few *ad hoc* measurements are available (ASOC 2010; Cabrerizo et al. 2012). However, it is reasonable to expect that increases in human activity would increase the likelihood of local environmental pollution while decreases in activity would decrease the likelihood of pollution.

8.3.1.2 Tourism Footprint

The number of tourists visiting Deception Island peaked in the 2006–2007 season (Fig. 8.2). Since then, the number of tourists, cruise ships and voyages to Antarctica has decreased as a combination of global economic crisis, retirement of vessels and companies pulling out of the market (IAATO 2011a).

Market demand to visit Antarctica is expected to continue, and therefore tourist numbers are expected to grow again from 2012 onwards should economic conditions become favourable (IAATO 2011b). Since August 2011, the International Maritime Organisation (IMO) includes an amendment to the International Convention for the Prevention of Pollution From Ships (MARPOL) which bans heavy grade fuel oils in the Antarctic. This new regulation is not expected to decrease the number of cruise ships visiting Deception Island since most of the vessels entering Port Foster Bay are smaller, specialised vessels for polar waters that already operate with light fuel. With continued growth in market demand, as large cruise ships are removed from the market, the number of voyages based on small- and medium-sized vessels is likely to increase. This could, in turn, lead to a rise in the number of visits to popular sites, including Deception Island. We expect that the growth in tourism visits to Deception Island would resume as the global economic crisis ends. This growth may take different forms. Regional warming due to climate change may lengthen the tourist season (New Zealand 2009). In addition, improved centralised planning of ship routes and landings could maximise the number of possible landings per day at popular sites. Taking the example of Whalers Bay, coordinated planning could allow two ships to arrive and land a total of 400 passengers per day. Over a season of 120 days (Lynch et al. 2010), this would equate to a total maximum of 48,000 tourist landings per season, which is two to three times greater than current numbers. While, based on current trends, there is high likelihood that growth of tourism to Deception Island will continue, unexpected changes in social values and global economy could also temper our forecasts.

Increased human visitation could lead to increases in the formation of footpaths and potential impacts on soil fauna (Tejedo et al. 2013). Wildlife may be disturbed by visits by humans or noise from vessels and vehicles (de Villiers 2008). The extent to which the seals on Deception Island are affected by human activity has not been examined. A study is currently underway to examine the stress levels of penguins on Deception Island associated with the cumulative effects arising from the continuous presence of human visitors (Pertierra unpublished data).

8.3.1.3 Marine Traffic and Accidents

Shipping traffic in the Antarctic Peninsula has increased significantly along certain routes (Lynch et al. 2010). At least two accidents have occurred in Deception Island in the last 10 years. The *MS Lyuvov Orlova* ran aground in Whalers Bay in November 2006 and had to be assisted. In January 2007 the tourist ship *MS Nordkapp* struck underwater rocks at the entrance to Foster Bay, resulting in a minor damage to its outer hull and a small oil spill (Argentina et al. 2007). To our knowledge, both events have had minimal environmental impacts. Large oil spills would potentially lead to more severe environmental impacts. Normal ship anchoring and accidental running aground could potentially damage the unique benthic fauna in Port Foster (Spain 2010a).

8.3.1.4 Introduction of Non-native Species

The Antarctic Peninsula is one of the areas of the world which is warming fastest (Turner et al. 2005, 2009; IPCC 2007). Climate change could increase the likelihood of the establishment of non-native species, whose seeds are carried to Antarctica by the increasing numbers of human visitors (Convey 2010). Due to its geothermalism and relatively high number of visitors, Deception Island is especially sensitive for colonisation (Hughes and Convey 2010). The non-native collembola *Hypogastrura viatica, Folsomia candida* and *Protaphorura* sp. have been found on Deception Island and their status of colonisation still needs to be established (Greenslade 2010). Two non-native plant species, *Gamochaeta nivalis* Cabrera and *Nassauvia magellanica* JF Gmelin have been discovered recently at Whalers Bay in an area that was frequently visited. However, whether their origins were natural or human-mediated could not been ascertained (Smith and Richardson 2011). The introduction and spreading of non-native species could substantially impact local biology leading to, in some cases, the permanent loss of existing biodiversity and community structures (Hughes et al. 2013).

8.3.1.5 Volcanic Activity

Active volcanism is an important driving force that has changed the landscape and human activity on the island. Eruptions in the late '60s early '70s devastated many buildings, including the Chilean and British stations which were not rebuilt. Scientific activity on the island was temporarily halted (Spain 2010b). The volcano is still considered to be active and it is expected that further eruptions will take place. Seismic activity is monitored during the summer season and the Deception Island Management Package contains an escape strategy in case of an eruption. Future eruptions could severely affect existing human activities.

8.3.1.6 Other Possible Developments

Other developments may also take place in the future, even though they may be considered to be unlikely in view of current conditions, For example, it is possible that other nations not currently active on Deception Island would express their interest in establishing a new station on the island, although the number of suitable sites is limited. Temporary field camps could become permanent refuges or stations. Increased visits from yachts may be difficult to regulate. The construction of a runway on Deception Island could significantly increase the amount of human activity on the island (Dibbern 2010).

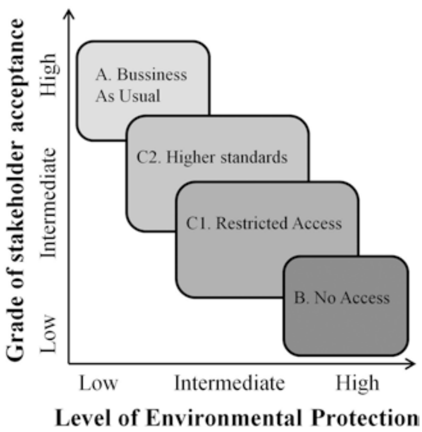
8.3.2 Future Regulatory Scenarios

Bringing together the preceding sections on human activity, regulatory mechanisms, environmental impacts, values to be protected and drivers of change, we present four future scenarios for the management of Deception Island. The four scenarios represent different points along, firstly, one continuum that ranges from lower to higher level of environmental protection and, secondly, another continuum that ranges from lower to higher likelihood of stakeholder acceptance (Fig. 8.4). Scenario A extrapolates from current trends into the future, assuming business will continue as usual. As new agreements will not be necessary, Scenario A has a higher likelihood to be accepted by stakeholders. The level of environmental protection delivered by Scenario A is expected to be lower than that of the other scenarios. Scenario B assumes that the island will be closed to all human access. While it delivers a higher level of environmental protection than Scenario A it also has a much lower likelihood of stakeholder acceptance. Scenario C proposes intermediate options that lie between the high acceptance/low protection Scenario A and the low acceptance/high protection Scenario B.

8.3.2.1 Future Scenario (A): 'Business-As-Usual'

The existing Deception Island Management Package provides a framework to coordinate science, logistic and tourism activities on the island. It has brought stakeholders together to agree on common environmental standards and has successfully promoted collaboration while avoiding direct confrontation. This way of working encourages consensus, commitment and support of regulations for the Deception Island ASMA, with implications on the wider ATS (see Braun et al. 2013). The management package aims to avoid 'unnecessary degradation and disturbance' while implicitly accepting some impacts (ATS 2005). Environmental impacts are mitigated (but not eliminated) while current legitimate activities are allowed to continue. Hence, under this scenario, necessary 'degradation and

Fig. 8.4 Comparison of four future regulatory scenarios for Deception Island



disturbance' of the environment will continue even without any increase in human activity. With time, and with the expected increase of human activity, degradation, disturbance and impacts on the environment are likely to accumulate.

Research studies, such as quantifying the extent of human-facilitated transportation of non-native species, examining the accumulation and risk of marine pollution arising from shipping traffic, analysing the effects of foot and vehicle traffic on Antarctic flora and soils and monitoring the levels of vandalism at historical sites, provide much needed scientific information on the environmental impacts of human activities on Deception Island. Many short-term studies have been conducted but a long-term, systematic and integrated monitoring system does not exist at the present. Baseline information on the current state of the island's ecosystems is sparse, with censuses and catalogues of species distribution often derived from national surveys. Site-specific guidelines stipulate the maximum number of visitors allowed, areas closed to visits, how visits to wildlife breeding colonies should be conducted and the minimum distance that humans should keep with wildlife (ATS 2011). However, effectiveness of these guidelines cannot be evaluated since there is little scientific research or monitoring on the population of the colony, its trends or the effects of human visitation on it. There is also a lack of information on the actual level of compliance to management measures. Few cases of incompliance have been officially reported (e.g. Argentina et al. 2009), although anecdotal evidence raises concern on the increase of new graffiti on historic artefacts, occurrence of occasional unauthorised entry into closed areas, the need for higher guide to visitor ratios and the lack of monitoring and supervision of small independent yacht activities (Roura 2010; Benayas unpublished data).

As the current low level of integration between information and management continues under the Business-As-Usual scenario, human impacts on Deception Island are likely to become more than minor and transitory over the long term, permanently degrading the values that are currently being protected.

8.3.2.2 Future Scenario (B): 'No Access'

In contrast to the Business-As-Usual scenario is a scenario which considers closing Deception Island to all human access, thereby avoiding further degradation of natural landscapes and values. This scenario could be created based on the necessity of giving priority to the protection of Antarctica's intrinsic, wilderness and aesthetic values as required under the Environmental Protocol—values that often receive less vocal support from human stakeholders (Liggett and Engelbertz 2013; see Neufeld et al. 2013; Roura and Tin 2013). However, under current trends of human activities and engagement in the Antarctic, there is very low likelihood that this scenario will be adopted by consensus. The establishment of a reserve with no access could impede the ongoing research work which has great interest to the international scientific community.

8.3.2.3 Future Scenario (C): 'Intermediate Protection'

In between the two extremes represented by Scenarios A and B lies a range of management options, which mixes various levels of environmental protection and likelihoods of being accepted and implemented. A first option, that we call *C1-Restricted Access*, includes the agreement among stakeholders to limit access during certain periods of time, or at certain locations. Closed areas and upper limits on number of people are strategies already in use (Tables 8.1 and 8.2) that could be extended and applied more widely. For example, maritime traffic into Port Foster could be limited to one ship per day, reducing the risk of accidents and limiting the magnitude and likelihood of environmental impacts. It could also be applied to sensitive sites such as breeding colonies or vegetated areas which have been impacted and are allowed to recover. Moreover, agreement could be reached among National Antarctic Programs to share their facilities and not to expand them any further, thereby reducing the human footprint, slowing down the process of accumulation of pollutants, and lowering the risk of introduction of non native species. However, agreement on such measures would require stakeholders' participation and commitment and therefore may be potentially more difficult to achieve.

A second intermediate scenario, *C2-Higher standards*, focuses on reducing human impacts rather than human presence. It builds upon the framework of the existing Deception Island Management Package, introducing additional standards and protocols while allowing existing human activities to continue, thereby increasing the likelihood of stakeholder acceptance. The concept of Limited Acceptable Change (LAC) has been widely used in the management of National Parks in the USA (McCool and Cole 1998) and has been proposed as a management tool for Antarctic tourism (Davis 1999; Bertram and Stonehouse 2007). Applying LAC to the case of Deception Island, stakeholders would agree on a system of indicators to be monitored and specific management actions to be implemented when trigger levels are reached. Current activities could continue to operate, but they will be delimited in order to minimise their environmental risks and keep their impacts to levels that are minor or transitory (New Zealand 2007). For example, soil compaction in a popular visitation site could be monitored and when compaction values reach a level that has been determined to significantly affect soil fauna, those areas will be temporarily closed (Tejedo et al. 2012). New protocols can be introduced under this scenario and existing activities can be adapted to meet higher environmental standards. For example, biosecurity measures for Deception Island can be developed from the general measures recommended for the Antarctic Treaty Area (summarised in Hughes and Convey 2010) but also include additional measures designed specifically to address the challenges on Deception Island. Measures that are easy to implement are more likely to be accepted and applied.

The strength of the intermediate scenarios lies in the fact that they are more likely to be implemented by stakeholders than Scenario B, while at the same time providing higher levels of environmental protection than scenario A.

However, their success relies on stakeholder involvement, systematic and continuous monitoring, scientific research and long-term commitment. Targeted research is paramount in filling in gaps on baseline information and improving understanding of key ecological relationships (Bargagli 2005; Kerry and Riddle 2009; Tin et al. 2009). A long-term integrated monitoring system can help to provide missing information, coordinate human activities, reduce duplication of research efforts and contribute towards sound science-based policy-making (Reid 2007; Hughes 2010; Klein et al. 2013; Sánchez and Njaastad 2013).

8.4 Conclusions

Deception Island is an emblematic site. It brings together protected areas, historic sites, scientific research and commercial tourism in one small space. Until now, self regulation of the tourist industry, complemented by ATS guidelines and the recommendations from the Deception Island ASMA Management Group, has been sufficient to sustain conservation of the island. One possible weakness lies in the low level of environmental monitoring and lack of characterisation of cumulative impacts for the long term. Long-term systematic environmental monitoring is a useful tool that can be developed to support decision making in the future.

The Deception Island Management Package has achieved a high level of acceptance from Antarctic Treaty parties in creating a zoning system to protect environmentally sensitive areas. It has succeeded in providing an elevated level of protection for the different values of Deception Island and it forms the basis from which future regulatory scenarios can be constructed. Looking into the future, we expect that the Deception Island Management Package would have difficulty in coping with the steadily increasing pressures from the growth of human activity and their cumulative impacts. An alternative scenario in which the island would be closed to all human access would result in no further degradation of the island's values and landscapes. This scenario represents the wilderness conservation position, being little represented in the parties involved on Deception Island and unlikely to achieve the levels of agreement needed for implementation and compliance. Between the extreme positions of these two scenarios, intermediate regulatory scenarios can be developed that can maximise the likelihood of stakeholder acceptance and level of environmental protection.

Intermediate scenarios can be based on a mixed formula that includes existing conservation strategies (such as the components in the Deception Island Management Package), additional standards of protection (including safety procedures) and limited access for vulnerable areas or critical periods. Such scenarios would allow current activities to continue while seeking commitment from all stakeholders to implement and comply with management measures and support the protection of Deception Island's values. In addition, the establishment of an early detection system would allow disturbances to the ecosystem to be detected and management measures to be implemented correspondingly. A systematic monitoring plan would be necessary in order to assess the efficiency of the policies in place and to anticipate future changes. Public awareness and involvement is a powerful tool that must be developed in the next few years. In the case of tourism, guides have an important educational role whereas National Antarctic Programs have to put in place training courses to ensure that their personnel are familiar with the management measures that are in place. The extent to which these activities will be developed will depend on the interest of Antarctic Treaty parties in furthering the protection of Deception Island and the resources made available towards this goal.

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References

Argentina, Chile, Norway, Spain, UK, USA. (2006). *Deception Island Antarctic specially managed area (ASMA) management group*. Information paper 19 presented at XXIX Antarctic Treaty Consultative Meeting, Edinburgh, UK. 12–23 June 2006.

Argentina, Chile, Norway, Spain, UK, USA. (2007). *Report of the Deception Island Antarctic specially managed area (ASMA) Management Group*. Information paper 108 presented at XXX Antarctic Treaty Consultative Meeting, New Delhi, India, 30 April–11 May 2007.

Argentina, Chile, Norway, Spain, UK, USA. (2009). *Report of the Deception Island Antarctic specially managed area (ASMA) management group*. Information paper 131 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, 6–17 April 2009.

ASOC. (2010). *Coastal hydrocarbon pollution. A case study from Deception Island, Antarctica*. Information paper 81 presented at XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay. 3–14 May 2010.

ATS. (2005). *Deception Island management package. ATCM Measure 3 (2005)*. Final report of XXVIII Antarctic Treaty Consultative Meeting, Stockholm, Sweden, 6–17 June 2005. Buenos Aires, Argentina: Antarctic Treaty Secretariat.

ATS. (2011). Site guidelines for visitors. Retrieved from: http://www.ats.aq/e/ats_other_siteguidelines.htm.

Bargagli, R. (2005). *Antarctic ecosystems: Environmental contamination, climate change, and human impact*. Berlin: Springer.

Bertram, E., & Stonehouse, B. (2007). Tourism management for Antarctica. In J. M. Snyder & B. Stonehouse (Eds.), *Prospects for polar tourism* (pp. 285–309). Wallingford: CABI Publishers.

Bó, M. S., & Copello, S. (2001). Distribution and abundance of breeding birds at Deception Island, South Shetland Islands, Antarctica, February to April 2000. *Marine Ornithology*, 29(1), 39–42.

Braun, C., Fritz, H., Mustafa, O., Nordt, A., Pfeiffer, S., & Peter H.-U. (2013). Environmental assessment and management challenges of the Fildes Peninsula region. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht: Springer.

Carpenter, S. R., Mooney, A. H., Agard, J., Capistrano, D., DeFriese, R. S., Díaz, S., Dietz, T., Duraiappahh, A. K., Oteng-Yeboahi, A., Pereira, H. M, Perringsk, C., Reid, W. V., Sarukhan, J., Scholesn, R. J., & Whyteo, A. (2009). *Procedings for National Academy of Sciences of the USA*, 106 (5), 1305–1312.

Cabrerizo, A., Dachs, J., Varceló, D., & Jones, K. C. (2012). Influence of organic matter content and human activities on the occurrence of organic pollutants in Antarctic soils, lichens, grass and mosses. *Environmental Science and Technology, 46*(3), 1396–1405.

Convey, P. (2010). Terrestrial biodiversity in Antarctica. Recent advances and future challenges. *Polar Sciences, 4*, 135–147.

Davis, P. (1999). Beyond guidelines. A model for Antarctic tourism. *Annals of Tourism Research, 26*(3), 516–533.

Dibbern, S. J. (2010). Fur seals, whales and tourists: A commercial history of Deception Island, Antarctica. *Polar Record, 46*(238), 210–221.

de Villiers, M. S. (2008). *Review of recent research into the effects of human disturbance on wildlife in the Antarctic and sub-Antarctic region.* Appendix I to Working Paper 12 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine, 2–13 June 2008.

Downie, R. (2007). Deception Island. In B. Riffenburgh (Ed.), *Encyclopedia of the Antarctic* (pp. 327–328). New York: Routledge.

Enzenbacher, D. (2007). Antarctic tourism policy-making: Current challenges and future prospects. In G. Triggs & A. Riddell (Eds.), *Antarctica: Legal and environmental challenges for the future* (pp. 155–189). London: The British Institute of International and Comparative Law.

Fretwell, P., Convey, P., Fleming, A., Peat, H., & Hughes, K. A. (2011). Detecting and mapping vegetation distribution on the Antarctic Peninsula from remote sensing data. *Polar Biology, 34*(2), 273–281.

Greenslade, P. (2010). Collembola fauna of the South Shetland Islands revisited. *Antarctic Science, 22*(3), 233–242.

Joyner, C. C., & Ewing, B. G, Jr. (1991). Antarctica and the Latin American States: The interplay of law, geopolitics and environmental priorities. *The Georgetown International Environmental Law Review, 4*(1), 1–46.

Hughes, K. A. (2010). How committed are we to monitoring human impact in Antarctica? *Environmental Research Letters, 5*, 041001. doi:10.1088/1748-9326/5/4/041002.

Hughes, K. A., & Convey, P. (2010). The protection of Antarctic terrestrial ecosystems from inter and intra-continental transfer of non-indigenous species by human activities: A review of current systems and practices. *Global Environmental Change, 20*, 96–112.

Hughes, K. A., Convey, P., & Huiskes, A. H. L. (2013). Global movement and homogenisation of biota: Challenges to the environmental management of Antarctica? In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht: Springer.

IAATO. (2001a). Tourism statistics. 1995–2000 statistics. Twelve season overview of sites visited in the Antarctic Peninsula—Part 1 (1989/90–1994/95). Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2001b). Tourism statistics. 1995–2001 statistics. Twelve season overview of sites visited in the Antarctic Peninsula—Part 2 (1995/96–2000/01). Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2002). Tourism statistics. 2001–02 statistics. Number of visitors (tourists, staff, crew) per vessel—Peninsula sites. Site landings. Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2003). Tourism statistics. 2002–03 statistics. Number of visitors (tourists, staff, crew) per vessel—Peninsula sites. Site landings. Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2004). Tourism statistics. 2003–04 statistics. Number of visitors (tourists, staff, crew) per vessel—Peninsula sites. Site landings. Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2005). Tourism Statistics. 2004–05 statistics. Number of visitors (tourists, staff, crew) per vessel—Peninsula sites. Site landings. Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2006). Tourism statistics. 2005–06 statistics. Number of visitors (tourists, staff, crew) per vessel—Peninsula sites. Site landings. Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2007). Tourism statistics. 2006–07 statistics. Number of visitors (tourists, staff, crew) per vessel—Peninsula Sites. Site landings. Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2008). Tourism statistics. 2007–08 statistics. Number of visitors (tourists, staff, crew) per vessel—Peninsula sites. Site landings. Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2009). Tourism statistics. 2008–09 statistics. Number of visitors (tourists, staff, crew) per vessel—Peninsula sites. Site landings. Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2010). Tourism statistics. 2009–10 statistics. Number of visitors (tourists, staff, crew) per vessel—Peninsula sites. Site landings. Retrieved from: http://iaato.org/es/tourism-statistics.

IAATO. (2011a). *Report on IAATO operator use of Antarctic Peninsula landing sites and ATCM visitor site guidelines, 2009–10 and 2010–11 seasons*. Information paper 105 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, 20 June–1 July 2011.

IAATO. (2011b). *Overview of Antarctic tourism: 2010–11 season and preliminary estimates for the 2011–12 season*. Information paper 106 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, 20 June–1 July 2011.

IPCC (International Panel for Climate Change. (2007). *Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the IPCC*. Cambridge: Cambridge University Press.

Kerry, K. R., & Riddle, M. (2009). *Health of Antarctic wildlife: A challenge for science and policy*. Berlin-Heidelberg: Springer.

Klein, A. G., Sweet, S. T., Kennicutt II, M. C., Wade, T. L., Palmer, T. A., & Montagna, P. (2013). Long term monitoring of human impacts to the terrestrial environment at McMurdo station. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht: Springer.

LaRue, M., Rotella, J., Garrott, R., Siniff, D., Ainley, D., Stauffer, G., et al. (2011). Satellite imagery can be used to detect variation in abundance of Weddell seals (*Leptonychotes weddellii*) in Erebus Bay, Antarctica. *Polar Biology, 34*(11), 1727–1737.

Liggett, D. H., & Engelbertz, S. (2013). Values and political decision-making: The case of Antarctic tourism. *Proceedings of 3rd Conference of the International Polar Tourism Research Network, Nain, Canada,* 17–21 April 2012.

Lynch, H. J., Crosbie, K., Fagan, W. F., & Naveen, R. (2010). Spatial patterns of tour ship traffic in the Antarctic Peninsula region. *Antarctic Science, 22*(2), 123–130.

Martin, S. (1996). *A History of Antarctica*. Sydney: State Library of New South Wales Press.

McCool, S. F., & Cole, D. N. (1998). *Proceedings—Limits of Acceptable Change and Related Planning Processes: Progress and Future Directions*. General Technical Report INT-GTR-371. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Mooney, H. A., Cropper, A., & Reid, W. (2004). The millennium ecosystem assessment: What is it all about? *Trends in Ecology and Evolution, 19*(5), 221–224.

Murray, C., & Jabour, J. (2004). Independent expeditions and Antarctic tourism policy. *Polar Record, 40*(215), 309–317.

Neufeld, E., O'Reilly, J., Summerson R., & Tin, T. (2013). Valuing Antarctica: Emerging views from international studies. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht: Springer.

New Zealand. (2007). *Environmental impact of tourism and other non-governmental activities in the Antarctic Treaty area.* Working paper 13 presented at XXX Antarctic Treaty Consultative Meeting, New Delhi, India, 30 April–11 May 2007.

New Zealand. (2009). *Past and future changes in sea ice around Antarctica*. Working paper 2 presented at Antarctic Treaty Meeting of Experts on ship-based tourism. Wellington, New Zealand, 9–11 Dec 2009.

Reid, K. (2007). Monitoring and management in the Antarctic making the link between science and policy. *Antarctic Science, 19*(2), 267–270.

Roura, R. M. (2010). *Being there: Tourist behaviour, impacts, and compliance as assessed through Antarctic tourism Web logs*. Paper presented at IPY Oslo Science Conference, Oslo, Norway, 8–12 June 2010.

Roura, R. M., & Hemmings, A. D. (2011). Realising strategic environmental assessment in Antarctica. *Journal of Environmental Assessment Policy and Management, 13*(3), 483–514.

Roura, R., & Tin, T. (2013). Strategic thinking and the Antarctic wilderness: Contrasting alternative futures. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht: Springer.

Roura, R. M., Dos Santos, M., Perez, C. M., & Tin, T. (2008). *Tourism and the human footprint at Deception Island, South Shetland Islands, Antarctica*. Paper presented at SCAR/IASC IPY open science conference. Polar research: Arctic and Antarctic perspectives in the international polar year. St.Petersburg, Russia, 8–11 July 2008.

Sánchez, R. A., & Njaastad, B. (2013). Future challenges in environmental management of National Antarctic Programs. In Tin, T., Liggett, D., Maher, P. T. & Lamers, M. (Eds.) *Antarctic futures: human engagement with the Antarctic environment*. Dordrecht: Springer.

Spain. (2010a). *Possible human impact on Deception Island*. Information paper 20 presented at XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay. 03–14 May 2006.

Spain. (2010b). *Volcanic risk on Deception Island*. Information paper 19 presented at XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay. 03–14 May 2006.

Smellie, J. L. (2001). Lithostratigraphy and volcanic evolution of Deception Island. *South Shetland Islands. Antarctic Science, 73*(2), 209–788.

Smith, R. I. L. (2005). The thermophilic bryoflora of Deception Island: Unique plant communities as a criterion for designating an Antarctic Specially Protected Area. *Antarctic Science, 17*(1), 17–27.

Smith, R. I. L., & Richardson, M. (2011). Fuegian plants in Antarctica: Natural or anthropogenically assisted immigrants? *Biological Invasions, 13*(1), 1–5.

Tejedo, P., Pertierra, L. R., Benayas, J.,Convey, P., Justel, A., & Quesada, A. (2012). Trampling on maritime Antarctica: can soil ecosystems be effectively protected through existing codes of conduct? *Polar Research, 31*,10888, http://dx.doi.org/10.3402/polar.v31i0.10888

Tejedo, P., Pertierra, L. R., & Benayas, J. (2013). Trampling the Antarctic: Consequences of pedestrian traffic on Antarctic soils.

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., et al. (2009). Impacts of local human activities on the Antarctic environment. *Antarctic Science, 21*(1), 3–33.

Tin, T., Lamers, M., Liggett, D., Maher, P.T., & Hughes, K. A. (2013). Setting the scene: Human activities, environmental impacts and governance arrangements in Antarctica. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht: Springer.

Turner, J., Bindschadler, R. A., Convey, P., Di Prisco, G., Fahrbach, E., Gutt, J., et al. (Eds.). (2009). *Antarctic climate change and the environment*. Cambridge: Scientific Committee on Antarctic Research.

Turner, J., Colwell, S. R., Marshall, G. J., Lachlan-Cope, T. A., Carleton, A. M., Jones, P. D., et al. (2005). Antarctic climate change during the last 50 years. *International Journal of Climatology, 25*, 279–294.

Chapter 9
Long-Term Monitoring of Human Impacts to the Terrestrial Environment at McMurdo Station

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Abstract The largest of the three scientific bases operated by the United States Antarctic Program (USAP), McMurdo Station has experienced numerous localised environmental impacts over its fifty-plus years of occupation. Since 1999 a long-term environmental monitoring programme has examined human impacts in the terrestrial and marine environments in proximity to the station. The programme was developed from an assessment of system attributes amenable to monitoring, an understanding of the nature of historical and ongoing environmental impacts and a consideration of the spatial scales over which impacts would be expected. While station operations continue to impact the local environment, the 'footprint' of human disturbance observed at McMurdo Station today primarily represents vestiges of historical practices. In the terrestrial environment, the impact of human activities is typically confined to within a few hundred meters of the station and contamination by petroleum hydrocarbons

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and metals are found where expected. This ongoing monitoring programme represents an important step in understanding how a legacy of human activities can affect the local environment surrounding an Antarctic scientific base. The developed framework is suitable for adaptation to other Antarctic research stations with similar physical settings and mix of human activities. The programme has provided, and will continue to provide, crucial baseline environmental information which can serve as the scientific basis for future assessments of the impact of human activities at McMurdo Station over the next 50 years.

Keywords Geographic information systems • Environmental monitoring • Petroleum hydrocarbons • Metals • McMurdo station • Soils

9.1 Introduction

McMurdo Station, Antarctica, is the largest of the three permanent scientific bases operated by the National Science Foundation's (NSF) United States Antarctic Program (USAP). Since 1999 a long-term environmental monitoring programme has examined human impacts in terrestrial and marine environments in proximity to the station. McMurdo Station, like other Antarctic bases, has experienced local human impacts (Bargagli 2005, 2008; Tin et al. 2009) and the 'footprint' of human disturbance observed at McMurdo Station today primarily represents vestiges of past practices from earlier in the station's 56 years of permanent occupation.

Station operations at McMurdo Station have varied in type, spatial extent and intensity over its history. As discussed in other chapters in this book, Antarctic governance has also changed greatly in response to evolving societal attitudes toward the environment. USAP environmental practices have mirrored these changes and over time USAP operations have been modified to reduce environmental impacts (Draggan and Wilkniss 1992). While station operations continue to impact the local environment, much of the environmental impact observed at McMurdo Station today is a legacy of former practices.

In the past 20 years, many of the most heavily impacted areas at the station have undergone remediation. This chapter outlines the development and implementation of a long-term monitoring programme focusing on the major environmental pollutants and disturbances that have impacted the terrestrial environment. The spatial extent of total petroleum hydrocarbons (TPH) and how the measured concentrations have changed over the duration of the monitoring programme are presented.

9.2 Background

McMurdo Station is located on a ~4 km^2 ice-free area at the southern tip of the Hut Point Peninsula on Ross Island (see Fig. 9.1). It is by far the largest Antarctic research station with a summer population commonly exceeding 1,000 people.

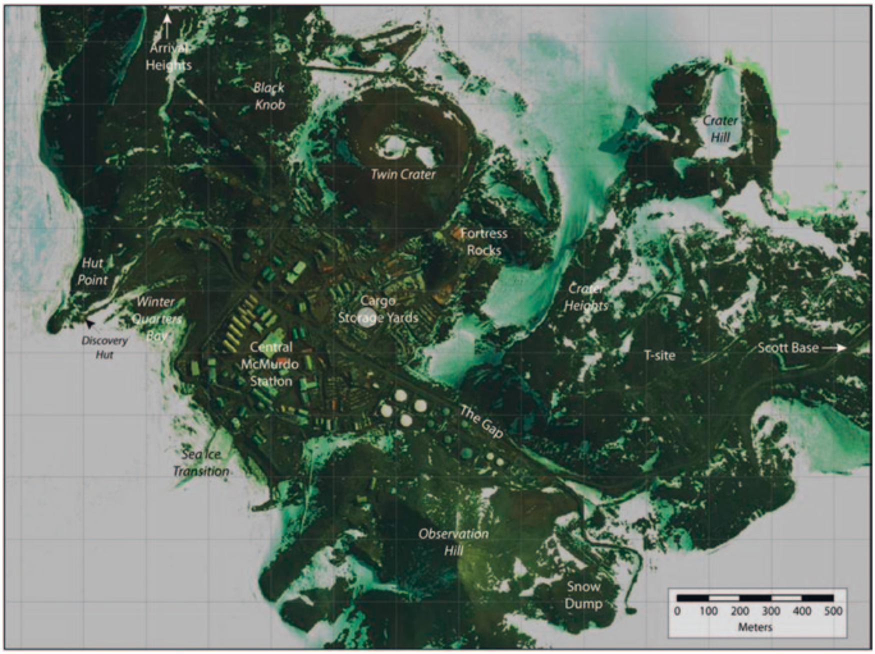

Fig. 9.1 Map of McMurdo station highlighting physical and human landmarks. The background image is a Quickbird satellite image acquired on January 1st, 2003, Copyright DigitalGlobe, Inc

Continuous human occupation began during the 1955–1956 austral summer and McMurdo Station continues to serve as the logistical hub of USAP activities today. It directly supports science operations in the McMurdo Sound region, including research in the McMurdo Dry Valleys and at Mt. Erebus, provides transportation for all personnel and materials to the Amundsen-Scott Station at the geographic South Pole, and provides logistical support for deep field science programmes. New Zealand's Scott Base is located ~2.5 km to the east of McMurdo Station. In addition to USAP personnel, some New Zealand and Italian Antarctic programme participants are transported through the station. To place this in the context of logistical activity, 2,866 passenger trips were made from Christchurch, New Zealand to McMurdo Station during the 2007–2008 season (Blaisdell, pers. comm.).

Human occupation at McMurdo Station dates to 1902 when the area served as the winter locale of Sir Robert Falcon Scott's Discovery Expedition. The historic Discovery Hut, which still stands, supported later British expeditions throughout the heroic age of Antarctic exploration. In addition to being the largest population center on the continent, this site has one of the longest legacies of continuous human occupation.

During the time that the United States has operated McMurdo Station, a number of environmental impacts have occurred. Fuel storage, handling and use have all led to localised soil contamination across the station. Prior to 1980 solid waste at McMurdo Station was disposed of in the Winter Quarters Bay landfill located along the bay's eastern edge. Combustible materials were burned at the southern end of the site while non-combustible waste was staged on the adjacent sea ice. Depending on sea ice conditions, during some years the material drifted out to sea while other years it sank into the bay (Chiang et al. 1997). After 1980, Fortress Rocks landfill became the primary waste disposal area and open burning of waste was practiced until 1991 (Crumrine 1992).

Both dump sites have been remediated and/or capped. Smaller trash disposal sites were located across McMurdo Station and most of these small sites have also been remediated. Today all materials are either consumed or retrograded off-continent for recycling or disposal. Chiang et al. (1997) provide a thorough review of pollution abatement at McMurdo Station. In addition, much of the ice-free landscape in close proximity to the station has experienced extensive surface scraping to obtain fines for construction activities. The development and environmental history of McMurdo Station is summarised in Klein et al. (2008).

9.3 History of the Environmental Monitoring Programme at McMurdo Station

As the location with the largest human presence on the continent, McMurdo Station is selected as the initial site for the development and testing of a long-term environmental monitoring programme. The intent was to apply the principles and lessons learned from this programme to the monitoring of other science activities and operations elsewhere on the Antarctic continent. It was also recognised that significant expertise and experience existed on environmental monitoring in temperate climates that could be customised to the special challenges of the Antarctic environment.

The long-term environmental monitoring programme has four main goals. The first was to establish the areal extent of disturbance associated with different environmental contaminants/disturbances and through continued monitoring determine if these impacted areas, hereafter referred to as 'footprints' are spatially and/or temporally changing. These observations provide feedback to management by quantitatively assessing the effectiveness of management decisions.

The second goal is to assess whether historically, 'heavily impacted areas' were stable. Stability infers that the footprint has the same or less areal extent over time. These studies focused on contaminated areas such as landfills or where fuel spillage had occurred in the past.

The third goal is to confirm the utility of various indicators to unambiguously provide assessments of effects by specific activities through the measurement of variables explicitly linked to a particular human activity such as TPH contamination resulting from fuel spills. The intent is to provide information to management to determine if changes in operating procedures are needed to reduce or minimise the footprint of potential stressors as evidenced by either a biological or ecological response.

Finally, the fourth goal is to provide an estimate of the overall health of the system for management and decision making. An important consideration is how monitoring information is communicated to and used by management.

The current monitoring programme was developed after an extensive multi-year effort guided by the findings of a series of national and international workshops. The programme also incorporated previous findings about the local McMurdo Station terrestrial and marine environment and documented environmental issues. In 1989, the NSF sponsored the 'USAP Environmental Monitoring Workshop' Workshop which addressed various issues related to environmental protection in Antarctica. At this time NSF also examined the legal foundations for US environmental efforts in Antarctica (NSF 1989) and began developing an environmental philosophy for USAP (Draggan and Wilkniss 1992).

In 1995 and 1996, two environmental monitoring workshops were conducted and their combined results were jointly published by Scientific Committee on Antarctic Research (SCAR) and the Council of Managers of National Antarctic programs (COMNAP) in the report 'Monitoring of Environmental Impacts from Science and Operations in Antarctica' (Kennicutt et al. 1996). These workshops guided what would develop into the environmental monitoring programme at McMurdo Station.

Building on the outcomes of these two workshops, technical documents tailored specifically to creating an environmental monitoring programme at McMurdo Station identified and outlined the appropriate. 'Spatial and temporal scales of monitoring' (Kennicutt and Wolff 1998) and 'System attributes amenable to long-term monitoring' (Kennicutt et al. 1998a).

These foundational documents were influenced by numerous basic and applied environmental studies undertaken at McMurdo Station through the 1990s and summarised this historical data (Kennicutt et al. 1998b). Key among these were a 1991 preliminary environmental assessment conducted by Argonne National Laboratories (ANL) that included soil sampling at 'heavily impacted' sites to determine the type, concentration and distribution of contaminants to assess whether past, and ongoing human activities were negatively effecting the environment (ANL 1992). An initial survey of petroleum hydrocarbons over a portion of McMurdo Station in 1994 (Chiang et al. 1997) also guided the initial terrestrial sampling design. All of this was undertaken to inform a pilot project design (Kennicutt et al. 1999).

9.4 Pilot Project Phase (1999–2002)

9.4.1 Background

A pilot environmental monitoring program was undertaken from 1999 to 2002 to test and revise the design elements. During this period both the terrestrial and marine environment were extensively sampled. A number of different matrices were examined (soil, marine sediment, sea ice, marine water column and run-off) to determine their amenability to long-term monitoring. Different sampling designs were tested to select a sampling strategy appropriate for a sustainable long-term environmental monitoring programme (Morehead et al. 2008).

The programme had the advantage of knowledge of what substances have been used on station and considerable information on soil contamination was identified in previous studies. It was therefore unnecessary to analyse for contaminants that were never used on the station. Based on this prior knowledge, analysis of contaminants in soils during the pilot programme focused on (1) a commonly used gross measure of hydrocarbon content known as total petroleum hydrocarbons and (2) a fairly common suite of metals (Al, Ba, Be, Ca, Cd, Co, Cu, Fe, Mg, Mn, Na, Ni, V, Zn, Pb and Hg) that result from human activities. Ancillary measurements of grain size, total organic carbon (TOC), and total inorganic carbon (TIC) were used to normalise the measured concentrations for variations in properties among samples as is common in temperate monitoring programmes.

Although the programme's marine component had a strong focus on benthic ecology, the terrestrial component focused on physical disruption of the surface and chemical contamination of soils because of the limited indigenous, terrestrial flora and fauna at the station. While it is known that human activities have introduced microbial species into the local McMurdo Station area and have altered microbial habitat (e.g. White 1978), the resident soil community of microbial and soil invertebrates is limited. Because the soil ecosystems are limited and the literature on the toxicity effects of our measured contaminants to these polar organisms is sparse, the monitoring programme does not directly assess contaminant impacts on soil organisms.

Physical disturbance at the station, scraping of land surfaces during construction, removed most local communities of lichens and mosses rendering them unsuitable for inclusion in a monitoring programme. Outside of the Brown Skua (Stercorarius Antarctica) no significant mammalian or avian habitats exist near the station so monitoring of contaminant levels in these organisms was not included as part of the terrestrial monitoring programme. Nor was it deemed necessary to monitor for invasive species.

The local McMurdo Station soils sampled as part of the programme are volcanic in nature and while they lack a biological component, these physically weathered materials are still justifiably termed soils (Campbell and Claridge 1987). Crockett (1998) identified two general soil types at McMurdo Station. The most spatially extensive is a gray soil composed of sand and gravel. The second, a red soil, is a crushed red oxidised scoria. The red soil is used for building soil and covering the station's ice pier, while the gray soil is used for roadways due to its greater cohesiveness. Prior to extensive surface scraping, much of the McMurdo Station area was underlain by a deflation lag as noted by early British explorers (Taylor 1922) but it has been extensively removed by scraping. In addition, much of the local area was covered by sand-wedge polygons, which are a ubiquitous periglacial feature in ice-free areas in the McMurdo Sound region (Péwé 1959; Taylor 1922), but these have been destroyed over most of the area adjacent to the station.

9.4.2 Methods

During the pilot programme over 1,500 soil samples and forty-eight runoff samples were collected in the local McMurdo Station area. Samples were collected using several different sampling schemes. Overall patterns of soil contamination were examined.

The pilot programme developed the following sampling methodology. Each of the 1,500+ locations was identified in the field using real-time differentially corrected Global Positioning System (GPS). At each site, a 1 m^2 area was characterised, photographed and sampled. The sampling's primary limitation was that the top of the ice-cemented ground typically lies within a few centimeters of the surface. The considerable physical effort required to disaggregate the frozen soil for sampling, typically limits sampling to the upper few centimeters of the soil and frequently requires the collection of available non-ice cemented soil. All soil samples were stored in pre-cleaned 250 ml glass jars. In the field a number of observations were initially planned to characterise the site including, depth to ice-cemented ground, snow depth, percentage of snow and vegetation in the 1×1 m sampling area, and a qualitative assessment of the level of disturbance. A photograph of each site was also taken.

Soils and sediments were transported back to the US for extraction and for organic and trace element analyses. The sample was extracted using an accelerated solvent extractor (Dionex ASE200) with methylene chloride, purified using alumina/silica (80–100 mesh) column chromatography, and solvent exchanged to hexane. Surrogates were added prior to extraction. For TPH, the sample was analysed by gas chromatography with flame ionization detection (FID). The instrument is calibrated with alkane standards and the detector response is summed to determine the total petroleum hydrocarbons present (Kennicutt et al. 1992, 2010).

9.4.3 Preliminary Results

The major outcome of the pilot project was to determine the sampling design to employ during long-term monitoring and select the suite of measurements most useful for characterizing contamination at the station. The selected approach is discussed in the following section. In addition, the pilot programme identified several revisions to the design to minimise the time and effort required and to ensure a cost-effective monitoring programme is undertaken. Runoff sampling was found to be difficult as flow volumes vary widely through space and time making results difficult to interpret so runoff sampling was not included as a routine element of the programme. The extensive disruption of the surface observed over nearly all of the sampling area has removed most vegetation in the area making it difficult to utilise any qualitative metric to describe physical impacts on the surface. Consequently measures of disturbance levels and vegetation amounts were dropped as routine observations as vegetation is nearly nonexistent and physical disturbance is so widespread to make these metrics uninformative.

Analytically, the pilot programme demonstrated that grain size, TOC and TIC were not useful measurements for interpreting terrestrial data and were discontinued. Analytical methods used for metals have also been adjusted over the years, analysis for sodium and calcium were discontinued while chromium and arsenic were added to the list of contaminants analysed and, with the exception of mercury, all samples were analysed using an inductively coupled plasma mass spectrometer (ICP/MS).

The most significant alteration to the proposed approach dealt with the level of analysis conducted on site. Initially, it was planned to do TPH extractions and analysis on site. However, this approach was not practical due to the number of samples and the per sample analysis time involved. Instead, terrestrial soil samples were shipped to an US-based laboratory frozen at −20 °C. This approach met the programme's analytical requirements while minimizing the programme's impact on station operations and science by limiting the time spent on station. In addition, solvent use and disposal on site was eliminated.

9.5 Long-Term Monitoring Phase (2003 – Present)

Based on the lessons learned from the pilot phase, a stratified random sampling scheme was selected as the appropriate sampling approach for the long-term monitoring of soils. The sampled area around the station was enlarged to include areas impacted by station activities but excluded from the initial samplings. With the exception of areas of ice cover or steep slopes, a grid of 4,460 hexagons with an edge-to-edge diameter of 25 m was placed over the area of McMurdo Station. Each year since 2003, 70 of these hexagons were randomly selected and sampled to characterise overall soil contamination at the station. In addition to the 70 random sampling sites, in 6 to 8 hexagons, 16 soil samples were collected to more intensely sample sites to better characterise historic or ongoing contamination (e.g. refueling station, heavy machine shops, helicopter pad). For both the random and intensive sites, power analysis indicated that this number of samples was suitable to detect a doubling of chemical contaminants from one sampling to the next. The current method results in approximately 250–300 soil samples being collected each year. As an example, the sampling locations in 2010 are illustrated in Fig. 9.2.

In addition to the chemical analysis, the monitoring programme continues to utilise USAP operational data to maintain and update a database of station infrastructure to track the construction and removal of buildings and fuel tanks within a Geographic Information System (GIS). Relevant aerial photography and satellite imagery are used as another means of documenting changes occurring on the station.

9.5.1 Results

An overview of the findings of the McMurdo Station environmental programme are summarised in Kennicutt et al. (2010). Therefore this chapter focuses on two

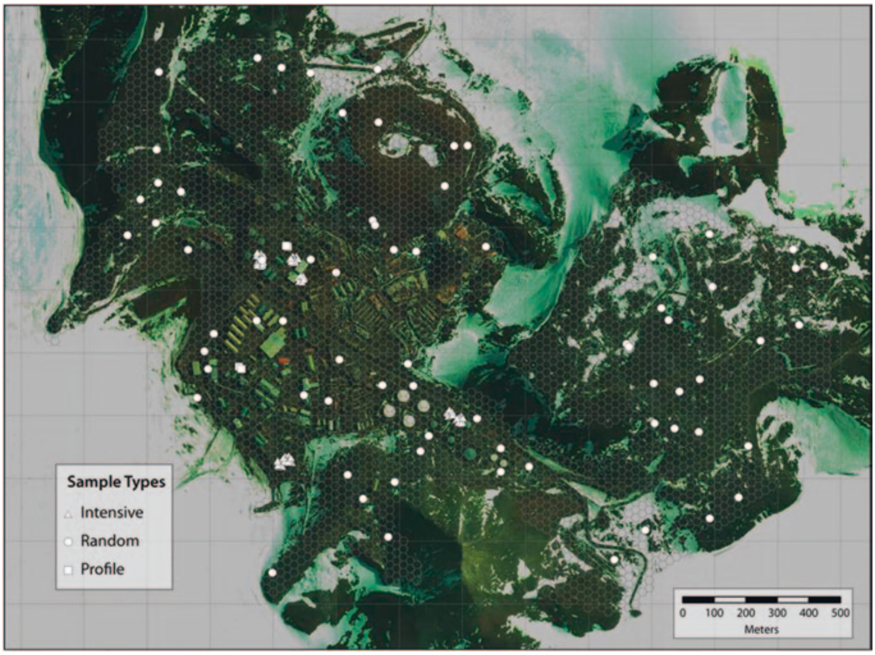

Fig. 9.2 Terrestrial sampling locations at McMurdo Station in 2010. *Triangles* indicate intensive sampling sites, *circles*: random sampling sites and *squares*: locations where depth profiles were sampled. The *hexagonal* sampling grid is shown in *gray*. The background image is a Quickbird satellite image acquired on January 1st, 2003, Copyright DigitalGlobe, Inc

localised environmental impacts, (1) the physical disturbance of the station and (2) TPH as illustrative of environmental impacts in the terrestrial environment near the station. McMurdo Station has experienced similar environmental contamination documented at other Antarctic stations (Bargagli 2005, 2008; Tin et al. 2009).

9.5.1.1 Physical Disturbance

The approximately 4 km^2 ice free area surrounding McMurdo Station has experienced extensive physical disturbance over the station's history due to activities such as construction of buildings and roads, cargo and fuel storage, landfilling and scraping of the surface to obtain building fill. The areas impacted by these activities have been tracked through mapping discussed in detail in Klein et al. (2008). Briefly, this mapping utilised aerial photography of the station and was accomplished by overlaying a hexagonal grid composed of individual 50 m diameter hexes on the geo-rectified aerial photographs. The date when the first significant disturbance was visible in each hexagon was recorded (see Fig. 9.3). Most of the disturbance had occurred by the 1970s as major construction to establish a

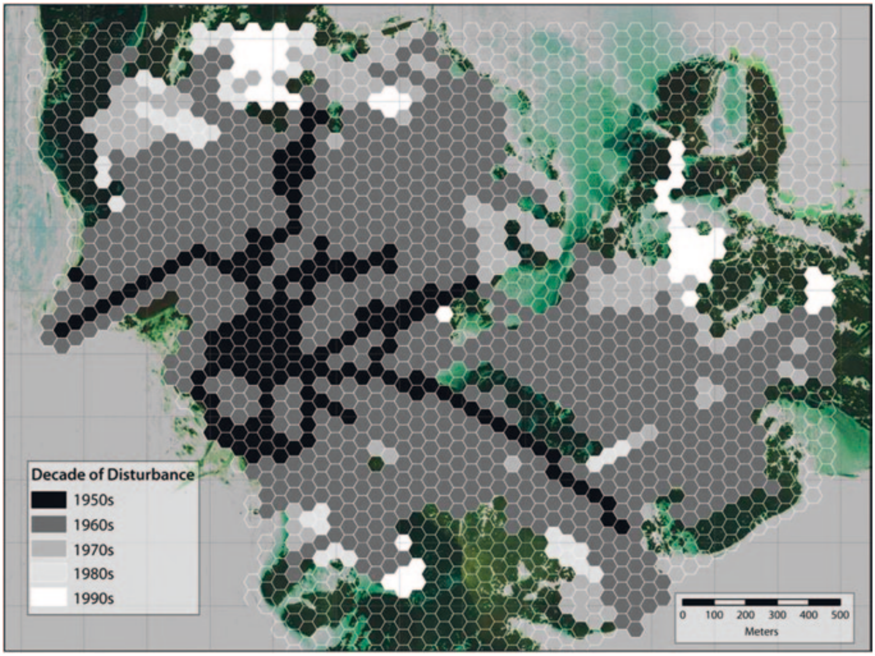

Fig. 9.3 Map showing the decade in which physical disturbance of the landscape was first observed in aerial photographs of the station. The background image is a Quickbird satellite image acquired on January 1st, 2003, Copyright DigitalGlobe, Inc

permanent station was largely completed. By 1980 approximately 2.5 km^2 of the area near McMurdo Station had experienced some sort of disturbance. The spatial extent of physical disturbance has been relatively stable for 30 years.

9.5.1.2 Petroleum Hydrocarbons

Petroleum hydrocarbons are by far the largest potential environmental contaminant by volume in USAP operations. In recent years, approximately 8.5 million liters (2.25 million gallons) are consumed each year at the station (NSF 2004). Potential pathways for contamination at McMurdo Station include the transfer of fuel during offload from tanker ships to bulk storage tanks and subsequent transfer to airfields as well as refueling of vehicles and storage tanks associated with heating for individual buildings. Emissions and leakages from fixed-wing aircraft and helicopters as well as from the station's vehicle fleet also occur. While current protocols require notification and remediation of any amount of spillage, they were not in place over much of the station's history. Consequently, traces of petroleum hydrocarbons are found across the station.

The terrestrial component of the monitoring programme measures TPH, which is a gross measure of hydrocarbons in the carbon range C_{10}–C_{35}, within the soil, and includes hundreds of hydrocarbon compounds. While the marine component of the programme also analyses for selected hydrocarbons including alkanes, organochlorine compounds and aromatic hydrocarbons, for soils, TPH provides a measure of petroleum hydrocarbon contamination. Because TPH measures a complex and variable mix of compounds it is difficult to determine a TPH concentration that would be expected to elicit a biological response and few studies of biological responses to contaminants have been undertaken on the continent (Alberta Environment 1993; Powell et al. 2005; Thompson et al. 2007). Therefore, the general approach taken has been to compare TPH concentrations measured on-station to off-station control sites and typically a conservative threshold of 30 ppm has been taken to represent background TPH concentrations.

At most locations at McMurdo Station, measured TPH is low with concentrations being within two standard deviations of that measured at off-station control sites. Less than 12 % of the samples collected exceed 100 ppm. Spatially, contamination occurs in patches 10s to 100s of meters in size. Geospatial analysis, including the probability kriging illustrated in Fig. 9.4, indicates that spatial autocorrelation in TPH extends only over distances of 35–70 m (Klein et al. 2012).

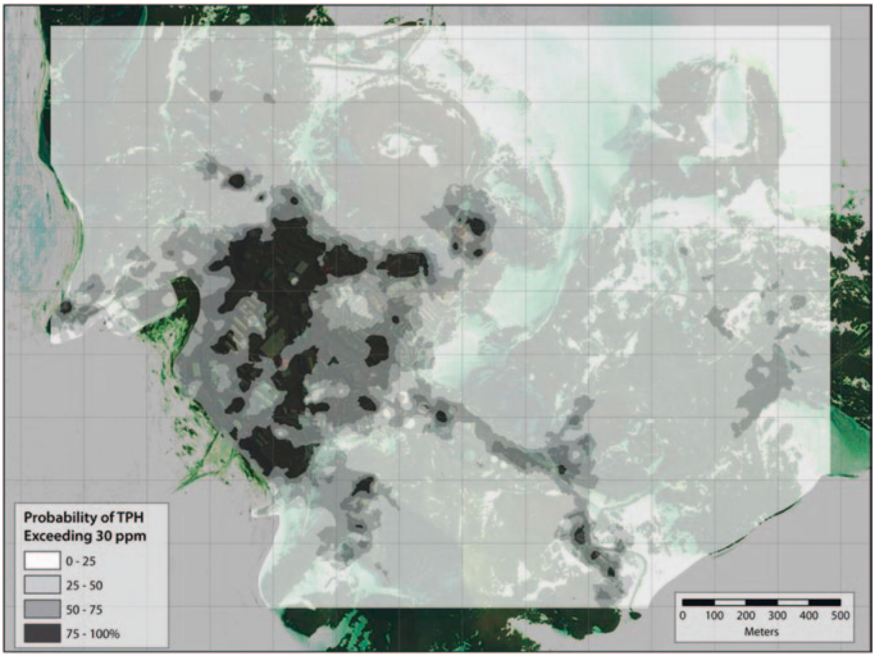

Fig. 9.4 Map illustrating the probability of soil TPH exceeding 30 ppm. The background image is a Quickbird satellite image acquired on January 1st, 2003, Copyright DigitalGlobe, Inc

Areas with the greatest probability of fuel exceeding background levels (and also the highest levels of contamination) occur in areas were fuel is or has been stored or utilised on station (see Fig. 9.4). These measured hydrocarbons are typically biodegraded except in areas of recent spillage. While soil sampling is limited to the upper 5 cm of the surface, a few profiles to 20–40 cm depth have been analysed. It does not appear that the spatial patterns or concentrations of TPH at the station would vary markedly if samples were collected at a greater depth.

The spatial heterogeneity of soil TPH makes it difficult to sample an area the size of the disturbed area at McMurdo Station on an annual basis at a reasonable cost. However, the 70 random samples collected each year permit investigation of trends in soil TPH levels over the duration of the study. As illustrated in Fig. 9.5, average TPH levels measured at three off-station control sites are less than 10 ppm with the variability among samples on the order of a few ppm. With the exception of Arrival Heights, median TPH concentrations at the control sites were typically under 2 ppm. In contrast, average soil TPH concentrations measured at McMurdo Station during the implementation phase beginning in 2003 typically varied between 45 and 65 ppm while median values ranged between 1 and 20 ppm. While TPH concentrations at McMurdo Station were elevated over

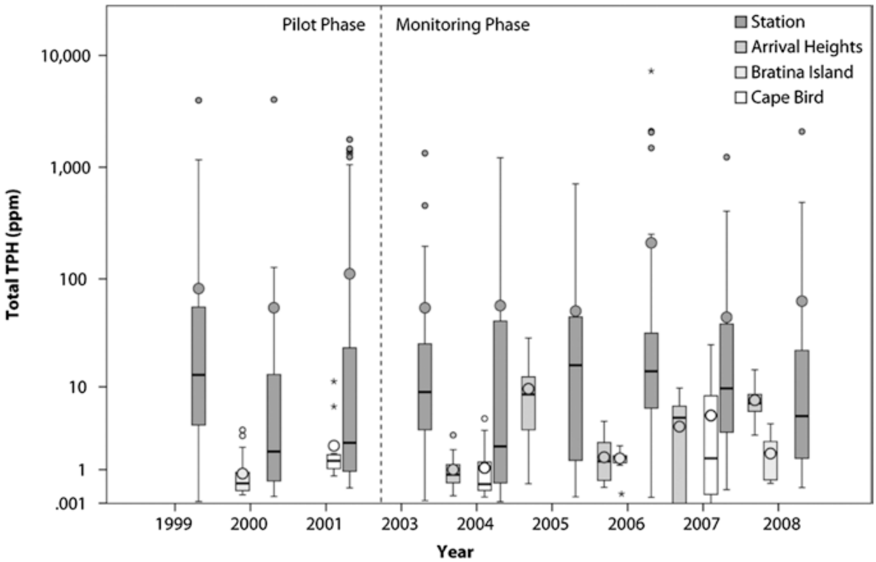

Fig. 9.5 Total Petroleum Hydrocarbons (*TPH*) measured at randomly located sites at McMurdo Station from 1999 through 2008 and at various off-station control sites (Arrival Heights, Bratina Island, Cape Bird). The box and whiskers plot indicates the median and inner and outer quartile ranges as well as the range of values excluding outliers. Outliers are indicated by small *circles* and *stars*. Mean TPH concentrations are indicated by the *large circles*. The Pilot Phase and Monitoring phase TPH values are not strictly comparable as different sampling strategies were tested during the pilot phase

control sites, typical TPH measured at the station was relatively low with much of the area having soil TPH concentrations at or near background levels. The higher average levels (211 ppm) in 2006 are due to four of the random samples having TPH concentrations in excess of 1,400 ppm and one in excess of 7,000 which illustrates the patchiness of the TPH distribution across the station. However, there is no indication that soil TPH levels increased during the course of the study.

9.5.1.3 Metals

While petroleum hydrocarbons are the major contaminant at McMurdo Station, metals are a secondary source of contamination. Numerous studies have documented that the metals contributing to local contamination in Antarctica are copper, lead, zinc, cadmium, mercury and arsenic (e.g. Tin et al. 2009). Our findings are similar for McMurdo Station. For the selected suite of metals that are annually analysed, lead is the metal that most commonly exceeds background concentrations. Nearly 60 % of the samples collected at McMurdo Station have soil lead concentrations two standard deviations or more, above the mean concentration measured at off-station control sites. Arsenic, mercury and zinc were the only other metals in which greater than 10 % of the samples collected at the McMurdo exceeded background levels. While the spatial footprints of contaminants varied, elevated concentrations were primarily limited to areas with historic or ongoing activities, such as landfilling that could be expected to introduce metals into the environment.

9.6 Conclusions

A cost-effective environmental monitoring programme has been ongoing at McMurdo Station since 1999 and continues today. The monitoring programme's current design was developed and modified based on a thorough assessment of system attributes amenable to monitoring, an understanding of the nature of historical, and ongoing environmental impacts at the sites and consideration of the spatial scales over which impacts would be expected.

Based on the programme's findings to date, the spatial extent of human activities at McMurdo Station is typically limited to a few hundred meters within the station. Contamination by petroleum hydrocarbons and metals is found in expected areas. At McMurdo Station, much of the physical disturbance of the local landscape occurred in the early years of station operation which is reflected in the observed chemical contaminants. Overall soil TPH levels do not appear to be increasing on station and *in situ* degradation of hydrocarbons is occurring. However, because the rates of natural removal of contaminants in cold climates are slow, as is recovery of the landscape from physical disturbance, environmental monitoring at the station needs to be a long-term effort.

The environmental monitoring programme underway at McMurdo Station is an important step in understanding how a 50-year legacy of human activities has affected the local environment surrounding one of Antarctica's largest scientific bases. The programme can serve as an example for future monitoring efforts, as the developed monitoring framework is suitable for adaptation to other Antarctic research stations with similar physical settings and mix of human activities.

The understanding of the levels and spatial patterns of contamination patterns developed as part of this, and similar, monitoring programmes can help inform the decision-making process of the managers of national Antarctic programs in order to minimise future impacts of scientific activities and operations on the environment. The programme has provided, and will continue to provide, crucial baseline environmental information which can serve as the scientific basis for future and ongoing assessments of the impact of human activities at McMurdo Station.

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References

Alberta Environment. (1993). *Use of gross parameters for assessment of hydrocarbon contamination in soils in Alberta*. Alberta: Alberta Environment.

ANL. (1992). *Final report, preliminary site investigation at McMurdo Station, Ross Island, Antarctica*. Washington, D.C: Prepared by Argonne National Laboratory for the National Science Foundation.

Bargagli, R. (2005). *Antarctic ecosystems: Environmental contamination, climate change, and human impact*. Berlin: Springer.

Bargagli, R. (2008). Environmental contamination in Antarctic ecosystems. *Science of the Total Environment, 400*, 212–226.

Campbell, I. B., & Claridge, G. G. C. (1987). *Antarctica: Soils, weathering processes and environment*. Amsterdam: Elsevier.

Chiang, E., Chang, S.C., & Brown, A.J. (1997). Pollution abatement at McMurdo Station, Antarctica. In: Seventh (1997) International Offshore and polar Engineering Conference (pp. 572–578). Honolulu, USA: The International Society of Offshore and Polar Engineers.

Crockett, A. B. (1998). Background levels of metals in soils, McMurdo Station, Antarctica. *Environmental Monitoring and Assessment, 50*, 289–296.

Crumrine, K.Z. (1992). Surface remediation at McMurdo Station, Antarctica. In: *Proceedings of the fifth symposium on Antarctic logistics and operations* (pp. 41–60). San Carlos de Bariloche, Republica Argentina.

Draggan, S., & Wilkniss, P. (1992). An operating philosophy for the US Antarctic program. *Marine Pollution Bulletin, 25*, 250–252.

Kennicutt, M. C. II, & Wolff, G. A. (1998). *Spatial and temporal scales of monitoring*. College Station, TX: Geochemical and Environmental Research Group, Texas A&M University.

Kennicutt, M. C. II, McDonald, T. J., Denoux, G. J., & McDonald, S. J. (1992). Hydrocarbon contamination on the Antarctic Peninsula: I. Arthur harbor–subtidal sediments. *Marine Pollution Bulletin, 24*, 499–506.

Kennicutt, M. C. II, Sayers, J. C. A., Walton, D., & Wratt, G. (1996). *Monitoring of environmental impacts from science and operations in Antarctica, a report for the scientific committee on Antarctic research (SCAR) and the council of managers of national Antarctic programs (COMNAP)*. Norway and College Station, Texas USA: Oslo.

Kennicutt, M. C. II, Wolff, G. A., & Alsup, D. (1998a). *System attributes amenable to long term monitoring*. College Station, TX: Geochemical and Environmental Research Group, Texas A&M University.

Kennicutt, M. C. II, Wylie, D. J., & Wolff, G. A. (1998b). *Summary of existing environmental data McMurdo Station, Antarctica*. College Station, Texas: Geochemical and Environmental Research Group, Texas A&M University.

Kennicutt, M. C. II, Wolff, G. A., Alsup, D., & Klein, A. (1999). *Long-term monitoring McMurdo Station, Antarctica, pilot project design*. College Station, TX: Geochemical and Environmental Research Group and Department of Geography, Texas A&M University.

Kennicutt, M. C. II, Klein, A., Montagna, P., Sweet, S., Wade, T., Palmer, T., et al. (2010). Temporal and spatial patterns of anthropogenic disturbance at McMurdo Station, Antarctica. *Environmental Research Letters, 5*, 034010.

Klein, A., Kennicutt, M. C. II, Wolff, G., Sweet, S., Bloxom, T., Gielstra, D., et al. (2008). The historical development of McMurdo Station, Antarctica, an environmental perspective. *Polar Geography, 31*, 119–144.

Klein, A.G., Sweet, S.T., Wade, T.L., Sericano, J.L., & Kennicutt, M.C. II. (2012). Spatial patterns of total petroleum hydrocarbons in the terrestrial environment at McMurdo Station, Antarctica. *Antarctic Science*. http://dx.doi.org/10.1017/S0954102012000429.

Morehead, S., Montagna, P. A., & Kennicutt, M. C. II. (2008). Comparing fixed-point and probabilistic sampling designs for monitoring the marine ecosystem near McMurdo Station, Antarctica. *Antarctic Science, 20*, 471–484.

NSF. (1989). *Strategy for compliance with environmental law in Antarctica: A report to the director from the office of the general council*. Washington, DC: National Science Foundation.

NSF. (2004). *United States Antarctic Program Master Permit, Permit Number 2005 WM-001*. Arlington, Virginia: National Science Foundation.

Péwé, T. L. (1959). Sand-wedge polygons (tesselations) in the McMurdo sound region, Antarctica: A progress report. *American Journal of Science, 257*, 545–552.

Powell, S. A., Snape, I., Bowman, J. P., Thompson, B. A. W., Stark, J. S., McCammon, S. A., et al. (2005). A comparison of the short term effects of diesel fuel and lubricant oils on Antarctic benthic microbial communities. *Journal of Experimental Marine Biology and Ecology, 322*, 53–65.

Taylor, G. (1922). *The physiology of the McMurdo sound and granite harbour region*. London: Harrison and Sons, Ltd.

Thompson, B. A. W., Goldsworthy, P. M., Riddle, M. J., Snape, I., & Stark, J. S. (2007). Contamination effects by a 'conventional' and a 'biodegradable' lubricant oil on infaunal recruitment to Antarctic sediments: A field experiment. *Journal of Experimental Marine Biology and Ecology, 340*, 213–226.

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., et al. (2009). Impacts of local human activities on the Antarctic environment. *Antarctic Science, 21*, 3–33.

White, G. J. (1978). *Microbial ecology of terrestrial Antarctica/are microbial systems at risk from human activities?* Idaho: Idaho Falls Idaho National Engineering Laboratory.

Part II
Regional Case Studies

Summary

The regional case studies in this book represent three models of human engagement with the environment, including different human activities, levels of stakeholder collaboration, and environmental management systems. In Chap. 7, Braun et al. focus on Fildes Peninsula, a region used by more than ten Antarctic Treaty parties for the purposes of conducting Antarctic research. This region is also frequented by tourism operators. The authors point out that there is insufficient coordination and cooperation between parties with significant duplication of research efforts. Visitors and National Antarctic Program staff working on Fildes Peninsula lack knowledge of environmental vulnerability, and existing international environmental obligations and measures are not enforced. As a result, environmental impacts and the human footprint on Fildes Peninsula are rapidly growing, and extensive and irretrievable damage to the local ecosystem is expected under a Business-As-Usual future. The authors urge that establishing an Antarctic Specially Managed Area would represent an important regulatory step in steering the region towards a more sustainable future.

In Chap. 8, Pertierra et al. focus on Deception Island where six countries work and manage the island collectively as one single Antarctic Specially Managed Area under the Deception Island Management Package. The authors postulate that the management package has been successful in bringing stakeholders, including the tourism industry, together to agree on common environmental standards, as well as encouraging consensus, commitment and support of regulations, while avoiding direct confrontation. The management package aims at avoiding 'unnecessary degradation and disturbance' while implicitly accepting some impact resulting from human activity. Hence, with time, and with the expected increase of human activity under a Business-As-Usual scenario, degradation, disturbance and impacts on the environment are expected to accumulate. The development of a long-term, systematic and integrated monitoring system and scientific research on the effectiveness and compliance of visitors' guidelines and other management

measures are suggested as important ways to address these future impacts in a pro-active manner.

In Chap. 9, Klein et al. focus on McMurdo station, which is used and managed by one single Antarctic Treaty Party—The United States of America. Human occupation dates to 1902 and McMurdo is the largest population center on the continent. McMurdo has experienced similar environmental contamination documented at other Antarctic stations: petroleum hydrocarbons and metals are major contaminants. The extensive disruption of the surface observed over nearly all of the sampling area has removed most vegetation in the area. A successful monitoring programme for McMurdo station has been put in place in 1999. The programme had four goals: (i) establish the areal extent of disturbance, (ii) assess the stability of heavily impacted areas, (iii) confirm the utility of various indicators to provide assessments of effects by specific activities and (iv) provide an estimate of the overall health of the system for management and decision making. In addition to providing baseline environmental information for McMurdo, this monitoring programme serves as an example that can potentially be adapted for use at other Antarctic research stations with similar physical settings and mix of human activities. The authors highlight that because the rates of natural removal of contaminants in cold climates are slow, as is recovery of the landscape from physical disturbance, environmental monitoring in the Antarctic needs to be a long-term effort.

Regional case studies can be regarded as small-scale experimental test beds from which lessons can be learned and applied to the wider Antarctic Treaty area, where 29 Antarctic Treaty Consultative Parties partake in governance efforts. As Chaps. 7 and 8 indicate, collaboration among, and co-ordination between, parties is paramount in ensuring that environmental standards are observed and respected. Chapter 9 demonstrates the feasibility and value of a long-term multi-indicator monitoring programme. Together, these chapters highlight a number of elements that are necessary in ensuring effective management of human activities and their environmental impacts. First, the collection of baseline data and an improved understanding of ecological processes and human impacts are important. Second, consensus and co-ordination is needed to implement management decisions, particularly in regions where multiple National Antarctic Program are active or where multiple human activities are undertaken by a mix of governmental and non-governmental parties. Finally, ongoing monitoring is essential to assess the effectiveness of management decisions, to ensure compliance and to further improve our understanding of human impacts.

Part III
Actors and Sectors

Chapter 10
Valuing Antarctica: Emerging Views from International Studies

Erin Neufeld, Jessica O'Reilly, Rupert Summerson and Tina Tin

Abstract In 2011, many countries celebrated the 50th anniversary of the coming into force of the Antarctic Treaty to which 50 countries have now acceded. The Treaty grew out of the success of the International Geophysical Year (1957–1959) and, as a consequence, science has been the principal motivation for engagement with Antarctica, at least overtly. The dominance of science in Antarctic Treaty forums has led to an evidence-based management paradigm, which has many positive aspects but has led to different values being underplayed. People have associated numerous meanings with Antarctica: as a scientific laboratory, a potential source of resources, a source of political influence and as a wilderness, amongst other things. As such, Antarctica has many values, several of which have been recognised, at least implicitly, by the Antarctic Treaty and others explicitly by the Protocol on Environmental Protection to the Antarctic Treaty. In this chapter, we describe the limited research carried out in the past on values in Antarctica, and we discuss the results of four recent multi-national studies of the values people attribute to Antarctica. These studies reveal several consistent themes, including

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the widespread value most people hold of the Antarctic wilderness and their desire to protect it. We discuss three possible scenarios for how the management of Antarctica could evolve: Business-As-Usual, Antarctic Sanctuary and World (Resources) Bank. How these or any other scenarios develop will be largely influenced by the values people ascribe to the region. Here, the results of our studies indicate that proactive management actions will strengthen some values, while reactive wait-and-see attitudes towards the protection of certain values, as in the case of wilderness values, are *de facto* decisions supporting the attrition of these values.

Keywords Antarctic values • Wilderness • Intrinsic values • Instrumental values • Extrinsic values

10.1 Introduction

Value is a term which has many meanings across disciplines.[1] In social psychology, it is the conventional way to express how people interact with and behave towards other people, objects and places (Kluckhohn 1951; Rokeach 1973; Schwartz 1992). Antarctica is no exception; it has been variously viewed, among other things, as a *terra incognita* to be discovered, a potential store of resources, a natural laboratory for science, and, as a wilderness to be experienced and protected (e.g. Beaglehole 1974; Gurney 1997; Tønnesen and Johnsen 1982; Lovering and Prescott 1979; Fogg 1992; Barnes 2011, 1982). While it is well-established that values invariably enter into our actions (Rokeach 1973; Schwartz 1977; Karp 1996), surprisingly little effort has, thus far, been put into a systematic examination of what values people attribute to Antarctica and how they have been translated into the way human activities in the Antarctic are managed. In this chapter, we provide an overview of results from four studies of Antarctic values. At the International Polar Year (IPY) Oslo Science Conference, 8–12 June, 2010, four research projects on the topic of values were presented and given the commonalities between them, we have chosen to bring these four projects together for the purposes of this chapter. While the studies were not designed as one coherent project, and hence have different methodologies and objectives, the width and breadth of both geographical and theoretical coverage provides a good place from which to begin this exploration. In this chapter, our aim is to explore the common threads running through the four research projects and examine their implications for the future of the Antarctic environment. This work will contribute towards the efforts of the newly formed Social Sciences Action Group of the Scientific Committee on Antarctic Research (SCAR SSAR) that aims to support a coordinated understanding of the values people place on Antarctica and how values might influence policy decisions made about Antarctica (SCAR SSAG 2010).

[1] For examples see Anthropology (Graeber 2001); Economics (Anderson 1993); Philosophy (Rescher 1982); Psychology (Rokeach 1973); Sociology (Spates 1983).

10.2 Values and the Antarctic Environment

Value theory is a complex field; theories of values have developed independently in the fields of social psychology and philosophy. According to Thomas (1998), in philosophy there are three main traditions in the theory of value: subjectivism, which holds that only humans can ascribe value; objectivism, which claims that while values must be human-related they can exist independently; and neo-Kantian rationalism which states that value is based on practical reason. Schwartz (1994), a psychologist who studies the relationship between values and politics, defines a value as 'a (1) belief, (2) pertaining to desirable end states or modes of conduct, that (3) transcends specific situations, (4) guides selection or evaluation of behaviour, people, and events and (5) is ordered by importance relative to other values to form a system of value priorities'. In essence then, values are cultural constructs that guide our actions and choices.

The Antarctic Treaty, which came into force in 1961, honours a variety of values, though they are not all explicitly stated as such. These values include peaceful use, international cooperation, freedom of scientific investigation and the conservation of living resources. Later agreements, which together with the Antarctic Treaty form the Antarctic Treaty System (ATS), recognise other values such as the uniqueness of Antarctic flora and fauna (protected under 1964 the Agreed Measures for the Conservation of Antarctic Flora and Fauna) and the integrity of marine ecosystems (protected by the 1981 Convention on the Conservation of Antarctic Marine Living Resources). Territorial interests have always underlain nations' engagement in Antarctica (Beck 1986; Berkman 2002). Antarctic science, which has demonstrated 'value for global baseline monitoring purposes' (e.g. Farman et al. 1985), is also credited with providing a common language in which Antarctica can be managed internationally and peacefully, above and beyond sovereignty disputes (Berkman 2002; Beck 1986; Vigni 2000).

The Protocol on Environmental Protection to the Antarctic Treaty, the 'Madrid Protocol', which came into force in 1998, introduced protection for a series of values in Antarctica. Article 3(1), on Environmental Principles, states that:

> The protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic values of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations on the planning and conduct of all activities in the Antarctic Treaty area.

In the context of the Madrid Protocol, the values to be protected are intrinsic values, wilderness and aesthetic values and value as an area for the conduct of scientific research (abbreviated as scientific values in the present discussion).

Intrinsic value attempts to encapsulate the idea of people, objects or places having value in-and-of-themselves. It is a complex concept derived from the field of environmental ethics and has been the subject of considerable debate (e.g. O'Neill 1992; Zimmerman 2001; Morito 2003; McShane 2007). Simply put, intrinsic value is used to refer to the value something has, regardless of whether it is useful for anything else, or whether something (or someone) else exists to value it (e.g. O'Neill et al. 2008; Lee 1999). It is conventionally contrasted with instrumental value, which is where something is judged to be valuable for the sake of something else, and with extrinsic value, which is the value a thing gets from some other source (O'Neill et al. 2008; Korsgaard 1983).

However, the Madrid Protocol does not provide any definitions of 'wilderness value' or 'aesthetic value' nor does it specify what these values are, nor how the impacts of proposed activities on these values should be judged. Reviews conducted by the Antarctic and Southern Ocean Coalition (ASOC 2006) and New Zealand (1999) of discussions and documents under the Antarctic Treaty System (ATS) suggest a general understanding of the key attributes of wilderness within the Antarctic context as being remoteness and a relative absence of people and indications of human activity. Wilderness values can be simply defined as those features of the Antarctic wilderness that are valued. For example, silence has been frequently commented on as a distinctive characteristic of the Antarctic environment (e.g. Bowden 1997). Although wilderness and aesthetic values are grouped together in the Madrid Protocol, it is generally accepted that they are different, albeit inter-related, sets of values (Summerson and Riddle 2000; Codling 2001). Aesthetic values are more complex and difficult to define but relate to the perceived value of scenic beauty, scenic grandeur and similar concepts. In this context aesthetic value does not, however, relate to art.

Of the values that are given protection by the Madrid Protocol, the value of Antarctica as an area for the conduct of scientific research would seem to be the least equivocal. However, what constitutes 'research that is essential to understanding the global environment' can still be open to debate and discussion.

10.3 Past Research on Values and the Antarctic Environment

The study of Antarctic values is a relatively new area of research. While there is a rich history of values research across different disciplines, very little has focused specifically on the Antarctic (SCAR SSAG 2010). In terms of aesthetic values, Codling (1997, 1998, 2001) focused on the development of an objective description and classification of landscape character for the Antarctic. She did not explore what constitutes scenic qualities in Antarctica but identified the need to understand better how and why people prefer certain Antarctic landscapes. Summerson adopted an empirical approach (Summerson and Bishop 2011) with three surveys, using a technique introduced by Daniel and Boster (1976) for surveying aesthetic preferences using photographs. Codling (1997, 1998, 2001) and Summerson and Riddle (2000) agreed that all Antarctica can be considered wilderness except for those areas that have been degraded by human activity. This conclusion has been arrived at as a consequence of the short history of human presence in Antarctica, the relatively minor human disturbance of the continent as a whole, the lack of indigenous peoples and the etymology and history of the word ‘wilderness’.

del Acebo Ibañez and Costa (2010) examined the views and values of 1,000 young people from Argentina towards Antarctica. Half of the respondents attach some economic and/or national territorial significance to Antarctica, another 20 % of the respondents associate Antarctica with ecological, aesthetic or utopian notions, and another 30 % respondents are indifferent to or uninterested in Antarctica. Maher (2007) examined the values that tourists travelling on cruise ships to the Ross Sea region attached to their visit. In this study, tourists were attracted to visit Antarctica because of its scenery, remoteness and wildlife, as well as the opportunities for education and adventure. A large percentage believed that they could be labelled ‘ambassador for the Antarctic’ as a result of the visit, although few expressed any intention to become more active in terms of environmental advocacy for the Antarctic wilderness or anywhere else. Examining environmental ethics for the Antarctic, Rolston III (2009) considered that ‘[l]ife at the limits of possibility commands our respect’ (Rolston 2002, p. 132). He acknowledged that Antarctica has value even if its value cannot be readily caught within the framework of classical environmental ethics and admitted that the meaning of the phrase ‘the intrinsic value of Antarctica’ eluded him (Lee 2006; Rolston 2006). Lee (1999, 2006) proposed that for non-living nature, which comprises more than 99 % of the surface of the Antarctic continent (Fox and Cooper 1994), the notion of intrinsic value should be recast as one of independent value. She defined independent value as the value that nature has because its existence is independent from the existence of humans, i.e. nature did not come into existence and does not continue to exist to serve human purposes and existed before human existence and will continue to exist after human extinction.

10.4 Current Research

During and just after the IPY 2007–2009, researchers in Australia, Canada, France, Netherlands, New Zealand and USA initiated four studies on Antarctic values. These studies made use of questionnaires and interviews, in-person, on the internet and by post, to reach members of the public in the Netherlands, USA, New Zealand, Antarctica and globally (Table 10.1). Between 2007 and 2008, Tin et al. examined how members of the public who have never been to Antarctica perceived the continent, their conception of wilderness, and their opinions about how Antarctica should be managed (Tin et al. 2011). In 2008, O’Reilly adapted Tin et al.'s questionnaire into an ethnographic interview and used it in California, USA. Researchers conducted long interviews (45–60 min on average) that asked open-ended questions about Antarctica, its protection, its future and its governance system. Respondents were encouraged to expound on what they knew and/or what they thought and where the sources of their information were located.

Table 10.1 Outline of on-going research projects in the area of Antarctic values included in this chapter

Investigators	Time period	Sample size	Language	Region	Method	Audience	Objectives	Results summary
Tin, Bastmeijer, O'Reilly, Maher	2007–2008	269	English, Dutch	Tilburg, Netherlands	Questionnaire with 15 questions administered by researcher	Dutch, equal number of males and females, ~40 % between 20 and 29 years old, many had secondary and higher levels of education. Never travelled to Antarctica	Get a better understanding of the perspective of the global public in respect of Antarctica and the way Antarctica should be managed now and in the future	Clearly supported protecting Antarctica as a wilderness, and acknowledged the importance of Antarctica as part of the Earth's climate system and an important science laboratory for the benefit of mankind
O'Reilly	January–May 2008	30	English	San Francisco and Santa Cruz, California, USA	In-person interviews	American, majority Caucasian, politically progressive, between 20 and 29 years old, university educated. Never travelled to Antarctica	As above	In favour of strong environmental protection for the Antarctic. 'Values' in ATS text met with suspicion

(Continued)

Table 10.1 (Continued)

Investigators	Time period	Sample size	Language	Region	Method	Audience	Objectives	Results summary
Summerson	2009	335	English, Japanese, French	Argentina, Australia Brazil Canada Chile Colombia Denmark France Germany India Ireland Japan Mexico New Zealand Peru Portugal Russia South Africa Sweden Switzerland United Kingdom United States	Internet survey with digital images of Antarctic landscapes	Invitations sent to Antarctic research institutes in more than 10 countries, all 100 members of IAATO, 2 environmental nongovernmental organizations and many individuals. Advertised on Antarctic related websites. 80 % of respondents have been to Antarctica at least once	Examine how wilderness and aesthetic values can be defined and the impact of human activities on these values measured	Major infrastructure has a statistically significant negative impact on perceptions of wilderness and aesthetic value. Aesthetic value includes not just scenic beauty but the vast scale of Antarctica, the awesome, the breathtaking and the grand

(Continued)

Table 10.1 (Continued)

Investigators	Time period	Sample size	Language	Region	Method	Audience	Objectives	Results summary
Neufeld	2009–2010	30	English	New Zealand	Paper survey	New Zealand residents between the ages of 18 and 90. A 2:3 ratio of female to male. Never travelled to Antarctica	Examine how people develop an understanding of a place through varying experiences	This was the preliminary study in an on-going research project. Participants highlighted the basic themes of wilderness and scientific engagement with the Antarctic and how they have engaged with Antarctica without having been
Neufeld	2010	45	English	Scott Base, Antarctica	Interviews	Researchers and staff at Scott Base, all members of the New Zealand Antarctic programme	As above	Part of an on-going project. Participants were asked about their perceptions about Antarctica and how these have been created through their experiences, both there and away. Analysis on-going

Between 2009 and 2010, Neufeld looked at how people developed an understanding of Antarctica through their varying experiences. Questionnaires were sent out by mail randomly to people across New Zealand. None of the respondents has been to Antarctica. In addition, personal interviews were conducted with researchers, staff and visitors at Scott Base in Antarctica in early summer 2010. The interviews dealt with perceptions of Antarctica based on their experiences and beliefs, as well as their environmentally related behaviours and were conducted in a semi-structured manner.

In 2009, Summerson made use of the internet to bring together respondents from over 20 countries to examine perceptions of wilderness and aesthetic values and the impacts of human activities on these values using an image-based survey. The survey was available in three languages and invitations to participate were sent to Antarctic research institutes, member organizations of the International Association of Antarctica Tour Operators (IAATO) and were posted on Antarctic-related websites. About 80 % of the respondents had visited Antarctica at least once. Respondents included scientists, tourists, tour operators, environmental advocates and National Antarctic Program personnel. The survey comprised a total of 90 images but each respondent was allocated randomly 3 sets of 30 images to review. Half of all the images included some form of human activity or infrastructure. The human component of the images was shown at different scales of size, intensity and proximity. An important distinction was drawn between transient activity and infrastructure, which is more or less permanent. Sixteen of these images were digitally manipulated to remove activity or infrastructure with the counterpart image, which appears to be a natural scene, included in another set of images so that no respondent saw both the original and the manipulated image. Respondents were asked to view the 30 images individually and to respond to two questions which reflected their perceptions of wilderness and aesthetic quality. In a third question, respondents were asked to rank how well each of 20 adjectives described the image (Summerson and Bishop 2011).

10.4.1 Common Themes

While these projects focused on different questions, the issue of values was common to all of them. After hearing each other speak at the IPY Oslo conference in 2010, the authors discussed their work more closely and identified several common themes across their research. These are illustrated here and used to establish a context from which to derive future scenarios of Antarctica in Sect. 10.5.

10.4.2 Science and Wilderness

Respondents to the Dutch and New Zealand studies identified both science and wilderness as important values of Antarctica. In the Dutch survey, respondents were asked if they would support one or more of 14 activities to take place in Antarctica. The majority of the respondents supported ‘designating Antarctica as a wilderness reserve where development of infrastructure is limited’ (79 %) as well as the construction of ‘new stations for conducting scientific research’ (66 %). In the New Zealand survey, respondents were asked about the meanings that they associate with Antarctica. The majority of respondents noted either exclusively environmental and wilderness terms (i.e. snow, wild, empty, penguins, etc.), or human interaction terms (i.e. science, Scott Base, research, exploration, etc.). Only a very small proportion (5 %) listed both. In both the Dutch and New Zealand studies, some respondents acknowledged that there was a conflict between valuing Antarctica as a wilderness (implying little or no human presence) and as a scientific laboratory (implying active human use and/or presence, permanent or transitory). Some respondents alluded to the need to weigh the benefit of the science being done versus the damage to the environment and the wilderness. In general, all respondents showed a lack of insight as to how they saw that this apparent conflict could be resolved in order that their vision of the coexistence of wilderness and science could take place.

10.4.3 Values

In the USA based study respondents were also in favour of the protection of Antarctica but were uncomfortable and suspicious by the lack of clarity and the vagueness conveyed by the term ‘values’. The phrase ‘protecting the wilderness values of Antarctica’ as mandated under Article 3 of the Madrid Protocol was met with suspicion. People called the phrase ‘a scam’, ‘controlling’, ‘an empty slogan’, ‘illogical’, ‘a non sequitor’ and ‘euphemistic’. For example, one person wondered why it was the ‘values’ being protected instead of the wilderness itself. Another respondent thought the phrase was unfavourably reminiscent of the George W. Bush administration, claiming that the terminology is vague, could easily contain loopholes, and begs the question: whose values are we talking about? Another respondent said that the phrase ‘sounds like a man’s term and is subjective to whoever wrote it’. Overall, respondents were in favour of the protection of Antarctica, but not of protecting vague ‘values’. Instead, participants wanted a more resource-based language, where animals, plants, landscapes and other members and features of the Antarctic community were explicitly protected.

Less than 1 % of respondents in the Dutch study agreed with the phrase ‘Antarctica does not have any value for mankind’. When asked what they thought was the importance of Antarctica, over half of the Dutch respondents saw the importance of Antarctica as a wilderness, a science laboratory for the benefit of humankind and as an important component of the Earth’s climate system. A minority of respondents considered the value of Antarctica as a tourist destination (11 %) While approximately one-fifth considered the continent as a reserve of mineral resources that might support society in the future.

10.4.4 Antarctic Wilderness Values and its Management

The majority of the respondents to the global image study considered that most infrastructure and large forms of transient activity, for example a tractor train, impact negatively on wilderness and aesthetic values. They also found images of mountainous regions with no evidence of human presence to have the highest aesthetic value, and the environs of Antarctic stations the least. Respondents concur on their choices on the most and the least aesthetic images. They thought that ‘beautiful’, ‘breathtaking’, ‘awesome’ and ‘grand’ were often more suitable than ‘delightful’, ‘lovely’ and ‘pretty’ as adjectives for describing undisturbed Antarctic landscapes, suggesting that aesthetic value includes not just scenic beauty but the vast scale of Antarctica, the awesome, the breathtaking and the grand.

Respondents in the USA study had diverse ideas about what Antarctic protection entailed which seemed to be based upon their experiences with environmental management outside Antarctica. Some things that respondents thought did not belong in a wilderness area such as Antarctica included structures, roads, large-scale destruction and/or resource extraction, fossil-fuel use, nuclear power, cell phones, power lines, private property, tourism, long-term habitation, hunting and people in general. Things that people thought could be included in a wilderness included tourism, regulations and research. One respondent, disagreeing with the majority, suggested that human activity in Antarctica should be determined by ‘whatever the market will bear’ and also noted that he would like to see oil companies ‘drill the shit out of the [US] Alaska National Wildlife Refuge’.

The majority of the Dutch respondents shared a similar understanding of the word wilderness. Many of them described it as a place with no or few people; a lack of infrastructure and a measure of silence or solitude were often cited. They suggested a wide range of activities that should be prohibited in a wilderness, commonly activities that ‘disturb the natural balance’ or ‘pollute’. Specific examples included hunting, infrastructure, industry, logging, mining and oil and gas exploitation. Overwhelmingly, tourism, specifically, mass tourism, was indicated as an activity that should be prohibited in wilderness. The prohibition of commercial activities or any human intervention was also frequently mentioned. Among the activities that respondents thought should be allowed to take place in wilderness were: research, tourism and education, all on a small scale.

Respondents were asked what the phrase ‘protecting the wilderness values of Antarctica’ meant to them. Similar to the responses from the American study, responses were not very specific. To many respondents, ‘protecting the wilderness values of Antarctica’, as mandated under Article 3 of the Madrid Protocol, meant the need to change Antarctica as little as possible, ‘ensuring that Antarctica remains as far as possible in its original condition’, and that it does ‘not become a tourist destination but just a piece of unspoiled nature, the way it was before it was discovered’. They also expressed that this would mean prohibiting tourism; that some level of scientific research should continue; that large-scale human activities should be prohibited; and that all other human activities should be avoided or kept at as small a scale as possible.

10.4.5 Discussion

The studies presented in this chapter were not designed as a single coherent project. Objectives, methodology and types of data that were collected differ and, in many cases, the results are not directly comparable. These studies were conducted between 2007 and 2011, and their results need to be interpreted within the space, time and the limited sample sizes which they represent. These caveats aside, the results from these studies provide a rare range of examples of how different people value Antarctica.

Participants in the Dutch and New Zealand research supported both science and wilderness. The global image study showed that most infrastructure and large forms of transient activity impact negatively on wilderness and aesthetic values. Antarctica's relatively pristine environment has always been considered as a principal resource for science and society (Berkman 2002). Scientific and wilderness values are not necessarily conflicting values. Bastmeijer (2008, p. 9) explained that 'the essence of wilderness protection is not the absence of social and economic interests or the absence of the need to balance interest' but that it lies in taking into consideration human uses to ensure that the wilderness characteristics of the area are maintained. Indeed, as pristine, untouched and wild areas disappear in the world, what wilderness does remain will become even more important for future scientific research, most notably as a comparison with more impacted areas and for research with sophisticated future technologies (Hughes et al. 2011).

Many of the Dutch and American respondents found the concept of protecting 'values' vague and difficult to grasp. At least some Antarctic Treaty Consultative Parties may share these sentiments. A total of 29 Antarctic Treaty Consultative Parties nations share more than 30 different official languages. The concepts of wilderness, aesthetic, intrinsic and other values have different shades of meaning depending on the culture and history of the different societies. This may be one of the reasons why a definition of wilderness values continues to be discussed at Antarctic Treaty Consultative Meetings (ATCMs) after more than a decade without reaching any substantial agreement or action (New Zealand 1999, 2011).

What do the results from these studies imply for the management of human activities in Antarctica? Keeping in mind the caveats stated at the beginning of this section, extrapolating from the results of these studies would imply that, generally speaking, management should ensure that a balance is maintained between science and wilderness, including the minimisation of stations and other large-scale infrastructure development. There should be no large-scale human activities allowed in Antarctica, and small-scale activities should be kept for the benefit of not-for-profit purposes, notably science and education. This does not exclude tourism, which needs to be controlled to minimise its impact on the Antarctic environment. Finally, all these considerations should be put into place to ensure as much of Antarctica as possible remains in its original condition.

We are not suggesting that the opinions of several hundred people, some of whom know very little about Antarctica, should dictate how Antarctica should be managed. Nevertheless, if the views put forward in these surveys are in any way representative of people who are interested in the way Antarctica is managed, it is quite clear that Antarctica is highly valued by the populace at large. The ATS often states that it manages Antarctica in the interest of humankind (see: Tin et al. 2011), thereby giving legitimacy to the relevance of the values and views of a much wider group of people than those with a narrow professional interest. We acknowledge that there are many levels of stakeholder participation in decision making in the real world. The values and views of mankind on whose behalf Antarctica is protected should also be heard.

10.5 What Does the Future Hold?

In 2011, the Antarctic Treaty nations celebrated the 50th anniversary of the Treaty entering into force. Twenty-one years ago, agreement on the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) collapsed and was replaced by the Madrid Protocol, which entered into force in 1998. Will these agreements hold until well into the future? While there is no reason for them not to hold, the development of possible scenarios for the future can be a valuable planning exercise (see Lamers et al. 2013). In this section, we examine where we are currently and three possible futures.

10.5.1 Present Situation

Sovereignty has always been one of the principal reasons for nations to engage in Antarctica (Rothwell 2010). Sovereignty issues are linked to geopolitical positions and national prestige on the international political stage. Nevertheless, national interests in the Antarctic also encompass economic interests such as exploitation of marine living resources, the potential access to mineral resources, the potential for economic exploitation of the findings of scientific research, tourism and more recently bioprospecting for medicinal compounds (e.g. Dodds 2011; Brady 2011, 2010). Since the International Geophysical Year and the development of the Antarctic Treaty, science has been adopted as the basis of a nation's political rights in Antarctica and as a tool of diplomacy to ensure peace and political stability in the region (Spiller 2004; Berkman 2010). Over time, the protection of the Antarctic environment also emerged as a significant component of the ATS. With the Madrid Protocol, mining was banned and a comprehensive environmental protection regime was established. The Committee for Environmental

Protection (CEP) was established to provide advice to ATCMs on the implementation of the Madrid Protocol, and it has become the workhorse of the ATCM, with almost 90 % of the legally binding measures adopted at ATCMs between 1998 and 2007 related to the CEP's work (Orheim et al. 2011; Sánchez and McIvor 2007). Environmental values now have more weight in Antarctic decision making than before the Madrid Protocol. Yet, intrinsic, wilderness and aesthetic values, which appeared in the ongoing research studies reviewed in preceding sections, have not achieved much prominence (e.g. Bastmeijer 2011; Hemmings 2009). Under the Madrid Protocol, Environmental Impact Assessment is a key tool used to achieve the Protocol's objectives. However, in these documents, aesthetic and wilderness values are considered only in a perfunctory manner (Bastmeijer and Roura 2008, Summerson 2012).

10.5.2 Business-As-Usual Future

Extrapolating from the present situation, we project that an Antarctic future that continues on a Business-As-Usual trajectory would be maintained by the present balance of values encompassing sovereignty, science and tourism. Sovereignty and national economic interests will remain the main driving values, among original Antarctic Treaty signatory nations, as well as among relative 'newcomers', such as Asian and ex-Soviet countries. The value of Antarctic science for humankind will continue to be used as a source from which to increase public support for engagement in Antarctica. Some Antarctic science will continue to be globally important especially that which is relevant to climate change. Environmental matters will continue their prominence in the discussions of Antarctic Treaty parties, where focus will continue to be on quantifiable parameters, biotic elements and anthropocentric motivations. Consideration of the protection of intrinsic, wilderness and aesthetic values will not exceed present levels. Tourism will continue to expand and, with it, concerns about its impact. The effects of the global financial crisis will continue to ripple through the Antarctic tourism industry for a number of years, but it is not possible to predict when the industry will fully recover. The effects of climate change will continue to grow, leading to the possible introduction of carbon pricing which will increase the cost of transport to Antarctica for both National Antarctic Programs and the tourism industry.

Antarctica's historical isolation has allowed it to maintain wilderness and aesthetic values as many parts of the world become occupied by human settlements and activities. Human activity in Antarctica has been expanding fast in recent decades, and Antarctica's wilderness and aesthetic values are no longer protected by the region's historical isolation (Hemmings 2009, 2007). Unvisited areas are becoming increasingly rare in the Antarctic (Hughes et al. 2011). Without deliberate efforts to protect Antarctica's wilderness and aesthetic values, these values will certainly diminish as the human footprint in the Antarctic and worldwide continues to grow (Tin et al. 2008; New Zealand 1999). In other words, in the face of growing human activity in the Antarctic, a reactive wait-and-see attitude towards the protection of these values is a *de facto* decision that supports their attrition.

10.5.3 Antarctic Sanctuary

To contrast a Business-As-Usual future, we borrow the vision of an 'Antarctic Sanctuary' as expounded by the environmental philosopher Holmes Rolston, III (Rolston 2002). In this vision, Antarctica is common heritage, not exploitable property held in common, but rather, a common gift shared by all. It belongs to nobody; no nation, no individual. The commitment to protect the intrinsic value of Antarctica, including its wilderness and aesthetic values, is put into practice, resulting in a transcultural ethic where Antarctic nature is valued independently of human presence. The seventh continent is set aside as a place for humankind to realise deeper perspectives and higher ideals than they can pursue at home.

Rolston did not provide suggestions as to how this vision may be achieved. The vision may be advanced at least partially by Hemmings' (2009, p. 56) proposition of 'a confident characterisation of Antarctica as a global interest managed collectively'. 'A deliberative Antarctic exceptionalism' is asserted where Antarctic-specific standards and norms are applied to Antarctic matters and where nations are willing to accept restraints on human activity and aspirations in matters such as territorial claims and commercial interests (Hemmings 2010, 2007). Bastmeijer (2011) further specifies that, in order to prevent human domination of the Antarctic environment, decision-makers need to pre-empt situations where human activities may take place in a vacuum of rules by establishing strong proactive management to regulate activities early, preferably before they begin. On a pragmatic level, Summerson (2012) proposes the adoption of ethics committees to assess proposals of scientific work to be undertaken at sites where there has been no prior human activity, in order to ensure a balance between the benefits to science against the degradation of the Antarctic wilderness. Similarly, Roura and Hemmings (2011) propose a Strategic Environmental Assessment process that can provide a systematic approach for the consideration of high-level environmental issues in the Antarctic, a tool that may also contribute towards realising Rolston's vision (see Lamers et al. 2013).

10.5.4 World (Resources) Bank

To bring in a contrasting future, one can imagine the modification or amendment of the Madrid Protocol, or the collapse of the ATS. The Madrid Protocol, like the Antarctic Treaty, may be modified or amended at any time. Fifty-years after its entry into force, a review of its operation may be requested by any Antarctic Treaty Consultative Party (Article 25, Madrid Protocol). In a World (Resources) Bank scenario, national economic and territorial interests dominate. Scientific values are used to yield economically valuable information or in grounding territorial claims. Mining, uncontrolled fishing, commercialisation of natural compounds or genetic materials found in Antarctic organisms (also known as bioprospecting) and mass tourism take hold. Wilderness and aesthetic values are commodities that are sold to the global consumer society, as experiences or concepts.

It is generally considered that the ATS is not likely to disintegrate in the near future, notwithstanding the contemporary challenges that it is facing (e.g. Dodds 2010; Hemmings 2007). However, a future in which Antarctic resources become key commodities on the global market does not belong to an inconceivable, impossible future. Sealing, whaling and fishing history in the Antarctic show proof of the commercial value of Antarctic resources. In the twentieth century, the ATS has contributed towards tempering and regulating of some of the commercial activity in the Antarctic, but illegal, unreported and unregulated (IUU) fishing, exponential growth of commercial tourism and various discussions on mining, harvesting of icebergs and bioprospecting are indications that interests in commodifying Antarctica are underway (Liggett 2011).

10.5.5 Other Considerations

The 'real' future is likely to be situated somewhere between the three scenarios described above, with the Business-As-Usual scenario featuring a higher likelihood, just because least amount of change from *status quo* is needed.

The Antarctic does not exist in a vacuum. The values that people bring to the Antarctic are rooted in their experience elsewhere, at home, outside the Antarctic. The evolution of the values that people attribute to the Antarctic then needs to be considered within the context of the evolution of global society. For example, in a world where more than half of the world's population now lives in cities, how will increasing urbanisation affect the way that intrinsic, scientific, wilderness and aesthetic values are valued? Some speculate that the more urban we become, the more we will value landscapes that are undisturbed by human activity (Williams and Watson 2007). With time, society may shift from emphasising economic growth and human dominance and use of nature to emphasising sustainable development, harmony with nature and a balance of human and non-human uses of nature (Cordell et al. 2003). With the achievement of higher socio-economic levels, individuals are more likely to favour environmental protection (Ingelhart and Welzel 2005). On the other hand, as people become wealthier and become more engaged in the consumerism-orientated lifestyle, their vision of Antarctica may also move away from one of utopia and mystery and beauty to one of resources and geopolitical importance (del Acebo Ibáñez and Costa 2010).

10.6 Conclusions

The world's population does not evolve as one coherent body. As each of the 29 Antarctic Treaty Consultative Parties (or more in the future) evolves, the values that each brings to the international diplomatic process will also evolve, likely at different rates. While each Party makes their own decisions with regards to the management of their National Antarctic Programs and the activities of its nationals, the ATS makes decisions based on consensus. How would the evolution of values of different Consultative Parties at different rates affect the ATS's decisions? Antarctica's future is shaped by people both with and without direct experience of the continent, through our individual experiences, individual behaviours, collective cultures (including values) and collective systems (including political and institutional). It is only by being increasingly aware of who we are, what we are doing and how we are making decisions that we can begin to go towards a more comprehensive and integral effort in understanding the complex issue of valuing the Antarctic (Esbjörn-Hargens and Zimmerman 2009). While the study of values attributed to the Antarctic is in its infancy, the four studies reviewed in this chapter, go some way to explore this highly complex and multi-faceted field of research and will hopefully lead to future studies to further our understanding.

References

Anderson, E. (1993). *Value in ethics and economics*. Cambridge: Harvard University Press.

ASOC. (2006). *Beyond direct impacts of multi-year maintained ice routes. Case study: McMurdo-South Polar surface re-supply traverse.* Information paper 85 presented at XXIX Antarctic Treaty Consultative Meeting, Edinburgh, United Kingdom, 12–23 June 2006.

Barnes, J. N. (1982). *Let's save Antarctica*. Richmond, Australia: Greenhouse Publications.

Barnes, J. N. (2011). The Antarctic treaty system: Perspectives of environmental nongovernmental organizations on addressing key issues. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science and the governance of international spaces* (pp. 277–280). Washington D.C., USA: Smithsonian Institution Scholarly Press.

Bastmeijer, K. (2008), Protecting Polar Wilderness: Just a Western Philosophical Idea or a Useful Concept for Regulating Human Activities in the Polar Regions? *Yearbook of Polar Law, 2008*. Available at SSRN: http://ssrn.com/abstract=1295430.

Bastmeijer, C.J. (2011). Intergenerational Equity and the Antarctic Treaty System: Continued Efforts to Prevent 'Mastery' (February 15, 2011). *Yearbook of Polar Law, Vol. 3, 2011*. Available at SSRN: http://ssrn.com/abstract=1762039.

Bastmeijer, C. J., & Roura, R. (2008). Environmental impact assessment in Antarctica. In C. J. Bastmeijer & T. Koivurova (Eds.), *Theory and practice of trans boundary environmental impact assessment* (pp. 175–219). Leiden, The Netherlands: Martinus Nijhoff Publishers.

Beaglehole, J. C. (1974). *The Life of Captain James Cook*. London, UK: A&C Black Ltd.

Beck, P. J. (1986). *The international politics of Antarctica*. Kent, UK: Croom Helm Ltd.

Berkman, P. A. (2002). *Science into policy: Global lessons from Antarctica*. San Diego, CA, USA: Academic Press.

Berkman, P. A. (2010). Polar research, common interests in the international space of Antarctica. *Polar Record, 46*, 7–9.

Bowden, T. (1997). *The silence calling*. Sydney, Australia: Allen & Unwin.
Brady, A.-M. (2010). China's rise in Antarctica? *Asian Survey, 50*(4), 759–785.
Brady, A.-M. (2011). New Zealand's strategic interests in Antarctica. *Polar Record, 47*(241), 126–134.
Codling, R. (1997). Concepts of wilderness in the Antarctic. *International Journal of Wilderness, 3*(3), 35–39.
Codling, R. (1998). *Wilderness and Aesthetic Values in Antarctica*. (PhD thesis, Open University, UK).
Codling, R. (2001). Wilderness and aesthetic values in the Antarctic. *Polar Record, 37*(203), 337–352.
Cordell, H. K., Tarrant, M. A., & Green, G. T. (2003). Is the public viewpoint of wilderness shifting? *International Journal of Wilderness, 9*(2), 27–32.
Daniel, T.C., & Boster, R.S. (1976). *Measuring landscape esthetics: the scenic beauty estimation method*. United States Department of Agriculture Forest Service Research Paper RM-167, Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture.
del Acebo Ibáñez, E., & Costa, M. (2010). Antarctic environmental problems: attitudes and behaviours of young inhabitants of two Argentine cities (Buenos Aires and San Carlos de Bariloche). *Polar Record, 46*(238), 257–263.
Dodds, K. J. (2010). Governing Antarctica: Contemporary challenges and the enduring legacy of the 1959 Antarctic Treaty. *Global Policy, 1*(1), 108–115.
Dodds, K. J. (2011). Sovereignty watch: claimant states, resources, and territory in contemporary Antarctica. *Polar Record, 47*, 231–243.
Esbjörn-Hargens, S. and Zimmerman, M.E. (2009). *An overview of integral ecology: a comprehensive approach to today's complex planetary issues*. Integral Institute, Resource Paper no. 2.
Farman, J. C., Gardiner, B. G., & Shanklin, J. D. (1985). Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction. *Nature, 315*, 207–210.
Fogg, G. E. (1992). *A history of Antarctic science*. Cambridge, UK: Cambridge University Press.
Fox, A. J., & Cooper, A. P. R. (1994). Measured properties of the Antarctic ice sheet derived from the SCAR Antarctic digital database. *Polar Record, 30*, 201–206.
Graeber, D. (2001). *Towards an anthropological theory of value: The false coin of our own dreams*. New York: Palgrave.
Gurney, A. (1997). *Below the convergence*. New York, USA: W.W. Norton & Co. Inc.
Hemmings, A.D. (2007). Globalization's cold genius and the ending of Antarctic isolation. In: L.K. Kriwoken, J. Jabour, J. & A.D. Hemmings (Eds.), *Looking south: Australia's Antarctic Agenda* (pp. 176–190). Leichhardt, NSW, Australia: The Federation Press.
Hemmings, A. D. (2009). From the New Geopolitics of resources to nanotechnology: Emerging challenges of globalism in Antarctica. In D. Leary, T. Koivurova, & G. Alfredsson (Eds.), *Yearbook of Polar Law* (Vol. 1, pp. 55–72). Leiden, The Netherlands: Martinus Nijhoff Publishers.
Hemmings, A.D. (2010). *Considerable Norms in the Antarctic*. Paper presented at Antarctic Visions: Cultural Perspectives on the Southern Continent. University of Tasmania, Hobart, Australia, 21–23 June, 2010.
Hughes, K. A., Fretwell, P., Rae, J., Holmes, K., & Fleming, A. (2011). Untouched Antarctica: Mapping a finite and diminishing environmental resource. *Antarctic Science, 23*(6), 537–548.
Ingelhart, R., & Welzel, C. (2005). *Modernization, cultural change, and democracy*. Cambridge, UK: Cambridge University Press.
Karp, D. G. (1996). Values and their effect on pro-environmental behaviour. *Environment and Behaviour, 29*(1), 111–133.
Kluckhohn, C. (1951). Values and value-orientations in the theory of action: An exploration in definition and classification. In T. Parsons & E. Shils (Eds.), *Towards a general theory of action* (pp. 388–433). Cambridge, MA: Harvard University Press.
Korsgaard, C. M. (1983). Two distinctions in goodness. *The philosophical review, 92*(2), 169–195.

Lamers, M., Liggett, D. & Tin, T. (2013). Strategic thinking for the Antarctic environment: The use of assessment tools in governance. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment* (p. 30). Dordrecht, Netherlands: Springer.

Lee, K. (1999). *The natural and the artefactual: The implications of deep science and deep technology for environmental philosophy*. Lanham, MD, USA: Lexington Books.

Lee, K. (2006). Biotic and abiotic nature: how radical is Rolston's environmental philosophy? In Preston, C. J., & Ouderkirk, W. (Eds.), *Nature, Value, Duty. Life on Earth with Holmes Rolston III*. (pp. 17–28). Dordrecht, The Netherlands: Springer.

Liggett, D. (2011). Antarctica—Economy. In: *Australia and Antarctica, Volume 10—The World and Its Peoples* (pp. 1430–1433). Tarrytown, New York: Marshall Cavendish Corporation.

Lovering, J. F., & Prescott, J. R. V. (1979). *Last of lands … Antarctica*. Melbourne, Australia: Melbourne University Press.

Maher, P. T. (2007). Advocating for Antarctic wilderness: short-term visits and human values. In A. Watson, J. Sproull & L. Dean (Comps.), *Science and stewardship to protect and sustain wilderness values: Eighth World Wilderness Congress symposium: September 30-October 6, 2005: Anchorage, AK* (pp. 170–177). Proceedings RMRS-P-49. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

McShane, K. (2007). Why environmental ethics shouldn't give up on intrinsic value. *Environmental Ethics, 29*, 43–61.

Morito, B. (2003). Intrinsic value: A modern albatross for the ecological approach. *Environmental Values, 12*(3), 317–336.

New Zealand (1999). *Towards additional protection of Antarctic wilderness areas*. Information Paper 80 presented at XXXIII Antarctic Treaty Consultative Meeting, Lima, Peru, 24 May–4 June 1999.

New Zealand. (2011). *Understanding concepts of footprint and wilderness related to the protection of the Antarctic environment*. Working Paper 35 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, 20 June–1 July 2011.

O'Neill, J., Holland, A., & Light, A. (2008). *Environmental values*. London, UK: Routledge.

O'Neill, J. (1992). The varieties of intrinsic value. *The Monist, 75*(2), 119–133.

Orheim, O., Press, A., & Gilbert, N. (2011). Managing the Antarctic environment: The evolving role of the committee for environmental protection. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science and the governance of international spaces* (pp. 209–222). Washington D.C., USA: Smithsonian Institution Scholarly Press.

Rescher, N. (1982). *Introduction to value theory*. Washington, D.C., USA: University Press of America.

Rokeach, M. (1973). *The nature of human values*. New York, USA: Free Press.

Rolston, H., III. (2002). Environmental ethics in Antarctica. *Environmental Ethics, 24*, 115–134.

Rolston, H, III. (2006). Living on Earth: Dialogue and dialectic with my critics. In C.J. Preston & W. Ouderkirk (Eds.), *Nature, Value, Duty. Life on Earth with Holmes Rolston III* (pp. 237–268). Dordrecht, The Netherlands: Springer.

Rolston, H., III. (2009). Antarctica. In J. B. Callicott & R. Frodeman (Eds.), *Encyclopedia of environmental ethics and philosophy* (Vol. I, pp. 53–58). Detroit, USA: Macmillan Reference.

Rothwell, D. (2010). Sovereignty and the Antarctic treaty. *Polar Record, 46*, 17–20.

Roura, R., & Hemmings, A. D. (2011). Realising strategic environmental assessment in Antarctica. *Journal of Environmental Assessment Policy and Management, 13*(3), 483–514.

Sánchez, R. A., & McIvor, E. (2007). The Antarctic committee for environmental protection: Past, present, and future. *Polar Record, 43*(226), 239–246.

SCAR SSAG. (2010). *Social Sciences Action Group—Values in Antarctica: Human connections to a continent.* Draft Report retrieved from http://www.scar.org/researchgroups/via/SocialSciencesAG_Rept_2010.pdf.

Schwartz, S. H. (1977). Normative influences on altruism. *Advances in Experimental Social Psychology, 10*, 221–279.

Schwartz, S. H. (1992). Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 25, pp. 1–65). New York, USA: Academic Press.

Schwartz, S. (1994). Are there universal aspects in the structure and contents of human values? *Journal of Social Issues, 50*(4), 19–45.

Spates, J. (1983). The sociology of values. *Annual Review of Sociology, 9*, 27–49.

Spiller, J. (2004). Re-imagining United States Antarctic research as a defining endeavour of a deserving world leader: 1957–1991. *Public Understanding of Science, 13*, 31–53.

Summerson, R. (2012). Protection of wilderness and aesthetic values in Antarctica. In F. Huettmann (Ed.), *Protection of the three poles* (pp. 77–112). Tokyo, Japan: Springer.

Summerson, R., & Bishop, I. D. (2011). Aesthetic value in Antarctica: Beautiful or sublime? *The Polar Journal, 1*(2), 225–250.

Summerson, R., & Riddle, M. J. (2000). Assessing wilderness and aesthetic values in Antarctica. In W. Davison, C. Howard-Williams, & P. Broady (Eds.), *Antarctic Ecosystems: Models for wider understanding* (pp. 303–307). Christchurch, New Zealand: University of Canterbury.

Thomas, A. (1998). Values. In E. Craig (Ed.), *Routledge encyclopedia of philosophy* (Vol. 9, pp. 581–583). London, UK: Routledge.

Tin, T., Hemmings, A. D., & Roura, R. (2008). Pressures on the wilderness values of the Antarctic continent. *International Journal of Wilderness, 14*(3), 7–12.

Tin, T., Bastmeijer, C.J., O'Reilly, J. & Maher, P. T. (2011). Public perception of the Antarctic wilderness: surveys from an educated, environmentally knowledgeable European community. In A. Watson, J. Murrieta-Saldviar & B. McBride (Comps.) *Science and stewardship to protect and sustain wilderness values: Ninth World Wilderness Congress symposium. 6–13 November, 2009, Mérida, Mexico*. (pp. 109–117). Proceedings RMRS-P-00. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Tønnessen, J. N., & Johnsen, A. O. (1982). *The history of modern whaling*. Canberra, Australia: Hurst.

Vigni, P. (2000). The interaction between the Antarctic treaty system and the other relevant conventions applicable to the Antarctic area: A practical approach versus theoretical doctrines. In J. A. Frowein & R. Wolfrum (Eds.), *Max Planck year book of United Nations Law* (pp. 481–542). Leiden, The Netherlands: Kluwer Law International.

Williams, D.R. & Watson, A.E. (2007). Wilderness values: perspectives from non-economic social science. In A. Watson, J. Sproull & L. Dean (Comps.), *Science and stewardship to protect and sustain wilderness values: Eighth World Wilderness Congress symposium: September 30-October 6, 2005: Anchorage, AK* (pp. 123–133). Proceedings RMRS-P-49. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Zimmerman, M. J. (2001). *The nature of intrinsic value*. Lanham, Maryland, USA: Rowman and Littlefield.

Chapter 11
Strategic Thinking and the Antarctic Wilderness: Contrasting Alternative Futures

Ricardo Roura and Tina Tin

Abstract The Protocol on Environmental Protection to the Antarctic Treaty outlines a vision for the Antarctic wilderness, and together with its six annexes, forms a framework that can readily serve as a basis for strategic thinking for environmental protection. Baumgartner and Korhonen (2010) defined the notion of 'strategic thinking' as characterised by three interrelated and distinct dimensions: strategy process, strategy content and strategy context. We use this framework to examine how strategic thinking is applied to protect the Antarctic wilderness. Since the Protocol came into force in 1998, the Committee for Environmental Protection and the Antarctic Treaty Consultative Meetings have adopted various *ad hoc* forms of strategic processes and have had varying amounts of strategic content in their discussions and decisions. Despite the protected status of the Antarctic Treaty area and the consideration of environmental issues in deliberations by Antarctic Treaty states, the strategic context of the region results in intense local, regional and global development pressures. Environmental protection may feature in a 'Business-As-Usual' future for the Antarctic, but on the margins rather than as a central guiding principle, risking a 'paper park' future. Environmental groups have called for a future Antarctica that includes the elements of wilderness, strategic thinking, international cooperation and stabilisation of the human footprint. We contend that Antarctic Treaty parties, encouraged by environmental groups and other actors, should ensure that implementing the

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objective and environmental principles of the Protocol becomes both a reality for the present and also a strategic vision for the longer term.

Keywords Alternative futures • Antarctica • Environmental organisations • Strategic thinking • Wilderness • Protocol on Environmental Protection to the Antarctic Treaty

11.1 Introduction

The Antarctic continent and adjacent areas south of 60 degrees south are protected by the 1991 Protocol on Environmental Protection to the Antarctic Treaty (Protocol), which entered into force in 1998 (e.g. Bastmeijer 2003; Bastmeijer and Roura 2008). The Protocol and its six Annexes[1] are the most recent component of the Antarctic Treaty System (ATS), which is 'the Antarctic Treaty, the measures in effect under that Treaty, its associated separate international instruments in force, and the measures in effect under those instruments' [Protocol Article 1(e)]. Thirty-three states are parties to the Protocol (USA 2011). In its Preamble, the Protocol states that the protection of the Antarctic environment and dependent and associated ecosystems is 'in the interest of mankind as a whole'. Decisions on the management of the Antarctic environment are taken by national governments, their National Antarctic Programs (NAPs), and—by consensus—by Antarctic Treaty Consultative Parties (ATCPs) at annual Antarctic Treaty Consultative Meetings (ATCMs) with the advice of the Committee for Environmental Protection (CEP). Environmental issues have become one of the main topics of deliberation of ATCMs (Sánchez and McIvor 2007; Orheim et al. 2011). However, decisions concerning the Antarctic marine ecosystem, such as fishing quotas and the designation of marine protected areas, are taken by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), which also meets annually and makes decisions by consensus.

Covering a terrestrial area of 14 million km^2 and marine area of 20 million km^2, with a rich endemic fauna and flora (see e.g. Shirihai 2002; Bergstrom et al. 2006; Knox 2007) and permanent human infrastructure covering well below 1 % of the land area, the Antarctic continent and its surrounding Southern Ocean are frequently referred to as one of the world's largest or last wildernesses [e.g. Resolution 3 (2011)[2] General guidelines for visitors to the Antarctic; Geoff 1986; IAATO 2007]. Although the region is protected as a designated 'natural reserve,

[1] Annex I Environmental impact assessment; Annex II Conservation of Antarctic flora and fauna; Annex III Waste disposal and waste management; Annex IV Prevention of marine pollution; Annex V Area protection and management; Annex VI liability arising from environmental emergencies (not yet effective).

[2] All ATCM Measures and Resolutions are available at: http://www.ats.aq/devAS/info_measures_list.aspx?lang=e.

devoted to peace and science' (Article 2 of the Protocol), the Antarctic wilderness is also under growing pressures. Pressures come from human activities within the Antarctic Treaty area, including science-related infrastructure developments, legal and illegal fishing for finfish, krill, expansion of coastal and inland tourism and biological prospecting (Tin et al. 2008; Hemmings and Roura 2007). Additional pressures on the environment result from global phenomena of different kinds, including climate change, long-range pollution and globalisation. At the same time, inadequate implementation of existing instruments and undercurrents of national and commercial interests by Antarctic Treaty states slow down progress in environmental decision making by the ATS as a whole. The effect has been that environmental governance has not sufficiently kept up with the pace of activity growth (Bastmeijer and Roura 2004; Hemmings 2010a; Roura and Hemmings 2011) and the inevitable erosion of the wilderness, intrinsic and environmental values the Protocol seeks to protect.

Is progress towards meeting the objective of the Protocol and compliance with its principles happening—to the extent it happens—as a result of strategic thinking, or just by chance? In this chapter, we use the conceptual framework of Baumgartner and Korhonen (2010) to examine how strategic thinking is used in Antarctic environmental protection under the Protocol—where the ATCM is the relevant decision-making body in all aspects of governance, and the CEP the main advisory body on environmental issues. In their discussion of strategic thinking for sustainable development, Baumgartner and Korhonen (2010) defined the notion of 'strategic thinking' as characterised by three interrelated and distinct dimensions, strategy process, strategy content and strategy context:

> The starting point for every strategy is the question of purpose of the whole endeavour. This is the input for strategy activities. The dimension of strategy process is the way to develop the strategy, i.e. the throughput (the how, who and when of strategy). The strategy content is the output of the strategy, i.e. the result of strategy activities. Conditions surrounding strategy activities are the strategy context, which has an influence on the possibilities and restrictions of strategic activities (2010, p. 73).

Following the three dimensions of strategy process, strategy content and strategy context (see also Lamers et al. 2013) we examine the current status of strategic thinking in Antarctic environmental management and sketch out two contrasting futures for the Antarctic wilderness. In Sect. 11.2, extrapolating from ongoing trends and decisions and discussions that have taken place within the ATS over the past two decades, we assess likely future outcomes for the Antarctic wilderness under 'Business-As-Usual conditions'. We then change perspective and in Sect. 11.3 delineate an alternative vision for the future of Antarctica based on the views that environmental groups have been advocating since the late 1970s. In this way we contrast the perspectives of national governments, which often reflect the search for international consensus in the context of conflicting national interests, with those of non-governmental, non-profit environmental organisations, which reflect the prioritisation of environmental protection. We conclude with a discussion of the basic actions we see as important to ensure the non-degradation of the Antarctic environment, ecosystems and wilderness as a legacy for future generations.

Our analysis is based on professional and personal experiences of the Antarctic and the ATS in various capacities, including but not limited to our participation as environmental non-governmental organization (ENGO) actors in the ATS for many years. This is complemented by examination of the final reports of the CEP (1999–2011)[3] and the Measures and Resolutions adopted by the ATCM in that period (see footnote 2).

Some basic terms used in this chapter require to be defined for clarity. The term 'strategic' can have a broad range of applications, but in this chapter we choose to use it narrowly as it applies to the planning and conducting of Antarctic activities with the ultimate mission of preserving the environments, ecosystems and wilderness of Antarctica. In this usage, strategic actions comply with the basic principles of the Protocol and contribute towards meeting the Protocol's objective, as discussed further below. Broadly speaking, strategic actions will usually involve large geographical areas, long timescales and interactions between different subsystems, components and stakeholders, in order to ensure system-wide and long-term environmental protection.

A detailed review of the concept of 'sustainable development' is beyond the scope of this chapter (for a review of the concept readers are referred to Keiner 2004; for a review of its application in international law see Schrijver 2008). We conceptualise sustainable development based on the concept of the 'egg of sustainability' originally designed in 1994 by the International Union for the Conservation of Nature (IUCN, cf. Guijt and Moiseev 2001) which emphasises that—as an egg yolk inside an egg white—people are within the ecosystem, and that the well-being of both is interdependent. However, any application of this concept to the Antarctic region should consider several important differences compared to the rest of the world. Antarctica has no indigenous people, and while it has some permanent settlements (i.e. research stations), residents are only temporary and represent a narrow segment of society (mostly scientists and logisticians). Human life in the Antarctic is largely dependent on food and energy sources originating from outside the region (conversely, marine living resources are extracted from the region for consumption elsewhere). Finally, a harsh climate, physical isolation, international cooperation, a focus on scientific research and a legal commitment to environmental protection are some of the important factors that influence human activities in the region.

Any discussion of this kind is naturally limited within certain boundaries. We acknowledge that strategic thinking for the Antarctic environment is not restricted within the CEP or under the Protocol, and that visions of governments and environmental groups come in all shapes and sizes. Despite these limitations, we hope that with this contribution we can spark off interest and discussion in the consideration of strategic thinking among the actors involved in the protection of the Antarctic wilderness.

[3] All CEP final reports are available at www.cep.aq.

11.2 An Assessment of Strategic Thinking in the Implementation of the Protocol

The Protocol and its Annexes provide an environmental planning framework that can readily serve as a basis for strategic thinking. The objective of the Protocol, as stated under Article 2, is to commit Treaty parties to 'the comprehensive protection of the Antarctic environment and dependent and associated ecosystems' and to designate Antarctica as 'a natural reserve, devoted to peace and science'. Article 3 (1) establishes the environmental principles of the Protocol:

> The protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area.

In this section, we follow the conceptual framework of Baumgartner and Korhonen (2010) to examine how Articles 2 (objective) and 3 (environmental principles) of the Protocol are implemented in practice by examining:

1. Examples of strategic environmental decision-making processes that have been used by the CEP and the ATCM;
2. The strategic content of the discussions of the CEP and of recent related Measures and Resolutions agreed by the ATCM and
3. The strategic context in which the CEP and the ATCM operate.

11.2.1 Examples of Strategic Decision-Making Processes in the CEP and the ATCM

The Protocol provides a broad vision and purpose, and together with its Annexes it contains some of the means that would help to achieve this. These include the establishment of the CEP as an advisory body to the ATCMs on environmental matters, the requirement of formal Environmental Impact Assessments (EIAs) prior to the conduct of science, tourism and other Antarctic activities, requirements for waste management and planning, the listing of specially protected species, the development of a protected area network and mechanisms to deal with liability emerging from environmental damage (e.g. Bastmeijer 2003). Of note is that the precautionary principle is implicit (Hemmings and Kriwoken 2010) in Article 3 (2) of the Protocol which requires 'information sufficient' to allow prior assessments of the possible impacts of proposed activities (see also Roura and Hemmings 2011), which enables anticipatory action in advance of having comprehensive and conclusive information about all possible impacts.

The CEP and the ATCM have also followed *ad hoc* forms of strategic processes. These pertain to processes that arise as a result of specific needs, and which are therefore restricted within discrete locations, concern specific actors, or simply aim to streamline discussions. One example is the Deception Island Antarctic Specially Managed Area (ASMA) which was developed for an island where conservation, scientific and tourism interests converge in a unique and fragile environment underlain by active volcanism (Pertierra et al. 2013). The process was strategic in the sense that it anticipated future developments of ongoing activities by NAPs and tour operators rather than being developed in response to specific activity proposals (Roura and Hemmings 2011). Another example is the Environmental Domains Analysis of the Antarctic continent. This systematic analysis divided the region into distinct ecological and geographical units, laying the necessary groundwork for systematic conservation planning whereby protected areas can be sited as part of a systematic network with the goal of protecting representative samples of Antarctic ecosystems and environmental values (New Zealand 2008; Terauds et al. 2012).

Decisions concerning the Antarctic environment follow from technical debates at the CEP and/or the ATCM, but whatever is decided at the end is often the output of national bureaucratic and international diplomatic processes, combined with other forces at play, which may include national, geopolitical and economic interests. A detailed analysis is beyond the scope of this chapter. It suffices to say that it is in this combination of processes and contrasting forces where the strategic processes of Antarctica sometimes depart from the Protocol's vision, often supporting but also sometimes opposing the objective and principles of the Protocol. As noted by Baumgartner and Korhonen:

> When any work is performed in a strategic manner, all individual activities serve to a common purpose…All actors and their actions contribute to a common vision, an overall goal. The actors and their activities do not go in different directions, nor are they competing (2010, p. 73).

If it is assumed that the Protocol provides a common vision and an overall goal, then all actions by Antarctic Treaty states and other actors should contribute towards them. A vision of an entire continent designated as a natural reserve may well mean no substantive development of the continent, while only allowing some activities that do not substantially alter the recognised values of Antarctica, including its wilderness. It is in our view that, without resorting to the introduction of fundamentally new concepts or practices, there is room for currently existing environmental decision-making processes to be put to action more strategically by the ATCM and the CEP. Roura and Hemmings (2011) suggest that this may be enacted through some formalised Strategic Environmental Assessment (SEA) process or, alternatively, through consciously giving existing processes for EIA and the designation of protected areas new *ad hoc* uses to address strategic environmental needs for particular regions, environmental domains or activity typologies. The concerted development of strategic visions and scenario analyses may also be used to guide the management of tourism and other human activities. Risk assessments and cost-benefit analyses are used by NAPs to support decision making on complex issues. These and other similar tools can be used more widely to integrate multiple stakeholder perspectives, long-time span and large geographical coverage to arrive at optimal solutions in meeting the objective and the principles of the Protocol (see Lamers et al. 2013). Ultimately, political will is the key ingredient in making any strategic decision or action happen, which in turn requires a refocusing on the original objective and environmental principles of the Protocol.

11.2.2 Strategic Content of CEP Discussions and of ATCM Instruments, 1998–2011

The CEP, which is mandated by Article 11 of the Protocol, was established in 1998 following the entry into force of the Protocol. Strategic considerations of environmental issues received sporadic interest during the first few years. Between 1999 and 2002, several papers by the environmental organisation Antarctic and Southern Ocean Coalition (ASOC 1999, 2000, 2001a, 2002) elaborated on the concept of SEA. While the papers were generally welcomed, they did not generate substantive discussion (CEP 2000, paragraphs 44–45; 2001, paragraph 35). Significant discussion of strategic directions of CEP's work took place between 2005 and 2008, partly fuelled by a workshop convened on Antarctica's future environmental challenges in 2006. An 'Aide mémoire CEP—The way forward' was developed (CEP 2005, Annex VI), and has been perhaps the most visionary set of statements of the CEP to date. Key points of this document include:

- A core goal of the CEP is to maintain and if possible improve the state of the Antarctic environment;
- CEP members will take a precautionary approach to environmental issues; and
- CEP members want to become proactive to the protection of the Antarctic environment.

Since then, a 5-year strategic plan and a new CEP agenda item titled 'Strategic Discussions on the Future Work of the CEP' were put in place and are still in use. However, an examination of CEP reports shows that the strategic content of CEP discussions has mostly been focused on streamlining the CEP's workload and reviewing how the CEP worked. In contrast, taking concrete action on cross-cutting issues or human–environment interactions, which are also important strategic considerations (CEP 2005, paragraph 16), have been largely left to the action of individual CEP Members (i.e. parties to the Protocol).

The CEP can advise the ATCM on issues that may subsequently result in the adoption of legal instruments, such as Measures and Resolutions, by the ATCM. Measures are 'texts which contain provisions intended to be legally binding once approved by all ATCPs in accordance with paragraph 4 of Article IX of the Treaty'. Instead, Resolutions are 'texts of a hortatory nature adopted at an Antarctic Treaty Consultative Meeting' (USA 2002, p. 121). In general terms, Measures influence Antarctic activities to a greater degree than non-binding resolutions and—being harder to negotiate and slower to become effective—have a longer shelf life. Both types of instruments, however, can be withdrawn or replaced by other instruments.

Since the Protocol entered into force in 1998, a total of 81 Measures have been adopted, excluding those that have been withdrawn. Most adopted Measures (78 %) address the establishment of, and management plans for, protected areas in Antarctica. Most of these Measures have been adopted after 2002, when Annex V (Area Protection and Management) entered into force. Nearly 15 % of the Measures address the designation and management of Historic Sites and Monuments (HSMs), which are also covered by Annex V.

Measures related to protected areas can contribute to meeting the objective and principles of the Protocol on different spatial scales. At the local scale they potentially provide long-term protection to discrete sites. Regionally, they can form a network of protected areas containing representative examples of Antarctic ecosystem types and environmental values. Antarctic Specially Protected Areas (ASPAs) are designated to protect the outstanding environmental, scientific or other qualities of particular areas, and require a permit for entrance, which is normally only given to scientific personnel. Antarctic Specially Managed Areas (ASMAs) are generally larger in surface area; and may contain ASPAs, HSMs, or be divided in management zones of different kinds. ASMAs are usually selected with the aim to prevent conflicts of use and interest among actors active in the area, as well as to protect sensitive environmental features. ASMAs and ASPAs provide the building blocks of a protected area regime. However, protected areas in Antarctica are small, covering less than 1 % of the surface of Antarctica (New Zealand 2005, 2009), and have rarely been designated in anticipation of future developments at particular locations (with the exception of some ASMAs, such as was the case of Deception Island discussed above).

The remaining Measures have been adopted to address the following issues:

- The adoption of Annex VI of the Protocol on Liability Arising from Environmental Emergencies;
- Insurance and contingency planning for tourism and non-governmental activities in the Antarctic Treaty area, and regulations for the landing of persons from passenger vessels (including restrictions on landings for ships carrying more than 500 passengers);
- Amendments of the Protocol's Annex II on Conservation of Antarctic Fauna and Flora;
- De-listing of fur seals (*Arctocephalus* sp.) as Specially Protected Species;
- Provisions for environmental monitoring;
- Global change research and international cooperation in Antarctica and
- The establishment of the Secretariat of the Antarctic Treaty.

A total of 76 Resolutions have been adopted since 1998. These cover a much broader range of topics than Measures, including tourism (21 % of the Resolutions), shipping standards and the prevention of marine pollution (13 %), protected areas (9 %), fauna and flora (8 %) and issues related to various aspects of the interaction between the ATCM and CCAMLR (5 %). Most Resolutions have been agreed in order to provide *ad hoc* solutions to ongoing and emerging issues. Since Resolutions are not mandatory their effect with regards to longer term environmental protection is arguably more limited. However, some Resolutions serve to pave the way for later actions and instruments. For example, Resolution 7 (2009) General Principles of Antarctic Tourism, explicitly refers to a strategic vision for tourism which could potentially set the stage for management decisions that could be more comprehensive and forward-looking than current efforts (see Jabour 2013).

Can Measures and Resolutions adopted since 1998 be said to be 'strategic'? None of them use the word 'strategic' (or related terms such as 'strategic' or 'strategies') in their title. It should however be noted that the word 'strategy' and related terms are absent in the Protocol itself. Some Measures and Resolutions refer to the concept of 'sustainable' environments or ecosystems, although this concept is not defined. For instance, Resolution 4 (2003) Support for the conservation of albatrosses and petrels expresses concern '…that populations of Albatrosses and Petrels are declining, due in large part to the unsustainable mortality of these birds from illegal, unregulated and unreported (IUU) fishing, to the extent that the status of many species of these birds is regarded as threaten (sic), endangered or vulnerable by the IUCN in its Red Data list'. Along the same lines, Measure 15 (2009) Landing of persons from passenger vessels in the Antarctic Treaty Area acknowledges '…the tourism industry's collaboration in efforts to ensure that its activities are sustainable and compatible with the objectives of the Antarctic Treaty'. The concept of 'long-term' appears in several instruments since 1992 including *inter alia* Resolution 5 (2007) Long-term effects of tourism and Resolution 7 (2009) General principles of Antarctic tourism.

Overall, this brief analysis suggests that the strategic content of CEP discussions and of instruments agreed by the ATS since the signature of the Protocol has not been absent, but has been relatively limited in extent and scope. Much of the CEP discussions have focused on streamlining the handling of its workload, while the organisation of actions that have a concrete effect on the ground has been largely left to individual CEP members. More recently the issue of climate change, however, has begun to be discussed by the CEP from a more strategic perspective (e.g. ATS 2012), although it is still not clear what type of concrete action will result from these discussions. Instruments approved by the ATCM, often following the advice of the CEP, have focused primarily on establishing or managing protected areas and on focused actions regarding important issues. Protected areas still cover a small percentage of Antarctica's territory and form an aggregate of disparate locations, rather than a coherent network.

11.2.3 Strategic Context: Emerging Pressures and Business-As-Usual

In this section we examine the larger regional and global socio-economic contexts in which environmental management of Antarctica is embedded, which enables us to consider the likely future consequences of following the present trajectory (Business-As-Usual). Strategic processes and content of ATS discussions do not take place in a vacuum. They are embedded within economic, political and physical contexts, both regional and global, which can all exert influence on the possibilities and restrictions of strategic activities.

11.2.3.1 Global Developments

Due to a range of global developments, including technological advance, increasing access to advanced technologies by a broader, increasingly wealthy community and new market conditions, it has become easier and cheaper for commercial interests and the public to access Antarctica. Activities such as fishing, tourism and biological prospecting have become economically viable and profitable activities that tend to develop further and expand. Scientific research is also able to take place in areas that has been hitherto difficult to reach. Many Treaty parties seek to maximise the economic benefits of Antarctic research and resource access—this is particularly obvious under the CAMLR Convention regime. Increasingly, human activity in Antarctic is becoming a regional manifestation of global phenomena (Hemmings 2007).

11.2.3.2 Global Climate Change

The Antarctic Peninsula is one of the fastest warming regions on Earth. Changes have direct effects on Antarctica's ecosystems and environment (SCAR 2009) and also how Antarctica is perceived by the society. New infrastructure and intense research activity in Antarctica, such as the International Polar Year 2007–2009, have been justified by the importance of using Antarctica as a pristine laboratory to understand the processes underlying global climate change—for example, see, the 2009 Washington Declaration on the International Polar Year and Polar Science (Antarctic Treaty-Arctic Council Joint Meeting 2009). Access to the region is changing, with potentially longer seasons in the milder months of the year where human activities can take place. Impacts of human activities may increase as non-native species and pollutants that have previously not been able to activate due to the low temperatures have a higher likelihood to become mobile (see Hughes et al. 2013). Changes in the surfaces of ice-covered land and of the ice-shelves may decrease the effectiveness of the Antarctic Treaty (e.g. Norway and United Kingdom 2010; Baker 2010).

11.2.3.3 Lack of Integration Across Regulatory Bodies

The Antarctic Treaty and its Protocol, the CAMLR Convention, the Agreement on the Conservation of Albatrosses and Petrels, the International Convention for the Regulation of Whaling, the International Convention for the Prevention of Pollution from Ships, and other international treaties and agreements, cover different elements of the Antarctic environment and their membership and areas of jurisdiction overlap partly but are not identical (see Woehler et al. 2013; Miller 2013; Leaper and Childerhouse 2013; Jabour 2013). They all have different emphases, some more oriented towards resource exploitation and management and others more towards conservation—or a combination of both approaches. Consequently, different components of the Antarctic environment are protected unevenly. In particular, large swaths of the marine environment south of 60 degrees south, which are explicitly covered by the Protocol, rely primarily on decisions made by CCAMLR. Under Article 2 of the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention) the notion of 'conservation' includes the concept of 'rational use', which includes (and is often conceived as exclusively) as harvesting, subject to several conservation principles.

11.2.3.4 Inconsistent Application of the Protocol

Antarctic Treaty parties have different priorities with respect to environmental management. Some do the minimum required by the Protocol, or not even that, while others introduce high environmental standards (ASOC 2001b; Tin et al. 2009; ASOC 2011). Breaches to the Protocol or instance of non-implementation—concerning for instance waste management and an absence of EIAs for many activities—are inexplicably still occurring 20 years after the signature of the Protocol (e.g. Braun 2013). Some issues are neglected, e.g. protection of wilderness values, infrastructure expansion and minimising and managing cumulative impacts of human activities. In addition, some instruments are applied but are not consistently effective, e.g. EIAs (Hemmings and Roura 2003; Bastmeijer and Roura 2008; Hemmings and Kriwoken 2010; ASOC 2011).

11.2.3.5 Business-As-Usual

Overall, the strategic context of Antarctica points to the increasing complexity of carrying out environmental planning and management in accordance to the Protocol. It also points to the increased difficulty for many Treaty parties to uphold the high environmental standards of the Protocol while resisting existing and emerging developmental pressures. However, the Protocol is not particularly suited to effectively address all of these pressures, and the ATS itself may be losing momentum to uphold the conservation values it accepted 20 years or more ago. Hemmings (2010b) has described the 'hollowing' of the ATS, by which it is meant that while the formal structure of the ATS remains, its substantive core has been disabled by both external forces—commercial pressures as well as competition from other global regimes—and from within, particularly with regards to the original question of sovereignty over Antarctic territory.

Taking into account past and ongoing strategic processes and content within the ATS and embedding it into the regional and global strategic context, what would happen if present trends continue into the future? A Business-As-Usual future for the Antarctic environment is likely to contain more of the current phenomena: continuous activity growth, expansion and diversification; loss of Antarctic exceptionalism—the conception of Antarctica as a different place ruled by different value systems than the rest of the world (see e.g. Hemmings 2009); encroachment upon and fragmentation of the Antarctic wilderness; and expanding commercial uses of Antarctica's natural resources, either through harvesting or use of ecosystem services (see Box 11.1). Environmental protection may still feature in this future, but on the margins of these other phenomena rather than as a central guiding principle, and with the practical application of the Protocol and other environmental components of the ATS not always complying fully with the letter and intent of these instruments. In other words, there is a risk that the Antarctic continent and surrounding oceans will be legally protected but will become, for all intents and purposes, a 'paper park'.

Box 11.1: Projection of a Business-As-Usual Future for the Antarctic Wilderness

- Human activities continue to diversify, grow and spread out spatially. Environmental management does not keep up with the pace of activity growth.
- Once a special continent where high ideals of how humankind relate to each other (peace and science for the benefit of mankind) and to nature (natural reserve) were possible, Antarctica and its resources and environment are consumed following lower global and domestic standards (Hemmings 2009, 2010a).
- The ensemble of small protected areas does not provide protection to a representative sample of Antarctic ecosystems or environmental values. The designation of the continent as a natural reserve does not procure meaningful protection. Basic tenets of the Protocol are not adequately implemented by a sizeable percentage of NAPs.
- More research stations and transport networks (coastal shipping lanes, maintained roads and air links) are established near existing stations and in isolated areas, further encroaching upon the Antarctic wilderness.
- In marine areas south of 60 degrees south CCAMLR rules entirely, and the area of application of the Protocol retreats *de facto* to the continent. The focus on 'rational use' understood solely as harvesting means that Antarctic krill and finfish fisheries expand in volume and into new marine areas, with limited consideration to land-based predators. Whaling continues.
- ATS continues to manage tourism in a piecemeal, reactive manner, without an effective overarching vision. Tourism industry continues to expand, increasing the number of people it transports to Antarctica. Types of tourist activities diversify including the establishment of land-based tourism infrastructure of different kinds. Tourism expansion and diversification progresses ahead of regulation. Tourism impacts remain largely unmonitored.
- Biological prospecting develops in a vacuum of regulation, targeting rare and extreme forms of Antarctic life, without any substantive share of the benefits being invested in environmental protection.
- Parties position themselves for a future lifting of the mining ban. The concept of what constitutes bona fide scientific research on mineral resources is eroded, so that some preliminary geological prospecting takes place on regular bases.

11.3 Beyond Business-As-Usual: Environmentalists' Perspectives for the Future of Antarctica

For over 30 years, ENGOs under the umbrella of the Antarctic and Southern Ocean Coalition (ASOC) have acted as watchdog, partner, dreamer and advisor to the Treaty parties in bringing environmental perspectives into Antarctic governance. The role of ENGOs is to speak out on issues that are important for the Antarctic environment and ecosystems in a territory that lacks a constituency made up of indigenous peoples or permanent residents. Excluded from the ATS deliberations initially, ENGOs have since earned expert observer status within the ATS and—with varying degrees of influence and success—have played active roles in substantive debates concerning the environment, including debates that stopped the minerals convention and created the Protocol (Roura 2007a, b). The perspectives of ENGOs sometimes coincide with, and sometimes oppose, the individual or collective policies of Treaty parties.

In the face of ongoing and new environmental pressures since the signature of the Protocol and its subsequent entry into force, environmental groups have continued to demand the ATCM to uphold its mission of protecting and safeguarding Antarctica as the last unspoiled wilderness and a global commons for the heritage of future generations of humans and wildlife. Environmental groups have called for a future Antarctica that is emphatically better, and certainly no worse than the current situation in terms of the preservation of Antarctica's intrinsic values, the integrity of its wilderness and the upholding of the key principles of the Antarctic Treaty and its Protocol (ASOC 1999, 2000, 2001a, 2009; Roura and Tin 2006; Barnes 2011). This vision for the future of the Antarctic environment includes a low environmental impact, protection of wilderness, strategic thinking and international cooperation. Combined, these elements would contribute to stabilise the human footprint so that it does not increase substantially compared to the current one (see Box 11.2).

ENGOs have never suggested that appropriate uses of the Antarctica should be stopped. Rather, development—to the extent that it exists in the Antarctic—should be qualitative rather than quantitative in nature and contained within the limits of the ecosystem as set by science and/or a precautionary approach, in order to ensure that the objective and principles of the Protocol are met in perpetuity. Achieving this vision would require a shift from the present paradigm of under-regulated and continuous growth towards a new paradigm, based on four main criteria.

First, the status of Antarctica as a natural reserve should be maintained through the proper implementation of the objective, principles, letter and intent of the Protocol. The prohibition of mineral resource activities should remain in place permanently. The commitment to protecting the entire Antarctic region should be strengthened. In addition, more and larger protected areas on land and at sea need to be established, chosen following systematic and holistic criteria.

Secondly, strategic thinking in the management of activities on land and at sea, as covered by the Protocol, should be formalised through the establishment of a SEA process or its equivalent (e.g. at a minimum a conscious strategic use

Box 11.2: An Aspirational Vision for the Future of the Antarctic Wilderness

- Antarctica remains a large contiguous wilderness area where there is little evidence of human presence. It continues to be set aside from the rest of the world, governed as a global commons using higher environmental standards than those used elsewhere in the world. It remains a symbol of humanity's willingness to cohabit in peace, to work together in the interest of humankind of today and tomorrow and to protect nature for its intrinsic values.
- Human footprint in the Antarctic stops growing and even shrinks as obsolete infrastructure is removed and new human activity is carried out with a view to minimise its footprint. Existing active facilities are removed at the end of their life cycle (typically ca. 25 years after initial establishment).
- Scientific efforts are focused on those that are globally significant for the benefit of humankind and not for national or commercial interests. Parties' influence within ATS is determined by the quality of their science and environmental standards and not by sheer presence in the Antarctic.
- Science is increasingly undertaken involving little infrastructure and human presence, relying mostly on temporary facilities and remote techniques rather than large-scale permanent stations. Infrastructure and logistics are shared between parties. International research stations become common. Infrastructure is constructed or upgraded using state-of-the art technologies, minimising local and global environmental impacts.
- Use of ecosystem services (such as fishing, biological prospecting, tourism and other activities based on harvesting or otherwise using natural resources) is based on an ecosystem approach, the precautionary principle and the overall minimisation of environmental impacts. Mineral resource activities remain banned permanently.
- Most of Antarctica remains open most of the time to appropriate, low-impact human activity; however, the option of limiting human activity at relevant spatial, temporal and activity scales remains available as a way to preserve Antarctic values.

of existing instruments). This would ensure that strategic decisions are made and result in concrete action in advance of particular developments. Decisions should be guided by a future vision that has been consciously and collectively chosen. In particular, as noted by Bastmeijer (2011), human activities should be managed proactively to prevent situations where governance is absent.

Third, strengthening cooperation between Treaty parties would allow a more effective and timely response to emerging pressures. Effective cooperation would minimise the chances that territorial or resource interests prevail over international obligations and the global benefit of protecting Antarctica (ASOC 2011).

Finally, these actions would contribute to the reinforcement of the ATS so that it remains stable, by strengthening its governance role to be able to resist commercial pressures for opening up the Antarctic for development. Commercial activities should be regulated under legally binding instruments, applying the precautionary principle and supported by the best available scientific data. Science, the preservation of international peace and the environment should remain the three foundational pillars of Antarctic governance. Expanding activities such as the development of scientific infrastructure, tourism and biological prospecting are allowed to take place as long as they do not negatively affect these basic pillars. The same applies for new activities that may emerge in the future.

11.4 Conclusions: Realising a Vision for Antarctica

Looking into the recent past and present, we see that the content and process of strategic thinking in the ATS are sufficiently adequate—certainly in relation to other regions of the world—although they could be considerably strengthened. In particular, there are emerging gaps between the letter of the Protocol and the way it is implemented, including in its relation with CCAMLR. However, looking to the future, we believe that various sorts of pressures are increasingly encroaching upon the basics of the Protocol, resulting in weaker environmental protection. Many of the current developments are about securing access to actual and potential resources, ecosystem services and territory, partly for activities such as science and tourism, and partly for legal and illegal extractive industries, particularly in the marine environment, at the expense of an attrition of the environmental and wilderness values of the region. Tensions between internationally agreed objectives and national interests (Bastmeijer and Roura 2004; Roura and Hemmings 2011; Hemmings 2010a, b) create further pressures on the environment and the capability (and willingness) of parties to respond to these pressures.

In this context, a Business-As-Usual future of the Antarctic environment is likely to result in snowballing pressures, and a growing attrition of the Antarctic wilderness. However, not all is 'doom and gloom' and there are still chances to preserve core environmental values, provided that there is sufficient political will. As noted above, in the 'Aide mémoire CEP—The way forward' included in the CEP VIII report, the CEP was able to produce a simple but remarkable visionary set of statements. Antarctic Treaty parties (or CEP members under a different hat) should now ensure that these statements are effectively put into action. This is not to deny that some progress has been made to protect the environment. However, it is also apparent, as noted earlier, that many Antarctic Treaty parties have increased difficulty to apply the environmental standards of the Protocol and that the collective of parties is losing momentum to uphold the conservation values it accepted more than 20 years ago.

One option would be to 'reboot' the ATS, reinvigorate and restore to its original mission of preserving what has been called 'Antarctic exceptionalism'—the unique nature of the Antarctic and its system of governance (Hemmings 2010a, b) and upholding, rather than eroding, the intrinsic values of Antarctica that parties themselves pledged to protect. This requires 'connecting the dots' so that strategic thinking—content, process and context—and resulting actions by the ATS and individual Treaty parties are fully in accordance with the stated objective and principles of the Protocol in order to prevent that these are derailed into a 'paper park' future.

During the Cold War era, with its underlying threat of nuclear warfare, it probably would have seemed naïve and idealistic to some people to dream of an entire continent designated as a natural reserve, devoted to peace and science in a context of international cooperation. A substantive step to make this dream a reality was achieved with the signature of the Protocol. In a discourse at the ceremony to commemorate the 50th anniversary of the entry into force of the Antarctic Treaty the former French Prime Minister Michel Rocard—one of the instigators of the Protocol—stated that the adoption of the Protocol had been a 'miracle' given the difficulty experienced over the past few decades in developing international agreements on issues like climate change (Statement by Michel Rocard in ATS 2011). Antarctic Treaty parties, encouraged by environmental groups and other actors, should ensure that implementing the Protocol becomes both a reality in the present and also a strategic vision for the longer term, and that the miracle does not turn into a mirage.

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References

Antarctic Treaty-Arctic Council Joint Meeting. (2009). *Washington Ministerial Declaration on the International Polar Year and Polar Science*. Antarctic Treaty–Arctic Council Joint Meeting, Washington, USA, 6 Apr 2009. Retrieved from: http://www.state.gov/g/oes/rls/other/2009/121340.htm.

ASOC. (1999). *Large scale Antarctic tourism*. Information Paper 121 presented at XXIII Antarctic Treaty Consultative Meeting, Lima, Peru, 24 May–4 June 1999.

ASOC. (2000). *Antarctic Strategic Environmental Assessment: application to the growing Antarctic tourism industry*. Information Paper 10 presented at XXII Special Antarctic Treaty Consultative Meeting, The Hague, Netherlands, 11–15 Sept 2000.

ASOC. (2001a). *Strategic needs and decision-making in Antarctica*. Information Paper 54 presented at XXIV Antarctic Treaty Consultative Meeting, St. Petersburg, Russian Federation, 9–20 July 2001.

ASOC. (2001b). *Legal implementation of the five annexes of the environmental Protocol to the Antarctic Treaty*. Information Paper 55 presented at XXIV Antarctic Treaty Consultative Meeting, St. Petersburg, Russian Federation, 9–20 July 2001.

ASOC. (2002). *Strategic environmental assessment in Antarctica: a 'stepping stone' to madrid protocol objectives*. Information Paper 82 presented at XXV Antarctic Treaty Consultative Meeting, Warsaw, Poland, 10–20 Sept, 2002.

ASOC. (2009). *Key elements of a strategic vision for Antarctic tourism*. Information Paper 53 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, 6–17 Apr 2009.

ASOC. (2011). *The Antarctic environmental protocol,* 1991–2011. Information Paper 81 (rev. 1) presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, June 20th–July 1st 2011.

ATS. (2011). Final Report of the XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina, June 20th–July 1st 2011. Retrieved from: http://www.ats.aq/documents/ATCM34/fr/ATCM34_fr001_e.pdf.

ATS. (2012). ATCM XXXV and CEP XV Agenda and Schedule. Special Paper 1 rev.1 presented at XXXV Antarctic Treaty Consultative Meeting, Hobart, Australia, 11–20th June, 2012.

Baker, F. W. G. (2010). Some reflections on the Antarctic Treaty. *Polar Record, 46*(1), 2–4.

Barnes, J. N. (2011). The Antarctic Treaty System: perspectives of environmental nongovernmental organizations on addressing key issues. In P. A., Berkman, M. A., Lang, D. W. H., Walton & O. R., Young (Eds.), *Science diplomacy: science, Antarctica, and the governance of international spaces*, Washington, DC, USA: Smithsonian Institution Scholarly Press.

Bastmeijer, C. J. (2003). *The Antarctic environmental protocol and its domestic legal implementation.* International Environmental Law and Policy series, Vol. 65. The Hague: Kluwer Law International.

Bastmeijer, C. J. (2011). Intergenerational equity and the Antarctic Treaty System: continued efforts to prevent 'mastery'. *Yearbook of Polar Law* 3. Leiden: Martinus Nijhoff.

Bastmeijer, C. J., & Roura, R. M. (2004). Regulating Antarctic tourism and the precautionary principle. *The American Journal of International Law, 98*(4), 763–781.

Bastmeijer, C. J., & Roura, R. M. (2008). Environmental impact assessment in Antarctica. In C. J. Bastmeijer & T. Koivurova (Eds.), *Theory and practice of transboundary environmental impact assessment* (pp. 175–219). Monographs series on legal aspects of sustainable development. Leiden: Brill/Martinus Nijhof Publishers.

Baumgartner, R. J., & Korhonen, J. (2010). Strategic thinking for sustainable development. *Sustainable Development, 18*(2), 71–75.

Bergstrom, D., Convey, P., & Huiskes, A. H. L. (Eds.). (2006). *Trends in Antarctic terrestrial and limnetic ecosystems, Antarctica as a global indicator*. Dordrecht: Springer.

Braun, C., Fritz, H., Mustafa, O., Nordt, A., Pfeiffer, S., & Peter H.-U. (2013). Environmental assessment and management challenges of the Fildes Peninsula region. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. (pp. 169–191). Dordrecht, Netherlands: Springer.

CEP. (2000). *Report of the committee for Environmental Protection (CEP III)*. The Hague: Author.

CEP. (2001). *Report of the committee for Environmental Protection (CEP IV)*. St. Petersburg: Author.

CEP. (2005). *Report of the committee for Environmental Protection (CEP VIII)*. Stockholm: Author.

Geoff, M. (1986). *Antarctica: Our last great wilderness*. Hawthorn: Australian Conservation Foundation.

Guijt, I., & Moiseev, A. (2001). *Resource kit for sustainability assessment*. Gland and Cambridge: IUCN.

Hemmings, A. D. (2007). Globalisation's cold genius and the ending of Antarctic isolation. In L. K. Kriwoken, J. Jabour, J. & A. D. Hemmings. (Eds.) *Looking South: Australia's Antarctic agenda*, 176–190. Leichhardt, Australia: The Federation Press.

Hemmings, A. D. (2009). From the new geopolitics of resources to nanotechnology: emerging challenges of globalism in Antarctica. *Yearbook of Polar Law, 1*, 55–72.

Hemmings, A. D. (2010a). *Considerable norms in the Antarctic*. Paper presented at Antarctic visions: Cultural Perspectives on the Southern Continent. University of Tasmania, Hobart, Australia, 21–23 June, 2010.

Hemmings, A. D. (2010b). *The hollowing of the Antarctic Treaty System and the governance of Antarctica*. Paper presented at the Symposium on the politics of Antarctica. University of Canterbury, Christchurch, New Zealand, 8–9 July 2010.

Hemmings, A. D., & Kriwoken, L. K. (2010). High level Antarctic EIA under the Madrid Protocol: State practice and the effectiveness of the Comprehensive Environmental Evaluation Process. *Journal of International Environmental Agreements: Politics, Law and Economics, 10*(3), 187–208.

Hemmings, A. D., & Roura, R. M. (2003). A square peg in a round hole: Fitting impact assessment under the Antarctic environmental protocol to Antarctic tourism. *Impact Assessment and Project Appraisal, 21*(1), 13–24.

Hemmings, A. D., & Roura, R. M. (2007). La nuova scoperta dell'Antartide [The new discovery of Antarctica]. *Il Polo, 62*(2), 39–46.

Hughes, K. A., Convey, P., & Huiskes, A. H. L. (2013). Global movement and homogenisation of biota: challenges to the environmental management of Antarctica? In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment* (pp. 113–117). Dordrecht, Netherlands: Springer.

IAATO. (2007). *IAATO wilderness etiquette*. Adopted at IAATO 18th Annual Meeting, Hobart, 2007. Appendix 1 in: Update on the Antarctic Peninsula landing site use and site guidelines, Information Paper 82 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine, 2–13 June 2008.

Jabour, J. (2013). Strategic management and regulation of Antarctic tourism. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment* (pp. 273–286). Dordrecht, Netherlands: Springer.

Keiner, M. (2004). Re-emphasizing sustainable development—the concept of 'evolutionability'. On living chances, equity, and good heritage. *Environment, Development and Sustainability*, 6(4): 379–392.

Knox, G. A. (2007). *Biology of the Southern Ocean*. Boca Raton: CRC Press, Taylor & Francis Group.

Lamers, M., Liggett, D., & Tin, T. (2013): Strategic thinking for the Antarctic environment: adapting tools and integrating governance. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. (pp. 307–327). Dordrecht, Netherlands: Springer.

Leaper, R., & Childerhouse, S. (2013). Present and future conservation management of Antarctic baleen whales. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. (pp. 97–112). Dordrecht, Netherlands: Springer.

Miller, D. G. M. (2013). Antarctic marine living resources—'the future is not what it used to be'. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. (pp. 51–95). Dordrecht, Netherlands: Springer.

New Zealand. (2005). *A review of the Antarctic protected areas system*. Information Paper 29 presented at XXVIII Antarctic Treaty Consultative Meeting, Stockholm, Sweden, 6–17 June 2005.

New Zealand. (2008). *Systematic Environmental Protection in Antarctica: Final report on Environmental Domains Analysis for the Antarctic continent as a dynamic model for a systematic environmental geographic framework for Annex V of the Protocol*. Working Paper 27 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine, 2–13 June 2008.

New Zealand. (2009). *Updated analysis of representation of Annex V categories and environmental domains in the system of Antarctic Specially Protected and Managed Areas*. Working Paper 31 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA, 6–17, Apr 2009.

Norway & United Kingdom. (2010). *Implications of climate change for management and governance of the Antarctic region—an overview*. Working Paper 1 presented at Antarctic Treaty Meeting of Experts on Climate Change, Svolvaer, Norway, 6–9 Apr 2010.

Orheim, O., Press, A., & Gilbert, N. (2011). Managing the Antarctic environment: the evolving role of the committee for environmental protection. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: science, Antarctica, and the governance of international spaces* (pp. 209–221). Washington, DC, USA: Smithsonian Institution Scholarly Press.

Pertierra, L. R., Tejedo, P., & Benayas, J. (2013). Looking into the future of Deception Island: Current status, drivers of change and policy alternatives. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human Engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

Roura, R. M. (2007a). The Antarctic and Southern Ocean Coalition–ASOC. In B. Riffenburgh (Ed.), *The Encyclopedia of the Antarctic* (pp. 41–43). New York: Routledge.

Roura, R. M. (2007b). Greenpeace. In B. Riffenburgh (Ed.), *The Encyclopedia of the Antarctic* (pp. 472–474). New York: Routledge.

Roura, R. M., & Hemmings, A. D. (2011). Realising strategic environmental assessment in Antarctica. *Journal of Environmental Assessment Policy and Management, 13*(3), 483–514.

Roura, R. M. & Tin, T. (2006). *Antarctic Futures: Growth, wilderness protection, and change.* Poster presented at the Committee for Environmental Protection (CEP) Workshop, Antarctica's Future Environmental Challenges. Edinburgh, United Kingdom, 9–10 June 2006. Retrieved from www.asoc.org.

Sánchez, R. A., & McIvor, E. (2007). The Antarctic committee for environmental protection: past, present, and future. *Polar Record, 43*(226), 239–246.

SCAR (2009). *Antarctic climate change and the environment*. Turner, J., Bindschadler, R. A., Convey, P., di Prisco, G., Fahrbach, E., Gutt, J., Hodgson, D. A., Mayewski, P. A. & Summerhayes, C. P. (Eds.), Cambridge: Scientific Committee on Antarctic Research.

Schrijver, N. (2008). *The evolution of sustainable development in International Law: Inception*. Meaning and Status. Hague Academy of International Law Pocketbook. Leiden: Martinus Nijhoff.

Shirihai, H. (2002). *The complete guide to Antarctic Wildlife. Birds and mammals of the Antarctic continent and the Southern Ocean*. Princeton: Princeton University Press.

Terauds, A., Chown, S. L., Morgan, F., Peat, H. J., Watts, D. J., Keys, H., et al. (2012). Conservation biogeography of the Antarctic. *Diversity and Distributions, 18*(7), 726–741.

Tin, T., Hemmings, A. D., & Roura, R. M. (2008). Pressures on the wilderness values of the Antarctic continent. *International Journal of Wilderness, 14*(3), 7–12.

Tin, T., Fleming, Z., Hughes, K. A., Ainley, D., Convey, P., Moreno, C., et al. (2009). Impacts of local human activities on the Antarctic environment: a review. *Antarctic Science, 21*, 3–33.

USA. (2002). *Handbook of the Antarctic Treaty system* (9th Ed.). Washington DC: US Department of State.

USA. (2011). *Report of the Depository Government of the Antarctic Treaty and its Protocol in accordance with Recommendation XIII-2*. Information Paper 22 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, 20 June–1 July, 2011.

Woehler, E. J., Ainley, D. & Jabour, J. (2013). Human impacts to Antarctic wildlife: predictions and speculations for 2060. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. (pp. 27–60). Dordrecht, Netherlands: Springer.

Chapter 12
Strategic Management and Regulation of Antarctic Tourism

Julia Jabour

Abstract Antarctic tourism is mainly ship-based and managed on a day-to-day basis by the industry using guidelines for behaviour designed specifically for tourist sites. Regulation comes mainly from international shipping law. There are increasing concerns about climate change, shipping accidents and growing tourist numbers, prompting calls for stricter governance to manage growth and risk. The Antarctic Treaty Consultative Parties collaborate with expert organisations to govern tourism but there are still regulatory lacunae that need attention. Initiatives such as a ban on heavier fuel oils in the Antarctic Treaty area and the imposition of a mandatory shipping code will slowly fill that gap. But a new suggestion is offered here to tighten regulation even further: the adoption of sponsoring states for tourism operators from among Antarctic Treaty Consultative Parties. This scheme will introduce a strict element of environmental liability for tourist activities, with greater enforceability.

Keywords Antarctic tourism • Management and regulation of Antarctic tourism • Mandatory shipping code • Sponsoring states • Tourism growth

12.1 Introduction

Antarctica is not isolated from the rest of the world; it is joined to it, in fact, by air and water. Only distance separates the continent from inhabited lands. This distance was once sufficient to ensure its protection but this is no longer the case as a modest but unrelenting human tide washes up on Antarctic shores each year. The tide will not be stopped. Visitors, especially those that pay for the privilege, are

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enrapt by the novelty of the place and would argue sophistically that it is not they who will have an impact on the Antarctic environment. Separating those that pay to go to the Antarctic from those who are paid to go as scientists and support staff is a management and regulatory strategy that is discriminatory and naïve. It perpetuates the legitimacy of scientific endeavours above all others but the truth is, of course, that all humans in this alien landscape leave their mark, however minor and/or transitory they claim it to be.

Antarctic tourism is characterised by cruise and ship-based tourism from South America to the Antarctic Peninsula from about October to March (Argentina 2010). Other operations include some continental activities, yacht cruising, over flights and fly–cruise, as well as limited visitation to East Antarctic destinations. The nomenclature applied to tourism is widely divergent and incommensurable (Murray and Jabour 2004) so in this chapter about 'tourism and non-governmental activity'—the official jargon used by the Antarctic Treaty Consultative Parties (ATCPs)—the term 'tourism' is used for convenience.

Tourism activities in the Antarctic Treaty area are a standing agenda item at annual Antarctic Treaty Consultative Meetings (ATCMs). Five decades ago, the parties began acknowledging tourism as a legitimate—though troubling—pursuit in an Antarctic environment jealously reserved for peace and science. Today, tourism is subject to a three-tiered management and regulation arrangement involving a coalition of industry affiliates—the International Association of Antarctica Tour Operators (IAATO), the ATCPs and flag states that might or might not be signatories to the Antarctic Treaty and its Protocol on Environmental Protection (also known as the Madrid Protocol). Day-to-day management of tourism is the responsibility of IAATO, with more formal regulation spilling over from decisions of the ATCPs implemented via the national legislation of flag states. Because the greatest majority of activities are ship-based, regulation comes also from the corpus of existing international maritime law via flag states (Jabour 2011) (Fig. 12.1).

Another note about terminology: The term 'management' is used here in the sense of the direction of day-to-day activities. On the other hand, the term

Fig. 12.1 The three-tiered tourism management and regulation arrangements

'regulation' is used in the more prescriptive sense of an activity being subject to rules or laws, and is not intended to be synonymous with management (see Haase et al. 2009).

The number of tourists grew slowly and steadily from the mid-1960s, with a growth spurt in the early 1990s prompting the formation of IAATO to protect member interests and to promote safe and environmentally responsible travel to the Antarctic (IAATO 2013a). Tourist numbers are not large because there are natural limits to industry expansion (Landau 2001) based on factors involving distance, climate, cost, lack of infrastructure, inadequate or non-existent charts and other vicissitudes of polar travel. Irrespective of the scale, there is a recognised need to manage and regulate tourism appropriately.

Strategic planning for future tourism governance is a problematic concept, however. Tourist and operator numbers fluctuate organically; because numbers are still comparatively low, simply taking one cruise ship off the Antarctic route altogether returns a significant percentage decrease in tourist numbers for that season. The global financial downturn bit into tourism in the 2008/2009 season and there was an 18 % decrease in paying passengers to the Antarctic from the previous season. According to IAATO annual reports to ATCMs, this was followed by a further 2.6 % fall in the 2009/2010 season, 8.3 % in the 2010/2011 season and 22 % in the 2011/2012 season. Numbers for the latest tourism season are estimated to rise by 24 % back to about 35,000 (IAATO 2012). Accordingly, to think strategically about the future and what approaches should be taken to reduce and manage risks associated with Antarctic tourism is not a simple matter. It might require that less emphasis be placed on actual numbers and instead, ask will tourism continue to increase, where will tourists go and what will they see?

Many pages of ink have been devoted to the multifaceted topic of Antarctic tourism governance over the years (among them the Annals of Tourism Research Special Edition 1994; Bauer 2001; Hemmings and Roura 2003; Molenaar 2005; Stewart et al. 2005; Enzenbacher 2007; UNEP 2007; Haase et al. 2009) and two recent works delve into specific aspects (cruise tourism, in Lück et al. 2010; climate change, in Hall and Saarinen 2010). It has been predicted for some time that governance needs to change (Liggett et al. 2010) and in fact, changes already initiated by the ATCPs in relation to ship-based tourism will serve to bolster an inadequate regulation and enforcement regime and help counter much existing criticism of the effectiveness of tourism regulation. The same can be said for IAATO's management regime, as it strives to keep itself significantly involved in any governance arrangements that might adversely affect the viability of its Antarctic market. But more is required.

This chapter begins by describing in brief how the ATCPs and the industry are regulating and managing tourism in today's scenario. It includes discussion of the most recent initiatives of the ATCPs, in conjunction with the International Maritime Organization (IMO), to regulate polar shipping. The chapter then expresses more strategically how the future of Antarctic tourism might play out between the ATCPs and IAATO, and presents one novel approach to regulation that might more adequately address criticism about mitigating environmental risk.

12.2 Current Governance and Its Problems

How the Antarctic Treaty and its Protocol on Environmental Protection operate is well documented elsewhere in this volume (see Tin et al. 2013). Parties to the Antarctic Treaty and Madrid Protocol meet formally once a year to make recommendations to their governments about matters relating to Antarctica, including tourism and non-governmental activity. Much foundational work is conducted in intersessional forums such as the Meeting of Experts on the Management of Shipborne tourism in the Antarctic Treaty Area, which convened in Wellington, New Zealand in December 2009. Despite the expert level of these kinds of meetings, the Parties only ever take formal decisions in an ATCM.

ATCM pronouncements are separated into obligation creating Measures, administrative Decisions and hortatory Resolutions and are based on the consensus position achieved by the 29 Consultative Parties. Consensus involves the lack of formal objection and may not, in fact, represent total agreement, although this is implied. Implementation of measures requires the force of law and thus becomes a state responsibility. There is, however, some disparity between the attitudes of different governments towards tourism, based among other things on the fact that some benefit directly (e.g. the parties with gateway ports) while others do not.

One reflection of the complexity and philosophical difficulties faced by individual Parties in relation to tourism is the fact that in the past 50 years, Measures about tourism number only two, and neither have yet entered into force. Measure 4 (2004) Insurance and Contingency Planning for Tourism and Non-governmental Activities in the Antarctic Treaty Area requires the ratification of the (then) 27 Consultative Parties to bring it into force. Currently only 11 signatures have been received. Measure 15 (2009) Landing of Persons from Passenger Vessels in the Antarctic Treaty Area has only three of the requisite (now) 29 Consultative Party signatures.

The Treaty parties had once been reluctant to show clear leadership in tourism regulation, preferring instead to abrogate management responsibility to IAATO. One positive move has been their decision to collaborate with the IMO on the regulation of polar shipping. In the last couple of years, incidents involving ships in Antarctic waters, primarily but not exclusively tourism vessels, had increased the need for the ATCPs to become more proactive. The sinking of the tourist vessel MV Explorer (without loss of life or major environmental damage) and the frequency of groundings and other incidents each year put the spotlight on high beam and aimed squarely at tourism vessels (Klein 2010). However, the sinking of the Ady Gil (without loss of life) during a campaign by the Sea Shepherd Conservation Society in January 2010, the loss of 22 lives when the Korean fishing vessel No. 1 Insung sank in December 2010 and the loss of 3 from the yacht Berserk in 2011 reinforces how dangerous Antarctic navigation is for all vessels.

The operation of the IAATO is also well documented elsewhere (IAATO 2013a). It has a membership of around 105 (IAATO 2013b) bound by a set of by-laws (IAATO 2013c). The operators collaborate in scheduling their voyages, in providing a companion route system for safety purposes, the submission of post-site visit reports and other statistics, and the use of a host of operational and behavioural guidelines determined through their sub-committees and ratified at each year's Annual General Meeting. Their majority decisions and guidelines are not legally binding, however, and the remedy for breaches is insubstantial (the downgrading of membership status or expulsion). Of note, however, is the fact that IAATO members take motions to admit new members by secret ballot.

The ATCPs and IAATO collaborate to permit tourism to be carried out according to mutually accepted industry and regional best practice. Measure 4 (2004) is designed to promote best practice (Jabour 2007) and Measure 15 (2009) is, in fact, a replica of an existing IAATO by-law that aimed to prevent ships carrying more than 500 passengers from making landings in Antarctica. And further, IAATO has adopted the language of the Madrid Protocol by committing its operators to having 'no more than a minor or transitory impact' on the Antarctic environment (IAATO 2013d, Madrid Protocol Article 8 and Annex I).

The uniqueness of the Antarctic as a tourism destination causes management and regulatory problems. Specifically, there is not one sovereign entity that can make and enforce a uniform set of laws relating to tourism activities in, or affecting, its territory in Antarctica that can be universally applied to every tourism operator, or tourist, or vessel. Article IV of the 1959 Antarctic Treaty rules out such an approach by indefinitely suspending territorial claims. This means that claimed territory does not have full sovereign territory status in the normal sense for any purpose other than the application of laws to the claimants' own citizens, companies, ships and aircraft. The claimants—Argentina, Australia, Britain, Chile, France, New Zealand and Norway—can, and do, make laws that apply to their Antarctic claim on this basis, which only becomes problematic when an attempt is made to apply those same laws to foreign nationals as well.

Another problem is that tourism operations are flagged to non-Treaty Parties (often up to 60 % out of the port of Ushuaia; Argentina 2010). The number of Antarctic Treaty Parties represents less than one-quarter of the total United Nations member states (50 out of 192), and only 29 of those actually make decisions in ATCMs. To further complicate matters, membership of IAATO is entirely voluntary and not restricted to companies registered in ATCP states, or even out in the broader group of signatory states (IAATO 2013b). So, even if adequate and appropriate regulations were in place and, as IAATO boasts, the vast majority of operators and tourists do come from Treaty countries (IAATO 2013d), the chance of large-scale compliance is still poor.

This is because there is no single body that can enforce compliance with Antarctic law. There is no border control *in situ* to enforce biosecurity or other environmental measures. With the exception of a New Zealand system of tourism observers on voyages to sub-Antarctic islands and the Ross Sea Dependency, there are no State observers onboard tourist ships to audit compliance and there are no universal mechanisms to deal with breaches. Together these factors complicate both managing and regulating activities in Antarctica. And now, major uncertainties posed by climate warming give greater emphasis to the need to examine governance options that might be necessary in the future.

12.3 Business-As-Usual Future Governance

Tourism is an increasingly popular activity but this is not a major problem as such: Antarctica is huge—over 14 million sq km—and human impact, one expression of which can be the number of ‘person days ashore’, is still relatively modest. But there is a disparity between tourist days and expeditioner days: In 2007/2008 the number of person days ashore was calculated to be about 17,000 for landed ship-borne tourists compared with a staggering 283,000 for summer-only national science programme personnel (Jabour 2009b). Under these circumstances, the distinction between tourists and science staff is rendered illogical. Instead, the focus should be on where tourists and expeditioners visit, the quality of the vessels they travel in, and the fact that growth in visitor numbers is occurring during a period of major climatological and ecological uncertainty.

The western Peninsula is the focus of most current sea-borne tourism activity, in addition to being the site of numerous research bases at maximum capacity in the austral summer. The whole Antarctic environment is vulnerable because of climate warming, but not uniformly so. Parts of the polar icecap are melting faster and will contribute to sea level rise, increasing storm surges, freshening the ocean, slowing ocean circulation and altering marine biological diversity. However, there is agreement that the Antarctic Peninsula is warming fastest and the extent, thickness and duration of sea ice in the western area of the Peninsula is reducing in comparison to other areas (ACE CRC 2009). Notwithstanding, climate models predict that sea ice will reduce by 24 % in total extent and 34 % in total volume by 2100 (ACE CRC 2009).

In this scenario, it is possible that there will be more ships of greater size encouraged into the area by a reduction in sea ice and a longer visiting season (fishing already occurs year round in the region). If these ships are not ice-strengthened, and many are not, and they continue to travel into poorly charted areas in relatively ice-free zones, safety concerns will be exacerbated. Localised extreme weather, especially during the summer cruising season, makes high latitude navigation increasingly risky when considered in combination with the presence of less predictable sea ice and changing local weather conditions (e.g. strengthening westerly winds).

Furthermore, even the tourism product itself may change. It is not yet possible to predict how the combined impacts of changing conditions will affect marine biodiversity. It is known, for example, that ‘sea ice plays a pivotal role in structuring Antarctic marine ecosystems…one of the major factors that make this region of the ocean so productive’ (ACE CRC 2009). It is also known that changes in sea ice characteristics will impact on all trophic levels from sea ice algae to whales, seals and penguins—the tourism draw-cards (McClintock et al. 2008; Jenouvrier et al. 2009). It is likely that in the near future, regional warming will affect the western Peninsula more than the rest of Antarctica and this may lead to a change in location of some tourism effort. If focus shifts to East Antarctica, a new set of problems arises. Distance, for example, increases the cost of tourism products and raises the degree of self-sufficiency needed to offset remoteness from emergency search and rescue (Jabour 2007).

Governance of Antarctic tourism today includes a host of dedicated arrangements such as site guidelines for the most popular Peninsula tourist sites. These were adopted incrementally by resolution at ATCMs (eg. ATS 2011a) and augment the guidelines and by-laws of IAATO. There are also standard maritime laws derived from the International Maritime Organization (IMO), with more in the pipeline (Jabour 2009a).

Formal collaboration began in 2004 when the ATCPs were instructed to work within the IMO towards developing guidelines for Antarctic shipping (ATS 2011b). All Antarctic Treaty signatories, with the exception of Belarus, are also IMO parties (IMO 2013). IMO initiatives now applicable to Antarctic ship-borne tourism and non-governmental activity are notable for their breadth and a shift from recommendatory guidelines to mandatory laws (Table 12.1).

Two of these initiatives might have particular significance for Antarctic tourism in the future. The first is the 2009 polar shipping code, parts of which will eventually become mandatory (Jabour 2012). The code, which outlines, among other features, new ice classification categories for ships, is likely to be applicable to all signatories to the International Convention for the Prevention of Pollution from Ships (MARPOL) and the Safety of Life at Sea (SOLAS) convention. This will

Table 12.1 Recent polar shipping initiatives of the International Maritime Organization (*Source* Jabour 2012 from IMO data)

Years	Title	Status
2002	Guidelines for ships operating in Arctic ice-covered waters MSC/Circ.1056–MEPC/Circ.399, 23 December 2002	Recommendatory
2006	Enhanced contingency planning guidance for passenger ships operating in areas remote from SAR facilities MSC.1/Circ.1184, 31 May 2006	Recommendatory
2007	Guidelines on voyage planning for passenger ships operating in remote areas A25/Res.999, 2 January 2008	Recommendatory
2009	Guidelines for ships operating in polar waters (updates MSC/Circ.1056–MEPC/Circ.399 2002) Resolution A.1024(26), 2 December 2009	Recommendatory then mandatory
2009	Guidelines for port state control under the revised MARPOL Annex VI Resolution MEPC.181(59), 17 July 2009	Recommendatory
2009	Guidelines for monitoring the worldwide average sulphur content of residual fuel oils supplied for use on board ships Resolution MEPC.183(59), 17 July 2009	Recommendatory
2010	Amendments to MARPOL Annex I to add Chap. 9—Special requirements for the use or carriage of oils in the Antarctic area Resolution MEPC.189(60), 26 March 2010	Mandatory from 1 August 2011
2010	Assuring safety during demonstrations, protests or confrontations on the high seas Resolution MSC.303(87), 17 May 2010	Recommendatory

mean a far greater reach than any in-house measures adopted by Antarctic Treaty Consultative Parties alone, and will ensure the almost complete capture of all flag states of tourist ships operating in Antarctic waters. Ships on government service might evade the code through sovereign immunity provisions, so too vessels constructed before 01 January 2011 as they only need comply 'as far as is reasonable and practicable'. Because one of the key provisions which will become mandatory is that 'Only those ships with a Polar Class designation or a comparable alternative standard of ice-strengthening appropriate to the anticipated ice conditions should operate in polar ice-covered waters' (IMO 2009) it is hoped that even vessels ordinarily exempt will be compelled to comply.

If this is the case, the eventual re-classification of ships will mean that some vessels will not be permitted to operate in certain ice conditions during certain times of the year. It does not necessarily mean that those ships will be knocked out of the market; rather, they could continue to operate within the new regulatory limits by taking steps such as modifying their itineraries, employing only accredited navigators and key crew, or even being re-fitted to comply with a more desirable ice-rating. Until these rules have been in operation for some years, it is not possible to predict their full impact on tourism effort.

The second important initiative of the IMO with significance for Antarctic tourism is the 2010 amendment to Annex I of MARPOL: from 01 August 2011, it became illegal for IMO-Party flagged vessels to use and carry heavy or intermediate fuel oils into the Antarctic area south of 60°S. This is a precautionary environmental law ensuring that, in the event of an accident, fuel spills will consist primarily of relatively innocuous substances more readily dispersed, thus causing less damage overall. A number of older vessels might not be permitted into Antarctic waters unless they are converted to run on a lighter fuel such as marine gas oil or diesel. Despite offsets through cheaper maintenance costs, it will be expensive (though not impossible) to modify engine parts such as filters, pumps and injectors.

Since 1990 the tourism industry has accessed older, ex-Soviet icebreakers for polar travel because of their suitability to the operating conditions. It is assumed that many of these vessels and larger cruise ships run on heavy or intermediate fuel oil because it is cheaper—otherwise, why would the IMO ban their use and carriage? The effect on the tourism industry of an ageing, perhaps non-compliant fleet has not yet been determined.

A simple review of all the vessels used by IAATO members in the 2010–2011 season (IAATO 2011) that could be located on the World Shipping Register™ (27 vessels) determined that the average age was 22.3 years (World Shipping Register™ 2011). Although this figure by itself is not particularly helpful in deciding whether or not these ships would be compliant, it is interesting to note that the average age of 29 vessels listed on a Council of Managers of National Antarctic Program database (not publicly available) and located on the World Shipping Register™ was slightly older, at 22.6 years. With 25 years being an optimal operating life for a ship, it seems valid to argue that in the near future, compliant vessels will replace non-compliant ones knocked out of the Antarctic tourism market by either the mandatory shipping code or MARPOL/SOLAS amendments, or both. For as long as the tourism market can absorb new operators and growth continues, operators with compliant ships can reasonably be expected to fill any gaps.

In summary, the good will of the tourism industry to keep their destination unspoiled and the desire of the ATCPs to protect Antarctica has the potential to see Business-As-Usual Antarctic tourism remain sustainable. Organic growth and decline are features of Antarctic tourism that only barely masks the fact that growth has been maintained right from the start and is likely to continue providing the market itself remains viable (Lamers et al. 2010). Today, in the shadow of the global financial crisis, numbers are still over 500 % higher than 2 decades ago (even accounting for a small blip corresponding with one less big ship operating in the 1996/1997 season and another blip caused by 9/11, as reflected in the 2001/2002 figures). Coupled with the fact that the global ship-borne tourism sector itself is reported to have grown 1,800 % since 1970 (Lück et al. 2010), it is not inconceivable to imagine a future Antarctic scenario of slow and steady growth, adversely affected by economic factors such as increasing compliance costs but with new operators ready to fill the breach. The difficulty is in determining how best this growth could be managed and regulated.

12.4 An Ideal Future: Managing and Regulating the Growth of Antarctic Tourism

The search for a new or different system to manage and regulate tourism growth is difficult because precedents simply don't exist. Regulation options that have always been available to the ATCPs include legally imposing specific operational requirements on all vessels (e.g. through a mandatory shipping code), open and closed tourism seasons and areas, quotas, centralised reporting to the Antarctic Treaty Secretariat in addition to IAATO, independent accreditation and independent observers mandated to conduct compliance audits and recommend remedies for breaches. The ATCPs have treated tourism with kid gloves but this has changed recently with the increasing involvement of the IMO and some commentators predict that regime change is both overdue and inevitable (Lamers et al. 2010).

The inability to enforce Antarctic-specific law universally can, in fact, be used to strengthen tourism management and regulation in the future. It is suggested here that one option to manage growth and risk could be to introduce 'sponsoring states' for tourism operators. This concept was formally adopted by the Treaty Parties and incorporated into the now expired 1988 Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA).

Extrapolating from the CRAMRA context, it could mean that States party to the Antarctic Treaty that have 'a genuine and substantial link' with a tourism operator (i.e. as per CRAMRA Article 1.12) could sponsor that operator. However, and this is the most significant aspect, a sponsoring state could be held strictly liable for the actions of the tourism operator (i.e. irrespective of fault, as per CRAMRA Article 8). In the CRAMRA era, strict liability related to an activity resulting in, or threatening to result in, environmental damage and the environment is still the focus over 20 years later in relation to tourism. Furthermore, in CRAMRA, residual liability fell on the sponsoring state. In the tourism context, this means that the sponsoring state would be required to have the means, and take all steps necessary, to ensure compliance and punish breaches (as per CRAMRA Article 8.3.a).

If the sponsoring state concept were adopted, the assumption would be that any vessels conducting tourism and non-governmental activity outside the specific regulatory framework would essentially be conducting illegal, unreported and unregulated activities (Molenaar 2005). This is how the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) perceives fishing activities undertaken outside its regulatory framework. To suggest that the ATCPs would be any more successful with tourism vessels than the CCAMLR Commission Members are with fishing vessels might be naïve, however at the very least a dedicated sponsoring state regime would be a legitimate position from which to argue for compliance by all tourism vessels. It would not only assist with environmental protection measures, but also introduce much stronger liability for environmental damage, not to mention help to secure the safety of life at sea. Although liability is already found in Annex VI of the Madrid Protocol, its language is weak with concessions and entry into force is lagging, with only 6 of the requisite 28 signatures have been received since 2005 (ATS 2013).

12.5 ATCP and IAATO Strategic Options

The ATCPs could show great initiative by introducing the concept of sponsoring states for tourism operators into their arsenal of potential strategic options. A Measure by itself, or establishing a seventh Annex, would take considerable commitment, time and political will but as the concept is not unprecedented, some of the groundwork has already been done. Certainly the existing language in CRAMRA need only be contextualised for tourism.

Any system to regulate growth and mitigate risk will need to balance the pressure of increasing activity with the capacity of the Antarctic environment and its dependent and associated ecosystems to absorb that activity under changing and increasingly stressful circumstances. Currently there is little scientific data at baseline level with which managers can confidently make decisions, and under circumstances of such uncertainty the only acceptable course of action is to act in a precautionary manner. Continuing to collect strategic, representative scientific information and adopting stronger regulation through a sponsoring state regime would address this need.

Like the ATCPs, IAATO operators also have a number of strategic options available to them. They could decide internally to try to prolong the *status quo*, doing nothing more or less than what they do now and gambling that the ATCPs will not tighten regulation in the near future. Even with the shipping code still some years off, IAATO operators could decide to become more proactive by designing and formalising their own voluntary scheme with new rules, e.g.

site-specific quotas, independent observers, minimum crew certification requirements for membership and open and closed seasons and areas.

While IAATO operators would be unlikely to adopt a voluntary quota system in a positive and buoyant market, the recent industry downturn is an anomaly that could provide an opportunity for them to implement quotas shared reasonably among those remaining in the industry. The downside is, some operators might push for a greater share of the dwindling market and in doing so cut corners, compromise safety and jeopardise the shared environmental principles of the group.

Often in environmental management, doing nothing is not an option. In this case, however, providing IAATO members believe that tourism at current levels is having less than a minor and/or transitory impact, there is—theoretically—no immediate need to act. The ATCPs have been talking up tourism for many years now but apart from two ATCM tourism Measures specifically and the Madrid Protocol's Annex VI Liability arising from Environmental Emergencies generally—none of which are in force—no rules have yet been imposed upon IAATO members that they did not inspire themselves or could not live with. The IMO's ban on heavier fuel oils and the polar shipping code may be exceptions, but rather than being seen as terminal challenges to tourism, they might also serve to tighten the industry and provide new economies of scale based on increasing compliance costs (one of the limitations identified in 2001 by Landau). Operators with the greatest capacity to absorb the new rules into their economic models would benefit at the expense of operators who could not. This would rationalise the industry and perhaps return it to its previous niche status, supported by a sponsoring state regime to help mitigate unregulated tourism.

12.6 Conclusion

The need to review tourism management is not only about numbers. It is as much about the potential for continued growth under circumstances of great uncertainty and about the capacity of the receiving environment, particularly the western side of the Antarctic Peninsula, which happens to coincide with the major concentration of scientific bases. The problems can be reduced to not knowing whether or for how long Antarctic tourism pathways and destinations can safely continue to absorb more visitors in more ships or aircraft over a longer season and what, exactly, tourist experiences will consist of when they arrive. The industry body, IAATO, has continued to actively engage in the day-to-day management of operators and to seek to implement industry best practice. However, tourism is first and foremost a commercial enterprise and it is not difficult to imagine disquiet among IAATO members, invoked by increasing competition for a piece of a smaller pie, destabilising the group. The continuing cohesion of IAATO is critical to ensure that Antarctic tourism does not become virtually unregulated.

The ATCPs have at their disposal a range of options to manage growth and risk, and to regulate tourism and non-governmental activity. Although they have been reluctant to engage in the past, they have begun a fruitful liaison with the IMO that will change this. One initiative through that organisation—the ban on heavier fuel oils south of 60ºS—is the most practical environmental proposition in the history of Antarctic shipping. Another—the shipping code—will go a long way towards addressing existing criticism of the weaknesses of ATCP regulation over ship-borne tourism. But still this is not enough. It has been suggested here that a scheme of sponsoring states be considered, wherein each Antarctic Treaty signatory could make itself comprehensively responsible and liable for tourism carried out under its flag. Then there would be no doubt about how seriously the Parties take their custodial role of the Antarctic, now or in the future.

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References

ACE CRC (Antarctic Climate and Ecosystems Cooperative Research Centre). (2009). Position analysis: Changes to Antarctic sea ice and their impacts. Accessed February 24, 2011, http://www.acecrc.org.au.

ATS (Antarctic Treaty Secretariat). (2011a). Resolution 1 (2010)—ATCM XXXIII/CEP XIII, Punta del Este + attachment, Site Guidelines for Visitors. Accessed February 23, 2011, http://www.ats.aq/devAS/info_measures_listitem.aspx?lang=e&id=471.

ATS (Antarctic Treaty Secretariat). (2011b). Decision 4 (2004)-ATCM XXVII-CEP VII, Capetown + attachment, Guidelines for ships operating in Arctic and Antarctic waters. Accessed February 23, 2011, http://www.ats.aq/devAS/ats_meetings_meeting_measure.aspx?lang=e.

ATS (Antarctic Treaty Secretariat). (2013). Measure 1 (2005) ATCM XXVIII-CEP VIII, Stockholm + approval details, Annex VI to the Protocol on environmental protection to the Antarctic treaty: Liability arising from environmental emergencies. Accessed February 23, 2011, http://www.ats.aq/devAS/info_measures_listitem.aspx?lang=e&id=331.

Bauer, T. (2001). *Tourism in the Antarctic: Opportunities, constraints and future prospects*. New York: The Haworth Hospitality Press.

Enzenbacher, D. (2007). Antarctic tourism policy-making: Current challenges and future prospects. In G. Triggs & A. Riddell (Eds.), *Antarctica: Legal and environmental challenges for the future*. London: British Institute of International and Comparative Law.

Argentina. (2010). Information Paper IP129, Report on Antarctic tourist flows and cruise ships operating in Ushuaia during the 2009/2010 austral summer season. ATCM XXXIII–CEP XIII–Meeting documents Accessed February 23, 2011, http://www.ats.aq/devAS/ats_meetings_documents.aspx?lang=e.

Hall, M., & Saarinen, J. (Eds.). (2010). *Tourism and change in polar regions: Climate, environment and experience*. Abingdon, Oxon: Routledge.

Haase, D., Lamers, M., & Amelung, B. (2009). Heading into uncharted territory? Exploring the institutional robustness of self-regulation in the Antarctic tourism sector. *Journal of Sustainable Tourism, 17*, 411–430.

Hemmings, A. D., & Roura, R. (2003). Antarctic tourism. A square peg in a round hole: Fitting impact assessment under the Antarctic environmental protocol to Antarctic tourism. *Impact Assessment and Project Appraisal, 21*, 13–24.

IAATO (International Association of Antarctica Tour Operators). (2010). Information Paper IP113 'IAATO Overview of Antarctic Tourism: 2009-10 Season and Preliminary Estimates for 2010-11 and Beyond' pp. 9–10. Accessed February 23, 2011, http://www.iaato.org/info.html.

IAATO. (2011). IAATO Member Vessels 2010–11. Accessed February 23, 2011, http://apps.iaato.org/iaato/vessel/listVessels.jsp.

IAATO (2012). IAATO and the Antarctic Treaty, Current IAATO Information Papers, IP39 'IAATO Overview of Antarctic Tourism 2011–12 Season and Preliminary Estimates for 2012– 3 Season'. Accessed 9 April 2013http://www.iaato.org/current-iaato-information-papers

IAATO. (2013a). What is IAATO. Accessed March 27, 2013, http://iaato.org/what-is-iaato.

IAATO. (2013b). IAATO Membership Directory. Accessed March 27, 2013, http://iaato.org/membership-directory.

IAATO. (2013c). What is IAATO: Bylaws. Accessed March 27, 2013, http://iaato.org/bylaws.

IAATO. (2013d). Who is IAATO, Antarctica tourism fact sheet 2012–13, p. 3. Accessed March 27, 2013, http://iaato.org/what-is-iaato.

IMO. (2009, December 2). Guidelines for ships operating in polar waters. *Resolution A.1024*(26), Guideline G-2.1.

IMO (International Maritime Organization). (2013). Member States. Accessed March 27, 2013, http://www.imo.org/About/Membership/Pages/MemberStates.aspx.

Jabour, J. (2007). Underneath the Radar: Emergency search and rescue insurance for East Antarctic tourism. *Tourism in Marine Environments, 4*, 203–220.

Jabour, J. (2009a). 'Safe Ships and Clean Seas': Evading a mandatory shipping code for Antarctic waters. *NZYIL, 6*, 93–110.

Jabour, J. (2009b). National Antarctic programs and their impact on the environment. In K. R. Kerry & M. J. Riddle (Eds.), *Health of Antarctic wildlife: A challenge for science and policy*. Berlin: Springer.

Jabour, J. (2011). Would you like ice with that? Antarctic tourism and climate change. In A. Jones & M. Phillips (Eds.), Disappearing destinations: Climate change and the future challenges for coastal tourism (pp. 177–190). UK: CABI.

Jabour, J. (2012). Maritime safety and pollution prevention in Antarctica. In A. D. Hemmings, D. R. Rothwell, & K. N. Scott (Eds.), *Antarctic security* (pp. 238–256). Abingdon, Oxon: Routledge.

Jenouvrier, S., Caswell, H., Barbraud, C., Holland, M., Stroeve, J., & Weimerskirch, H. (2009). Demographic models and IPCC climate projections predict the decline of an emperor penguin population. *Proceedings of the National Academy of Sciences, 106*, 1844–1847.

Klein, R. A. (2010). Cruises and bruises: Safety, security and social issues on polar cruises. In M. Lück, P. T. Maher, & E. J. Stewart (Eds.), *Cruise tourism in polar regions: Promoting environmental and social sustainability*. London: Earthscan.

Lamers, M., Amelung, B., & Stel, J. H. (2010). Business as (un)usual: Integrated scenario analysis of tourism in Antarctica. In M. Hall & J. Saarinen (Eds.), *Tourism and change in polar regions: Climate, environment and experience*. Abingdon, Oxon: Routledge.

Landau, D. (2001). Antarctic tourism: What are the limits? Extract from world tourism convention—striking a new balance—exploring new horizons; October 31–November 2, Hobart, Tasmania.

Liggett, D., McIntosh, A., Thompson, A., Storey, B., & Gilbert, N. (2010). Stakeholder perspectives on the governance of Antarctic cruise tourism. In M. Lück, P. T. Maher, & E. J. Stewart (Eds.), *Cruise tourism in polar regions: Promoting environmental and social sustainability*. London: Earthscan.

Lück, M., Maher, P. T., & Stewart, E. J. (Eds.). (2010). *Cruise tourism in polar regions: Promoting environmental and social sustainability*. London: Earthscan.

McClintock, J., Ducklow, H., & Fraser, W. (2008). Ecological responses to climate change on the Antarctic Peninsula. *American Scientist, 96*, 302–310.

Molenaar, E. J. (2005). Sea-borne tourism in Antarctica: Avenues for further intergovernmental regulation. *IJMCL, 20*, 247–295.

Murray, C., & Jabour, J. (2004). Independent expeditions and Antarctic tourism policy. *Polar Record, 40*, 309–317.

Stewart, E. J., Draper, D., & Johnston, M. E. (2005). A review of tourism research in the polar regions. *Arctic, 58*, 383–394.

Tin, T., Lamers, M., Liggett, D., Maher, P. T., & Hughes, K. A. (2013). Setting the scene: Human activities, environmental impacts and governance arrangements in Antarctica. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht, Netherlands: Springer.

UNEP. (2007). *Tourism in the polar regions: The sustainability challenge*. Washington, DC: United Nations Environment Program Sustainable Consumption and Production Branch, Paris and The International Ecotourism Society.

Various. (1994). *Annals of tourism research,* 21/2.

World Shipping Register™. (2011). Ships search. Accessed February 23, 2011, http://e-ships.net/ships.htm.

Chapter 13
Future Challenges in Environmental Management of National Antarctic Programs

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Abstract This chapter attempts to outline the main challenges that National Antarctic Programs (NAP) likely will have to face in the future, as a consequence of changing circumstances stemming both from inside and outside of the Antarctic continent. Such circumstances will likely be the ultimate result of currently observed ongoing trends. Issues challenging the NAPs' environmental management framework in the resulting future scenarios will be analysed, in conjunction with tools aimed to check and control the NAPs' environmental performance. The main objective of this exercise is to provide Antarctic managers—and other involved decision-makers—with a basis for understanding the future, and thereby enable them to act with these likely future situations in mind.

Keywords Antarctica • Environmental management • Environmental protection • Madrid protocol • National Antarctic Program

13.1 National Antarctic Programs: What Are They?

A National Antarctic Program (hereinafter referred to as NAP) is defined as 'the entity with national responsibility for managing the support of scientific research in the Antarctic Treaty Area on behalf of its government and in the spirit of the Antarctic Treaty' (COMNAP 2008a: 2). Each signatory to the Antarctic Treaty normally establishes a National Antarctic Program to coordinate its activities in Antarctica.

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Most of the Antarctic scientific research and associated logistical operations are therefore brought under the umbrella of governmental agencies, which on occasions may work in association with non-governmental entities, such as private universities, research institutions and other service providers. Antarctic activities of commercial nature, such as fishing and tourism, are not the responsibility of NAPs, and therefore fall outside the scope of this chapter.

Although NAPs naturally share some common characteristics, they are also very different in nature. The magnitudes of their activities and/or the infrastructure they manage are highly variable. Some NAPs administrate more than eight permanent and seasonal stations (e.g. Argentina and Chile), while others have none (The Netherlands). Some NAPs operate stations where more than 200 people overwinter (USA), whereas in others less than ten people do (e.g. Germany, Norway, Uruguay). Their administrative association is also quite variable. For example, some NAPs are associated with a number of national agencies while others form a single Antarctic or polar devoted institution. Some of the NAPs are associated with agencies dealing with foreign affairs, defense, environmental protection, or science and technology. The way logistical assistance is provided also varies among NAPs: some rely on private contractors, others on military personnel and some employ their own staff. Combinations of these schemes also exist.

Regardless of the differences between them, NAPs have recognised their collective interests and the need to work closely together when they decided to create the Council of Managers of National Antarctic Programs (COMNAP) in 1988. COMNAP is an international association that brings together National Antarctic Programs to develop and promote best practices in managing the support of scientific research in Antarctica (COMNAP 2008a).

13.2 The Environmental Responsibility of NAPs

The basic environmental principles that NAPs are to observe while conducting their Antarctic activities are contained in the Protocol on Environmental Protection to the Antarctic Treaty (hereinafter referred to as the Protocol) (ATS 1991; see also Tin et al. 2013). The Protocol defines environmental principles that must be considered in the planning and conduct of all activities (including, but not limited to, those which are under NAP's responsibility) in the Antarctic Treaty area, and also define certain specific mechanisms that should be put in place in accordance with appropriate national procedures. Each signatory to the Antarctic Treaty must design its own internal institutional structures and procedures, to suit—and comply with—the Protocol's requirements. [1]

[1] Currently 35 nations have ratified the Protocol: 29 consultative parties to the Antarctic Treaty (those entitled to participate in decision making in the Antarctic Treaty Consultative Meetings) and six non-consultative parties (they are invited to attend the Consultative Meetings but do not participate in the decision making). All nations that have ratified the Protocol are full members of the Committee for Environmental Protection.

Acknowledging that these basic principles and specific mechanisms might not be enough to ensure that the Protocol is implemented in an adequate and standardised manner, a number of practical guidelines have been agreed and adopted in different Antarctic fora since the Protocol entered into force. Although not mandatory, these have been tailored to provide Antarctic operators with advice on how to approach specific environmental management issues contained in the Protocol's annexes.

Such guidelines, plus a number of related instruments, provide advice not only on administrative processes (e.g. how to prepare an Environmental Impact Assessment—EIA) but also on more operational practices (e.g. how to operate aircraft near bird colonies, or how to develop and design environmental monitoring programmes).

The fact that these guidelines are based on the work of well-recognised technical Antarctic bodies, such as the Committee for Environmental Protection of the Antarctic Treaty (CEP), the Scientific Committee on Antarctic Research (SCAR) and COMNAP has widely promoted their use by NAPs.

13.3 What Will the Future Bring to Antarctica?

A number of factors will affect (or continue to affect) current environmental management regimes in the future. The sources of such factors will come from both outside and inside Antarctica. The influence NAPs can exert on the causes and effects of these factors is highly variable. Regardless of the degree of NAPs' influence on them, these factors do not work separately. They usually interrelate, and the way a certain factor evolves over time may have a strong influence on others.

13.3.1 Funding

World politics and economics play a dominant role in Antarctic research. The international socio-economic crisis that has affected most regions of the planet since the mid-nineties has resulted in a general need to consider budget allocations, including financing of Antarctic activities.

When compared to basic services like public health, education and social security, research in Antarctica may not be seen as a top priority issue by politicians, considering that Antarctic science is a relatively high resource-demanding activity. If budget cuts are to be made, some governments may prioritise other areas of public spending at the expense of Antarctic research. However, some administrations may perceive research in Antarctica as having such a global or strategic significance (e.g. global climate change) that allocation of resources may be prioritised regardless.

13.3.2 Oil Price

Future global oil production and cost could also play a dominant role in the conduct of NAPs activities, as most of them still depend heavily on the consumption of fossil fuels, which again will consequently have an influence on the level of environmental impacts they cause. Budget constraints and high oil prices, along with other factors, have played a role in inducing NAPs to implement different strategies and initiatives in order to reduce the costs of working in Antarctica. Some of these strategies and initiatives, and particularly their environmental consequences, will be discussed in more detail later in this chapter. It is likely that these measures will remain in place for the foreseeable future.

13.3.3 Diversification of Services Provision

Another factor that may influence NAP operations is changes with respect to ownership, financing sources and objectives associated with Antarctic science operations and related activities. Traditionally, Antarctic operations have mostly been a purely national responsibility, with clear national structures and organisations behind them. As more external private interests are becoming involved, both with regard to logistics (station construction/operation, transport, etc.) and thereby potentially also indirectly with respect to science priorities, the role of NAPs may become gradually more diffuse in the future. As the presence of non-governmental bodies becomes increasingly common, and influential, in Antarctica, there may be confusion regarding responsibility for conforming with all aspects of the Antarctic Treaty and the Environmental Protocol. This trend raises questions with respect to issues related to *inter alia* cooperation between operations and science, between various (national and private) operators, between operators and COMNAP, and between operators and national authorities (Norway 2010).

13.3.4 New Technologies

The introduction of new technologies will likely influence the way NAPs conduct both their logistical and scientific activities. This will certainly have implications for the Antarctic environment. Positive implications would for example arise from the advancement of new technologies that aim to reduce costs, by reducing oil demands (from shipping, aviation and stations) as well as manpower. As a positive side effect, this would result in lesser human impacts to the Antarctic environment, by reducing carbon emissions and the human footprint in the continent as a whole. Later in this chapter some examples of these ongoing advances will be outlined. It should be noted, however, that the advancement of new technologies also could facilitate easier access over larger, currently pristine areas, leading to more human presence and potentially undesirable impacts on the Antarctic environment.

13.3.5 Global Policy Frameworks

The future evolution of global policies, in particular those associated with global climate change, is also a factor that will influence the current environmental management regimes in Antarctica. Future progress on policies and agreements on global issues may affect the preparation of, for example, new regulations within the Antarctic Treaty System (ATS).

13.3.6 Regulation

Out of the variety of factors that will affect current environmental management regimes, the evolution of ATS regulation emerges as the one with more potential to modify NAPs' current behaviour. More stringent environmental provisions and standards may be put in place for Antarctica in future years. The CEP has adopted a number of guidelines since it was established in 1998. These practical tools address issues such as environmental impact assessment, protection of Antarctic species and areas, preventive management of historic remains, and environmental monitoring. Although these guidelines are usually not legally binding for NAPs (as they are adopted as hortatory texts at Antarctic Treaty Consultative Meetings—ATCMs), over time, they have proved to be influential on the practices of Antarctic managers.

The work of COMNAP and SCAR has also been relevant in providing advice on the above mentioned guidelines, and on the conduct of different Antarctic activities, through manuals, codes of conduct and handbooks.[2] All these materials have contributed to the establishment of standardised criteria and practical procedures, to promote both good practices and minimisation of environmental impacts through their implementation. Therefore, one can reasonably expect that such guidance will continue to be provided by expert bodies, and eventually be adopted by the ATCM. For example, one of the current high priority Antarctic environmental concerns, the introduction of non-native species, has been subject within the CEP to the elaboration of a manual with procedures and practices to minimise this

[2] Some examples include the SCAR/COMNAP Checklists for Supply Chain Managers (SCAR/COMNAP 2011), the SCAR's code of conduct for the exploration and research of subglacial aquatic environments (SCAR 2011), the SCAR's environmental code of conduct for terrestrial scientific field research in Antarctica (SCAR 2009a), the COMNAP Fuel Manual (COMNAP 2008b) and the COMNAP Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica (COMNAP 2005).

risk (ATS 2011: 329). Some other initiatives aimed at achieving higher environmental standards (e.g. energy and fuel management), have been on the agenda of COMNAP members regularly over the last few years. All these fields are therefore likely to become subject to further regulations in the near future.

The impact that proposed new provisions and standards may have on the NAPs' future work is hard to assess. For instance, smaller NAPs are likely to be flexible and more able to adapt their internal organisations to adjust to new environmental standards. Implementing best practice can have a considerable cost and NAPs with larger financial resources may be better able to conform to new procedures and requirements in a timely manner. Implementing new standards may necessitate changes in normally accepted routines; therefore cultural factors may also play a major role when the time of implementing modifications comes. Therefore, regardless of the resources a NAP may have available, and regardless of its relative size, some NAPs would inherently be more flexible than others to change their way of working in Antarctica.

Adjusting current operations to new environmental standards can be achieved through a number of complementary measures, *inter alia*, implementing more aggressive awareness programmes, changing internal policies and establishing new lines of staff recruitment. Finally, NAPs having Environmental Management Systems (EMS)[3] in place would be prone to respond quicker, and more rapidly adjust to new regulations than those who have not. The implementation of an EMS in the Antarctic context, and its likely consequences, will be discussed later in this chapter.

13.3.7 Environmental Changes

Ongoing environmental change in Antarctica will constitute an additional factor that may influence future management. The effects of the predicted climate change over the next century may be extensive, especially within the northern and western Antarctic Peninsula.[4] This may lead to changes in the stability of ice sheets and sea ice (SCAR 2009b). With rapid climate change occurring in some parts of Antarctica, along with a growing human activity in these regions, the risk of alien species being established will also increase, with consequent increases in impacts on ecosystems (Frenot et al. 2005; Hughes and Convey 2010; Hughes et al. 2013).

Although these and associated global issues are becoming increasingly important on the agenda of Antarctic fora, NAPs' influence on these processes is

[3] An Environmental Management System (EMS) is a set of processes and practices that enable an organisation to reduce its environmental impacts and increase its operating efficiency.

[4] For example, the Faraday/Vernadsky Station has experienced warming of +0.53°C per decade for the period 1951–2006, while the 100-year record from Orcadas Station on Laurie Island, South Orkney Islands, shows a warming of +0.20 °C per decade.

rather limited. However, the changes that are occurring due to these global processes may require adaptive efforts by NAPs, which in the end may have bearings also on their environmental management regimes. For example, the higher the risk of establishment of non-native species, the higher the focus on preventive and reactive measures required. Also, areas that have been robust so far with respect to human activity may become more sensitive, and it might be necessary for some NAPs to put more emphasis on preventive and adaptive measures to ensure the necessary level of environmental protection in the changing environmental setting.

13.3.8 Pressure from Science

Finally, the scientific community is exerting a growing pressure on NAPs, by demanding more access to Antarctica. The scientific interest in Antarctica is increasing due to the obvious importance of this area in understanding global processes. This presents NAPs with the challenge of attempting to support a wider array of potential activities within budgetary frameworks that often remain constant, as well as a relatively stringent environmental framework. This will require NAPs to consider new and innovative approaches that may substantially influence how the programmes develop in the future.

In summary, all the factors described above will affect (or continue to affect) current environmental management regimes. Although money seems to be a fundamental driving force, there are other factors that will also—directly or indirectly—influence future NAP strategies. As noted, although such factors may come from sources both outside and inside Antarctica, the NAPs' influence on their causes and effects will vary on a case by case basis.

13.4 Future Environmental Challenges

In the future, and as a result of the combination of the factors described in the previous section, NAPs will have to cope with changing circumstances. Taking into account the broad variety of characteristics between NAPs, the impact of these changes will greatly differ among them. One can expect, therefore, to see changes of varying degrees on the way NAPs will manage their resources (e.g. means of transportation, land-based infrastructure, manpower) and their related activities in Antarctica. The introduction of institutional changes and policies within the internal structures of NAPs can also be reasonably expected. In all likelihood, all such changes will gradually have mostly positive consequences on the Antarctic environment. However, the question remains whether these changes will be implemented rapidly enough—or be adequate—to cope with the threats that may face the Antarctic environment over coming years.

13.4.1 Strategic Approaches

Before addressing specific challenges, a brief reference will be made to the need of NAPs to approach environmental issues strategically within their operations. To ensure a strategic approach to environmental management NAPs could consider implementation of EMS as framework and tool for the conduct of their activities. This would enable them to commit to compliance with applicable environmental legislation and regulations, and to continually improve, for which an EMS provides the framework.

The Protocol establishes that activities in the Antarctic shall be planned and conducted so as to limit adverse impacts on its environment, and that to achieve such an objective regular and effective monitoring shall take place to assess the impacts of ongoing activities, including the verification of predicted impacts. Through this, the Protocol introduces a sequence similar to that applied to the first objective of any Environmental Management System (EMS), i.e. to identify and control the environmental impact of a given organisation's activities.

Implementing EMS for the whole range of Antarctic activities would allow NAPs to identify and control their environmental impact, and it would also let them ensure that their environmental performances be continually reviewed for ongoing improvement. Furthermore, implementing an EMS would enable NAPs to apply a systematic approach that would allow environmental objectives and targets to be set, achieved and, importantly, to demonstrate that they have been achieved.

An additional step for NAPs that have already an EMS in place could be to acquire ISO 14001[5] certification (or equivalent). The advantages of ISO 14001 certification in the Antarctic context are that the standards they propose can be implemented by a wide variety of organisations, whatever their current level of environmental maturity (the current NAPs' case).[6] Current examples include certification of ISO 14001 at Australian stations, Gabriel de Castilla Station (Spain) and Marambio Station (Argentina). Before the fire that destroyed most of Ferraz Station (Brazil) in February 2012, plans to obtain ISO 14001 certification were at an advanced stage (Brazil 2011). As more NAPs obtain certification the effect of establishing a common reference for communication about environmental management issues between them will be strengthened.

Issues that may challenge NAPs' environmental management framework in the future may stem from different operational and organisational activities, both current and in the past. New challenges will also be associated with utilisation of

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[5] ISO 14001 is an internationally accepted standard that expresses how to establish an effective EMS. ISO 14001 is part of a family of a number of international ISO 14000 standards designed to assist organisations in reducing their negative impact on the environment.

[6] It is fair to mention some caveats associated to ISO 14001 certification. First, as ISO 14001 does not specify levels of environmental performance, the benefits achieved are dependant on the goals the organisation has set up for the process. If they are not very challenging or ambitious, then the ISO 14001 framework may be of little benefit. Secondly, ISO 14001 certification may be costly, may take considerable manpower and may result in more bureaucracy.

different existing tools to check and control their environmental performance, to ensure continual improvement. These challenging issues are analysed below.

13.4.2 Operational Issues

Under this heading matters related to land-based infrastructure and transportation will be discussed.

13.4.2.1 Stations and Infrastructure

Initiatives are already being implemented by NAPs in order to face the increasing costs of working in Antarctica, and to achieve higher environmental performances at stations. These include, for instance, sharing infrastructure and replacing (or renewing) old stations with new, sustainable ones. Higher technical and environmental standards on fixed and mobile infrastructure are gradually being established by NAPs.

Currently, standards of environmental practice at most Antarctic stations are in line with the provisions of the Protocol. However, there have been reports from official inspections indicating that at a few stations the environmental standards set up by the Protocol are yet to be achieved (e.g. Australia 2011). In spite of this, an overall substantial improvement in station operations over the last 20 years since the signing of the Protocol has been achieved.

The number of land-based installations run by NAPs is not likely to increase much. First, most of the well-established NAPS are not planning to substantially expand their range of stations. Furthermore, some NAPs have even decided to decrease their geographical range of stations, instead focusing on mobile platforms that allow them to become more flexible to undertake research activities in more distant regions of Antarctica. Currently, NAPs seem to be more interested in reducing station's manpower, especially during the winter.[7] Also, unless new, unknown opportunities arise on the continent, the number of nations involved will probably remain relatively stable. Since the Protocol was ratified in 1991, only three countries acceded to the status of Consultative Party, and there are currently no strong indications of potential new acceeders to the Treaty. Moreover, new Consultative Parties that access the Antarctic Treaty may have no intention to build a station, but rather cooperate with other Parties on existing platforms (as The Netherlands currently do) or by inheriting stations from Parties that are decreasing their number of stations (as Ukraine did when it acceded the Treaty).

On the other hand, the practice of individual states building and operating facilities under their own flags still persists, and some new stations run by a single

[7] Key to such reduction would be automating as many jobs as possible, using multi-skilled technical staff that can cover more than one field, and building infrastructure that can be easily mothballed when numbers are low.

national operator are currently being constructed.[8] Regardless, the future will probably see more sharing of Antarctic stations, in order to lower the costs of operating in Antarctica. Currently there are some examples of states sharing scientific facilities as alternatives to building a new, single-state station. These include various operational models, such as joint stations (France and Italy jointly built and are jointly operating the Concordia station), joint logistics (the Finnish and Swedish programmes share some logistics due to proximity of their stations); new partnerships (the formerly Australian Law station became Law-Racovita station, now jointly run by Australia and Romania); and appended facilities to existing operational stations (Germany has set up joint laboratories at Jubany-Carlini as of 2012 and O'Higgins stations, with Argentina and Chile, respectively). Some NAPs have also chosen to close down or transfer old stations. For example, from 1984 until 1997, four British stations that were no longer in use were transferred to other states, including Chile, Ukraine and Uruguay (ASOC 2006).

13.4.2.2 Energy Efficiency and Renewable Energy Technology

All new stations are now being planned and constructed with an aim to minimise environmental impact during their construction, operation and decommissioning. Cutting edge technology is used to design energy efficient stations, aimed to minimise the use of fossil fuels and to maximise the use of renewable energy.

It is fair to assume that existing stations, where practical and efficient, will gradually be equipped with more wind turbines and solar panels to supplement their power capacities. General improvements in station infrastructure to increase heat retention and to lower power requirements will steadily be introduced as well, leading to enhanced energy efficiency. Reducing the fuel requirements for stations also reduces the environmental risks associated with transportation, storage and handling of fuel.

Some examples of the application of new technological and environmental concepts at Antarctic stations are described in Box 13.1, and include the use of renewable energy and the introduction of energy efficiency procedures.

A substantial part of the electricity used by NAPs continues to be produced with fossil fuel-based generators. Therefore, programmes to rationalise energy use have been put in place in several stations. Energy efficiency measures taken at Antarctic stations include changes from electrical to hot water heating of buildings, improvements on the efficiency of heating via direct use of fossil fuels rather than via an electrical system, the use of energy saving devices and caps on electricity use (perhaps the most effective and simplest of the energy efficiency measures). Improving energy efficiency of old buildings has been also achieved by the application of newer designs, and by enhancing the insulation within buildings (Tin et al. 2009). These innovations and the

[8] Belgium's Princess Elisabeth Station, China's Kunlun Station, (both opened in 2009), South Korea's Jang Bogo Research Station and India's Barathi Station (both scheduled to be operational by 2012) are very recent examples of this trend.

examples in Box 13.1 demonstrate that NAPs can make an important contribution to fuel and cost savings with substantial environmental benefits.

Box 13.1 Recent initiatives in renewable energy and energy efficiency at Antarctic stations

During the first 4 years of operation (2002–2006), wind turbines at Mawson station (Australia) achieved a significant average annual fuel saving (29 %) coupled with a significant reduction in the quantity of atmospheric emissions. In addition, on the basis of fuel reductions observed at Mawson, the available bulk fuel tanks were now able to hold sufficient fuel to meet station needs for 2 years instead of one, creating significant cost savings by removing the need for annual ship visits to supply fuel. Again, this could reduce the amount of emissions released to the Antarctic atmosphere even further (Australia 2007).

A new wind farm is being constructed on Ross Island with the eventual goal of providing 100 % of the energy for New Zealand's Scott Base and meeting part of the power requirements of the neighbouring US's McMurdo Station. So far, this wind farm has achieved to supply 20 % of McMurdo's and 86 % of Scott base's electricity demands. At Neumayer III (Germany) a combination of recycling of thermal energy and the operation of a five-turbine wind farm will allow the station to reduce fuel consumption and minimise its environmental impact (COMNAP 2010). Similar efforts are being investigated and instituted at the Norwegian station Troll. Belgium's summer station Princess Elisabeth opened in 2009 and was designed to run on 100 % renewable energy.

Solar energy is being used more frequently to increase the renewable content of energy supply at research stations as well as at smaller seasonal field camps (Tin et al. 2009). At Concordia station (France-Italy), where winter temperatures can fall below −80 °C, different types of solar panels are being tested with the aim of covering the additional energy demands during summer (Yves Frenot, pers. comm.). At the stations where solar power is used, it is combined with wind turbines and diesel generators to meet energy needs. Solar thermal energy is also often used to provide air and water heating (Tin et al. 2009).

The installation of grey water treatment units at remote and inland stations provides a good opportunity to save water and reduce the amount of waste water discharged into the environment. This is particularly important in such locations where melting snow to generate water is extremely costly. At Concordia station (France-Italy), more than 80 % of grey water is recycled, which also reduces the costs associated with snow melting and the corresponding consumption of fossil fuels (Yves Frenot, pers. comm.).

As most of the fuel consumed in Antarctica is traditionally used in ships, NAPs have already recognised the reductions in fuel use that can be achieved by increasing air operations for passenger transport to stations (COMNAP 2009). Therefore, NAPs have introduced a number of changes in the means of transportation to and within the Antarctic continent over the last few years, and this trend will surely continue in the future with new technologic developments. During the 2007/08 austral summer Australia introduced an air service between Australia and Antarctica, as part of a strategy aimed at the development of a modern, flexible and cost-efficient Antarctic programme. This air service complements the traditional use of ships for marine science, the supply of bulk cargo to stations and passenger movement (Australia 2008). A similar approach is seen in Drønning Maud Land, where a number of NAPs have implemented a cooperative transport effort through the DROMLAN aviation network.[9] Carrying out return flights, without having to refuel in Antarctica, is also becoming common practice in air operations around the continent. Major logistical operations associated with the transport of aviation fuel to Antarctica, the refuelling of aircrafts and the environmental impacts and risks associated with these actions are thereby avoided. Current developments in air transportation also include the use of drones (also known as unmanned autonomous vehicles, or UAVs), which may make a variety of scientific survey work easier, cheaper and less polluting than using full-sized aircraft.

However, on the occasion, replacing the use of aircraft by ground transportation can also lead to energy efficiency. A striking example is given by the US Antarctic programme, which in 2008 started to change the fuel delivery to the South Pole station. Moving from LC-130 aircraft to hauling cargo overland from McMurdo station has so far allowed the US programme to save nearly four times the amount of fuel consumed, from 1.4 to 0.36 l of fuel consumed for each litre of fuel delivered to the South Pole (COMNAP 2010, op.cit.). Also, at US stations electric trucks are being trialed with view to in due course replace current fossil fuel powered vehicles, whose energy efficiency under the present operating conditions (more than 2500 kg; 360 HP and average speed less than 6.5 km/h) is very poor (COMNAP 2010, op.cit.).

These are all examples of NAPs that have spearheaded environmental actions at their stations. It is recognised that not all NAPs have been in a position to initiate similar actions. However, it is fair to assume that as technology—and experience with the use of it—evolves further, more NAPs will be able to follow these practices and initiatives.

13.4.2.3 Waste Disposal and Pollution

Past operational activities have left an undesirable legacy in some locations of the Antarctic continent, with potential to cause environmental impacts on its natural values. Several Antarctic stations that were built before the adoption of the Protocol had waste dumps as part of their operations. Before the SCAR's Code of

[9] DROMLAN is an air network which facilitates communication and the transportation of scientists and equipment between Cape Town and Drønning Maud Land, and between the scientific stations and field locations within Drønning Maud Land. It is supported by a consortium of the national programmes that have stations or operations in or around Drønning Maud Land.

Conduct for Antarctic Expeditions and Station Activities (1975),[10] waste disposal was performed based on practices and standards which would be unacceptable today, and environmental issues were usually of secondary consideration, if addressed at all (COMNAP 2006).

The Protocol's adoption encouraged many NAPs to engage in major clean-up programmes,[11] like those that have been (or are still) in place at Marambio Station (Argentina), Casey Station (Australia), former Cape Hallett Station (New Zealand and United States) and some abandoned bases and field sites of the UK. In order to continue this trend, a strong, long-term environmental commitment is needed, given that clean-up activities usually involve high costs and human and technical resources (COMNAP 2006, op.cit.).

Annex III to the Protocol (Waste Disposal and Waste Management) includes a set of provisions related to waste management in Antarctica. It establishes priorities for waste management practices (waste reduction, as a 'priority number one'), and obligations to clean-up past and present waste deposits. It also proposes different methods for dealing with different types of waste in Antarctica and a waste classification scheme to assist in waste management planning.

Discussion of waste management issues have received a lower priority at CEP meetings, which probably is a reflection of the higher importance given to these issues in operational forums, such as COMNAP (Sánchez and McIvor 2007). However, the issue of waste and clean-up of sites of past activities was discussed in detail during the XIV CEP meeting (Buenos Aires 2011), and, as a result, the Committee decided to give higher priority to such issues in the future (ATS 2011, p. 33).

Clean-up operations require collective efforts in a number of different areas (e.g. logistics, training, administration) to plan, design, implement, monitor and document activities. Therefore, it is a challenge for the entire NAP, and therefore should be part of an organisational strategy. If results from clean-up operations are promoted in a strategic manner, particularly to the general public, they can become a powerful tool to obtain resources for funding of continued efforts. In doing so, partnerships with the private sector should not be dismissed. For example, the Australian and French NAPs have reported good, long-term waste management practices in East Antarctica, and have noted that the cooperative partnership between the private sector and these two NAPs have demonstrated that continual improvement and sustainable waste management practices can be achieved. (COMNAP 2006, op.cit.). COMNAP has played a significant role in facilitating the exchange of experiences and best practices on waste management. The workshop on waste management in Antarctica, held in 2006, was an important contribution in this regard. It would be useful if such workshops, among other

[10] The SCAR's Code of Conduct for Antarctic Expeditions and Station Activities was the first serious attempt to incorporate recommendations on how to deal with specific operational activities in Antarctica, mainly those associated with waste management (SCAR 1975).

[11] Since the Madrid Protocol entered into force (1998) the development of more than 10 different clean-up programmes of historic wastes have been informed through the CEP.

initiatives, were to be organised regularly to ensure a continuous flow of technical information among those responsible for waste management in Antarctica.

The issue of pollution and contaminated land resulting from past activities should also be strategically approached by NAPs, in order to ensure their removal from Antarctica and/or remediation. Such an objective should be achieved without compromising the environment and the possible historic value that some waste types and waste sites may have.

13.4.3 Organisational Issues

Another challenge for NAPs relates to their internal organisational framework. Although the Protocol was agreed almost 20 years ago, and ratified more than a decade ago, many NAPs do not have a dedicated Environmental Officer within their organisations.[12] Environmental officers within NAPs could assist in identifying environmental issues, help in providing solutions and sound strategies, as well as designing and implementing proper environmental procedures. However, irrespective of who carries the environmental responsibilities, NAPs should ensure that technical advice on environmental management be prioritised in any decision making process.

In 1996, COMNAP established a network for dealing with environmental issues, the Antarctic Environmental Officers Network (AEON), which brought together those officers who were responsible for practical and technical environmental management of NAP's operations, with the primary purpose of sharing practical environmental information. The fact that such a network specifically referred to 'environmental officers' was a clear recognition of the importance of such a position within NAPs' internal structures.

With a broad internal reorganisation that COMNAP started in 2008, AEON ceased to exist and was replaced by a new Expert Group on Environmental Issues. The future challenge of COMNAP, which is collectively run by NAPs, is to keep this group active and ensure that its primary objective is properly fulfilled, which is to offer advice and exchange information on best practices and procedures among its members. This will have the added benefit of aiding those less experienced members in enhancing environmental management within their programmes.

These two challenges (ensuring that the environmental advice be duly prioritised through the inclusion of a person with designated environmental responsibility in their permanent staff, and to ensure COMNAP stimulates the capacity of its Expert Group on Environmental Issues) are intimately related, to the point that without ensuring the former, the latter can do little to help achieve higher environmental standards among NAPs.

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[12] However, depending on size and structure of the NAP, it may vary whether the Environmental Officer needs to be a separate position or whether a competent person within the structure could be given additional responsibilities within the framework of environmental management.

The facilitation of information exchange and the establishment of international cooperation have traditionally been the most extensively used courses of action to develop and promote best environmental practice among NAPs. A number of initiatives for exchanging practical environmental information were supported by COMNAP, mainly through AEON. These have included, *inter alia,* the organisation of workshops, the production of manuals, surveys and reports on different environmental matters, and also the establishment of an electronic environment where this environmental information can be shared by COMNAP members. However, although these initiatives deserve credit, they still fail to fully achieve their original objectives, partly due to the limited active participation of its members. The fact that the environmental management issue was not adequately represented—or covered—within some NAPs could surely be one of the reasons why these do not actively participate in this forum. Another reason could be that potential users of this forum prefer to make bilateral consultations rather than participate in a collective forum, when environmental advice is needed.

International cooperation, through bilateral or multilateral partnerships, also provides the opportunity to enhance environmental standards, due to the need to standardise procedures as partnerships evolve, and also due to the natural transfer of knowledge as the result of keeping multi-programme operations running. Partnerships often occur among NAPs that already share similar standards, which limits the necessary extent of improvement in environmental performance. Examples of cooperation between NAPs with different standards (including operational, environmental and even cultural differences) are less frequently found.

Other strategies to develop best practices have stemmed from the CEP, mainly through the elaboration of various guidelines to standardise procedures and practices for Antarctic activities. However, this may not always be the best strategy to collectively achieve better environmental standards. As the standards move upward, the resources (e.g. human, technical, economic) needed to implement them tend to vary greatly among NAPs. Consequently, the gap between implementation levels of different NAPs tends to become larger, rather than smaller.

All of these examples, although positive and well-intentioned in nature, have not yet achieved the ultimate objective of fully developing and promoting best environmental practice among NAPs. Some other innovative approaches should therefore be explored in order to ensure a proper transfer of knowledge, expertise and technology to achieve higher environmental standards across the system of NAPs. For example, environmental consultancy, advice and mentoring can be the result of the establishment of exchange programmes for environmental officers, undertaken bilaterally between NAPs that work in the same Antarctic region and/or share common cultural features (e.g. language).

13.4.4 Utilisation of Tools to Monitor and Control

A significant environmental challenge NAPs are likely to face in the future is related to the need for consistent monitoring of the effects of their operations.

The following paragraphs will discuss the supervision of Antarctic activities by NAPs, including monitoring activities and inspection mechanisms.

The Protocol's preamble acknowledges the unique opportunities that Antarctica offers for scientific monitoring of global and regional processes. Chapter 3 states that regular and effective monitoring shall take place to allow assessment of the impacts of ongoing activities, including the verification of predicted impacts and the early detection of possible unforeseen effects of activities, carried out both within and outside the Antarctic Treaty area, on the Antarctic environment and dependent and associated ecosystems. Furthermore, monitoring is specifically identified in Annex I to the Protocol (Environmental Impact Assessment) as a key element in assessing the environmental impacts of activities in Antarctica. Whilst not explicitly stated, monitoring is also likely to be a primary means of meeting additional requirements of the Protocol, such as the need for obtaining and exchanging information (1) on the status of flora and fauna (Annex II), (2) on any significant change or damage to any protected area (Annex V) and (3) to the need of analysing the environmental effects of waste and waste management (Annex III).

Therefore, in order to meet the requirements of the Protocol, NAPs should establish monitoring programmes capable of assessing the impacts of human activities in Antarctica. Establishing long-term datasets of chemical, physical and biological indicators is essential for understanding and determining the influence of human intervention and natural variability, and for generating models to predict responses to future environmental management measures.

The issue of monitoring has continuously appeared on the agenda of Antarctic bodies involved in environmental matters, such as the CEP, COMNAP and SCAR. Through workshops and reports, both SCAR and COMNAP have provided extensive guidance on various aspects of environmental monitoring programmes (SCAR-COMNAP 1996; COMNAP 2005). In principle, the aim of these were to provide the ATCM with advice on practical, scientifically sound and cost-effective monitoring that would meet the requirements of the Protocol.

Environmental monitoring in Antarctica has been conducted by a number of NAPs for many decades (see, for example, Klein et al. 2013). However, not all of them are regularly doing (or have done) so (see for example, Tejedo et al. 2013). NAPs have usually (sometimes off the record) argued that allocating resources for monitoring activities is challenging because of the costs of staying in the same place for a long time to collect data, the potential competition for funds between monitoring programmes and science programmes, and the fact that monitoring often gives little scientific merit and therefore a lower status to the scientists involved (ATS 2005, p. 407). With adequate resources lacking to ensure that these activities are performed at appropriate frequency and intensity to achieve full compliance with the Protocol's requirements, NAPs are clearly challenged to heighten the priority of monitoring activities and to implement simple, and cost-effective environmental monitoring programmes for their stations and field sites. Making these data easily accessible is also important, to ensure that monitoring research is well represented in the scientific literature. Currently, monitoring data for most

Antarctic stations are not available. Although ATCPs are required to supply details of their monitoring work through the ATS's Electronic Information Exchange System, only a very minor portion of them have done so during the last few years (Hughes 2010). The diversity of station surroundings and activities is largely variable among NAPs. Nevertheless, co-ordination and exchange of information on monitoring, among COMNAP and SCAR, should be improved to allow a more effective interaction between NAPs. The existing SCAR/COMNAP meeting offers such a forum where experiences, challenges and data can be explored and exchanged.[13] This way, scientific knowledge and advances will be conveniently linked with environmental monitoring requirements and protocols.

Similar considerations apply to monitoring in the context of the EIA procedures. Annex I establishes that in the conduct of certain types of EIA monitoring programmes may or shall be put in place to assess the impact of the activity and to check how well the predictions were borne out. Monitoring activities are usually included in EIAs of medium to large-scale activities, but it remains hard to assess whether a close follow up of these EIAs has ever been done[14] (ATS 2005, p. 407).

Inspections are another tool that can assist in checking and controlling the environmental performance of NAP's facilities and equipment in Antarctica. Inspections are a formal mechanism within the ATS to ensure the observance of regulations in place (including the environmental regulations), specified in Chapter VII of the Treaty. According to this Chapter, each Contracting Party has the right to designate observers to carry out inspections of any station, installation and equipment in Antarctica, including all ships and aircraft operating in the area. Chapter 14 of the Protocol presents the promotion of environmental issues as an additional objective of an inspection. Inspections should be undertaken in the spirit of mutual cooperation and understanding and may work like an audit, looking for 'opportunities for change', rather than 'errors'. The 'audit' approach should not be underestimated as a powerful tool to contribute to the enhancement of environmental performances of Antarctic stations, both from the inspected side and from the observers' team. However, in practice, this mechanism has not proven to be effective at regularly supervising Antarctic stations.[15] Since the Protocol was adopted (1991), this mechanism has, on average, led to a station visit only once per decade. Even the most inspected station has received only five visits in that

[13] At the Workshop of Practical Biological Indicators of Human Impacts in Antarctica (NSF-SCAR-COMNAP 2005) it was recommended that every fourth year a monitoring workshop should be held during the SCAR/COMNAP joint meetings.

[14] However, according to Protocol's Annex I, including information on the establishment of monitoring programmes is a requirement only for CEEs (activities causing more than a minor or transitory impacts). According to the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 4, 2005), including information on monitoring programmes is 'often useful' for IEEs (activities causing minor or transitory impacts).

[15] Thirteen year-round stations (which accounts for one third of all stations in Antarctica) have been inspected only once since the Protocol's adoption, while another three of them have never been inspected at all.

20-year period.[16] In addition, due to the short duration of inspections (usually less than a full day) they can only provide a very superficial picture. Taking into account the resources needed to deploy a group of observers to a number of Antarctic stations during one season, inspection rates are not expected to increase in the future. Therefore, they should be taken as a complementary, but rather limited, way to supervise the environmental work of NAPs in Antarctica. Inspections have been effective in promoting a minimum of environmental standards at stations, but are not likely to promote or encourage the implementation of measures tailored to achieve higher environmental standards than those set by the Protocol.

13.5 Conclusions

In the future, NAPs will have to adapt to new circumstances which may result from currently observed trends. Among these circumstances, budget restrictions and increasing oil prices are likely to exert the greatest pressure on NAPs' available resources. On the other hand, advances in technology will provide NAPs with new tools, which may make their work more easy, more economically efficient and more environmentally effective in the future.

New environmental regulations, stemming from the ATS or from external sources, will have an impact on the future work of NAPs. The extent of impact of changing regulations will be dependent on the nature of each NAP and its commitment and capacity to adapt. For NAPs, adapting to such changes will necessarily imply making adjustments in their current way of working in Antarctica, in relation to their assets (e.g. infrastructure, equipment, vehicles), as well in their internal structures and procedures.

The future challenge for individual NAPs will be to find a balance between efficient management of available resources to undertake (or even expand) their Antarctic activities, while at the same time achieving effective protection of the environmental values present in Antarctica. Collectively, NAPs should commit to promote the implementation of better environmental standards throughout their diverse range of operations, based on the spirit of mutual cooperation present in the ATS. The environmental challenge for NAPs will only be met if environmental progress is made collectively.

Finally, NAPs will also need to work hard to keep society informed on—and engaged with—their activities in Antarctica. As the environmental message is much stronger today than in the past, societies should become aware that human

[16] Since the Treaty entered into force, 45 inspections have been carried out, by 19 Consultative Parties. Nineteen inspections (involving 15 Parties) have taken place, since the Madrid Protocol was ratified (1991). On average, each inspection covered around 6.5 stations. The average number of inspections carried through per year, both before and after the Protocol, is just around 1 inspection per year. Data on inspections can be found on the Antarctic Treaty Secretariat website: www.ats.aq/e/ats_governance_listinspections.htm (accessed: 12.03.12).

presence in Antarctica will allow progress in science and technology, but in a manner that will not compromise the outstanding natural values of the continent.

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References

ASOC. (2006). Station sharing in Antarctica. Information paper 94 presented at XXIX Antarctic Treaty Consultative Meeting, Edinburgh, UK.

ATS. (1991). The protocol on environmental protection to the Antarctic treaty. Buenos Aires: Secretariat of the Antarctic Treaty. Retrieved from: http://www.ats.aq/e/ep.htm.

ATS. (2005). Final report of the twenty-eighth antarctic treaty consultative meeting. Part II measures, decisions and resolutions. Stockholm. Buenos Aires: Secretariat of the Antarctic Treaty. Retrieved from: http://www.ats.aq/documents/ATCM28/fr/ATCM28_fr002_e.pdf.

ATS. (2011). *Final report of the thirty-fourth consultative meeting*. Buenos Aires. Buenos Aires: Secretariat of the Antarctic Treaty. Retrieved from: http://www.ats.aq/documents/ATCM34/fr/ATCM34_fr001_e.pdf.

Australia. (2007). *Mawson station wind farm—four years of operational experience.* Information paper 48 presented at XXX Antarctic Treaty Consultative Meeting, New Delhi, India.

Australia. (2008). *Australia's Antarctic Air Service 2007/08.* Information paper 53 presented at XXXI Antarctic Treaty Consultative Meeting, Kyiv, Ukraine.

Australia. (2011). *Australian Antarctic treaty and environmental protocol inspections: January 2010 and January 2011.* Working paper 51 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina.

Brazil. (2011). *Sistema de Gestão Ambiental na Estação Antártica Comandante Ferraz.* Information paper 14 presented at the twenty-second RAPAL (Reunión de Administradores de Programas Antárticos Latinoamericanos), Lima, Peru.

COMNAP. (2005). *Practical guidelines for developing and designing environmental monitoring programs in Antarctica.* Hobart: Council of Managers of National Antarctic Programs. Retrieved from: https://www.comnap.aq/Publications/Comnap%20Publications/comnap_guidelines_practicalmonitoring_2005.pdf.

COMNAP. (2006). *Waste management in Antarctica.* Proceeding of the 2006 workshop held by the COMNAP Antarctic environmental officers network (AEON) on 10–11 July 2006. Hobart: Council of Managers of National Antarctic Programs. Retrieved from: https://www.comnap.aq/Publications/Comnap%20Publications/COMNAP_waste_management_2006.pdf.

COMNAP. (2008a). COMNAP Constitution. Adopted in Plenary Friday 04 July 2008. Hobart: Council of Managers of National Antarctic Programs. Retrieved from: https://www.comnap.aq/Shared%20Documents/comnap-constitution-adopted-04-july-2008.pdf.

COMNAP. (2008b). *COMNAP fuel manual (v.1, April, 2008).* Hobart: Council of Managers of National Antarctic Programs. Retrieved from: https://www.comnap.aq/Publications/Comnap%20Publications/fuel-manual-v1.pdf.

COMNAP. (2009). *Final report of the twentieth meeting of the COMNAP.* St. Petersburg, Russian Federation. Hobart: Council of Managers of National Antarctic Programs.

COMNAP. (2010). *Proceedings of the COMNAP symposium 2010. responding to change through new approaches*. Buenos Aires, Argentina. Hobart: Council of Managers of National Antarctic Programs. Retrieved from: https://www.comnap.aq/Publications/Comnap%20Publications/COMNAP%20Symposium%202010%20ProceedingsA5.pdf.

Frenot, Y., Chown, S. L., Whinam, J., Selkirk, P. M., Convey, P., Skotnicki, M., et al. (2005). Biological invasions in the Antarctic: Extent, impacts and implications. *Biological Reviews, 80*, 45–72.

Hughes, K. A. (2010). How committed are we to monitoring human impact in Antarctica? *Environmental Research Letters,* 5(041001). Retrieved from: http://iopscience.iop.org/1748-9326/5/4/041001.

Hughes, K. A., & Convey, P. (2010). The protection of Antarctic terrestrial ecosystems from inter- and intra-continental transfer of non-indigenous species by human activities: a review of current systems and practices. *Global Environmental Change, 20*, 96–112.

Hughes, K. A., Convey, P. & Huiskes, A. H. L. (2013). Global movement and homogenisation of biota: Challenges to the environmental management of Antarctica? In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Netherlands: Springer.

Klein, A. G., Sweet, S. T., Kennicutt II, M. C., Wade, T. L., Palmer, T. A. & Montagna, P. (2013). Long term monitoring of human impacts to the terrestrial environment at McMurdo station. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Netherlands: Springer.

Norway. (2010). *The 2009 Norwegian Antarctic inspection under Article VII of the Antarctic treaty.* Working paper 57 presented at XXXIII Antarctic Treaty Consultative Meeting, Punta del Este, Uruguay.

NSF-SCAR-COMNAP. (2005). *Report of a workshop on practical biological indicators of human impacts in Antarctica. Volume 1 workshop deliberations and recommendations*. Bryan/College Station, Texas, USA. Retrieved from: https://www.comnap.aq/Publications/Comnap%20Publications/Practical_Biological_Indicators_of_human_Impacts_in_Antarctica_%28March2001%29_Vol.1.pdf.

Sánchez, R. A., & McIvor, E. (2007). The Antarctic committee for environmental protection: Past, present, and future. *Polar Record, 43*(226), 239–246.

SCAR. (1975). *Code of conduct for antarctic expeditions and station activities*. Cambridge: Scientific Committee on Antarctic Research. Retrieved from: http://www.ats.aq/documents/recatt%5Catt071_e.pdf.

SCAR. (2009a). *SCAR's environmental code of conduct for terrestrial scientific field research in Antarctica.* Information paper 4 presented at XXXII Antarctic Treaty Consultative Meeting, Baltimore, USA.

SCAR. (2009b). *Antarctic climate change and the environment.* In J. Turner, R. Bindschadler, P. Convey, G. di Prisco, E. Fahrbach, J. Gutt, D. Hodgson, P. Mayewski, & C. Summerhayes (Eds.), Cambridge: Scientific Committee on Antarctic Research. Retrieved from: http://www.scar.org/publications/occasionals/ACCE_25_Nov_2009.pdf.

SCAR. (2011). *SCAR's code of conduct for the exploration and research of subglacial aquatic environments.* Information paper 33 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina.

SCAR/COMNAP. (2011). *SCAR/COMNAP checklists for supply chain managers.* Working paper 12 presented at XXXIV Antarctic Treaty Consultative Meeting, Buenos Aires, Argentina.

SCAR/COMNAP (1996). Monitoring of environmental impacts from science and operations in Antarctica. Report of the SCAR/COMNAP workshops on environmental monitoring in Antarctica, held in Oslo, Norway 17–20 October, 1995, and at college station, Texas, 25–29 March, 1996. Cambridge: Scientific Committee on Antarctic Research.

Tejedo, P., Pertierra, L. R., & Benayas, J. (2013). Trampling the Antarctic: Consequences of human traffic on Antarctic soils. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Netherlands: Springer.

Tin, T., Sovacool, B. K., Blake, D., Magill, P., El Naggar, S., Lindstrom, S., et al. (2009). Energy efficiency and renewable energy under extreme conditions: Case studies from Antarctica. *Renewable Energy, 35*(8), 1715–1723.

Tin, T., Lamers, M., Liggett, D., Maher, P. T. & Hughes, K. A. (2013). Setting the Scene: Human activities, environmental impacts and governance arrangements in Antarctica. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.) *Antarctic futures: Human engagement with the Antarctic environment.* Netherlands: Springer.

Chapter 14
Strategic Thinking for the Antarctic Environment: The Use of Assessment Tools in Governance

Machiel Lamers, Daniela Liggett and Tina Tin

Abstract The Antarctic Treaty System has established the strategic vision of Antarctica as a natural reserve, set aside for peace and science in the interest of all of humankind. However, the strategic focus that is implied by the notion of a stable, long-term institutional arrangement is not reflected in the system's current operating rules and regulatory decisions. A combination of the growing human footprint, avoidance to deal with contentious issues, weaknesses in the implementation of the Environmental Impact Assessment process and lack of strategic thinking in the environmental management of the Antarctic region as a whole contribute to the accumulation of environmental impacts, the degradation of the once-pristine Antarctic environment and the attrition of Antarctica's unique values. Experiences in the use of strategic thinking and strategic environmental assessment tools in and outside of Antarctica represent exemplars that can be adopted by stakeholders in an Antarctic setting and can be scaled up to the Antarctic region as a whole. A more strategic approach to environmental governance in Antarctica should consist of different components, including strategic thinking (resulting in visions, goals and action plans), planning, decision making (engaging decision makers to commit the necessary resources to implement decisions), implementation and monitoring

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(observing and reflecting on the effectiveness of actions). In view of growing global interests in Antarctic activities and resources and the loss of Antarctic exceptionalism, a more collective and structural approach to strategic governance is necessary to guarantee the future sustainability of the Antarctic region.

Keywords Strategic thinking • Assessment tools • Antarctic governance

14.1 Introduction

Over the last two decades, the level of human activity in the Antarctic increased dramatically with the numbers of tourists visiting this region exceeding 30,000 per year and National Programmes expanding their scope of operations and their facilities (Sánchez and Njaastad 2013). The extent and intensity of fishing in the Southern Ocean has surged as well and might soon reach a dangerous tipping point (Miller 2013). At the same time, globalism is gradually eroding the foundation of Antarctica's exceptionalism (Hemmings 2009), which hitherto served as a practical protection mechanism that ensured Antarctica's special status. With technology decreasing the effectiveness of Antarctica's natural barriers, its remoteness and inhospitable climate and globalism demoting the continent's uniqueness by 'den[ying] us the capacity to treat any place differently' (Hemmings 2009, p. 69), there is a dire need to strengthen the legal framework protecting Antarctica and to embrace a strategic approach to managing the Antarctic environment.

In this chapter, we examine how strategic environmental assessment tools that have been developed for use outside Antarctica could be adapted and used in the context of Antarctic governance and environmental management. As the usefulness of tools depends on the governance framework in which they are embedded, we also explore the elements of a strategic governance framework which will be essential if environmental assessment tools, and indeed any type of strategic thinking or planning, are to deliver their promise.

It is our hope that this chapter will contribute towards the growing literature and discourse on the application of strategic thinking to Antarctic environmental management (see for example Roura and Hemmings 2011; Roura and Tin 2013; Lamers et al. 2012). With this chapter, we intend to encourage and expand on an informed discussion surrounding strategic thinking by:

1. providing a brief overview of examples of strategic decision making in the Antarctic Treaty System (ATS),
2. identifying useful strategic environmental assessment tools and examining how they suit the Antarctic context and
3. exploring the need for, and elements of, a framework for strategic governance.

The term 'strategy' came from the ancient Greek '*strategos*', which means 'general of the army' (Lerner 1999). Building on its military roots, strategic thinking was introduced into business in the mid-1950s as a synonym for long-term and 'big-picture' thinking (Steiner 1979). Strategic thinking has since spread widely and has been adopted in public and non-government organisational planning (e.g. Bryson 1988) and in assessing and governing environmental problems and sustainable development (e.g. Baumgartner and Korhonen 2010; Kemp et al. 2007; Loorbach 2007). The term ‘strategic’ is used frequently in the Antarctic context, often in conjunction with geopolitical questions, military and logistical matters, or resource rights (e.g. Berkman et al. 2011).

In this chapter, we borrow the typically strategic concepts of a large geographical range, a long-time span and the involvement of multiple stakeholders to look at issues pertaining to the management of the Antarctic environment. This is relevant because Antarctic environmental issues are frequently strategic in nature, involving many states, National Antarctic Programs (NAPs), commercial and non-governmental organisations, spanning over large areas of land and ocean, and taking into consideration the benefits and costs to past, present and future generations (Roura and Hemmings 2011; Bastmeijer 2011).

14.2 Strategic Thinking and the Antarctic Treaty System

The Antarctic continent and part of its surrounding ocean, the area south of 60° latitude south, has been set aside for peace and science by the 1959 Antarctic Treaty. The Antarctic Treaty and successive agreements that make up the ATS, in particular the 1991 Protocol on Environmental Protection to the Antarctic Treaty (also known as Madrid Protocol), effectively limit and regulate the use of the ‘frozen commons’ (Joyner 1998, p. 55) by those states that are signatories to the Antarctic Treaty. This unique system of Antarctic governance allows for collective action and an institutionalisation of resource use, which has been labelled in the past as proactive, long-term and strategic, but also as elitist and increasingly cumbersome (e.g. Berkman et al. 2011; Stokke and Vidas 1996). The Antarctic Treaty Consultative Parties (ATCPs) succeeded in developing the ATS into a stable institution that has addressed a number of challenges, including harvesting marine living resources (Miller 2013), mining (e.g. Cullen 1994) and the impacts of human activities on the environment (e.g. Joyner 1998). On the highest level, the Antarctic Treaty System (1959) provides a strategic vision for human use of the Antarctic, namely that Antarctica shall only be used for peaceful purposes with ‘freedom of scientific investigation and cooperation towards that end’. The Madrid Protocol can be considered as a strategic environmental planning framework, designating the whole of Antarctica ‘as a natural reserve, devoted to peace and science’ and setting up a Committee for Environmental Protection (CEP) to advise the Antarctic Treaty Consultative Meetings (ATCMs) on environmental issues. The 1980 Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) can also be considered as a strategic process as it was adopted to regulate a potential drastic growth in krill fisheries and as it takes an ecosystem-based approach to the conservation and use of marine living resources. More recently, the systematic analyses of the ecological and geographical regions (or domains) of the Southern Ocean and the Antarctic continent can also be considered as a strategic process, as they lay the necessary groundwork, allowing protected areas to be sited as part of a systematic network that would protect representative samples of ecosystems and values (Roura and Hemmings 2011; Roura and Tin 2013; CCAMLR 2007).

However, the strategic focus that is implied by the notion of a stable, long-term institutional arrangement is not reflected in the system's current operating rules and regulatory decisions. In fact, as we are reminded by Hemmings (2009), the ATS 'lack[s] capacity to address substantive policy matters, and consensus decision making has in practice now meant not doing very much at all beyond low level *status quo* management' (Hemmings 2009, p. 62). Conflict has also been largely circumnavigated by avoiding discussion on contentious and strategic issues. The ATCPs have addressed matters as these came up, primarily through non-binding regulatory measures such as recommendations and resolutions, and have not taken a long-term approach that takes into account potential future developments and the integrated and complex nature of the issues to be addressed (Ibid). The way in which the ATCPs approached matters of tourism, biological prospecting and the growth of human infrastructure exemplify such a piecemeal and ad-hoc approach (see e.g. Bastmeijer and Roura 2004; Roura and Hemmings 2011; Jabour 2013). In the case of environmental management specifically, meetings of the CEP over the past decade had limited strategic content, with most discussions being focused on streamlining the workload of the CEP (Roura and Tin 2013). Furthermore, weaknesses in the implementation of the Antarctic Environmental Impact Assessment (EIA) process (Hemmings and Kriwoken 2010; Roura and Hemmings 2011), along with the continuous development of tourism and research-related activities raises concern for environmental impacts at multiple geographical scales (Lamers et al. 2012; Roura and Tin 2013) and emphasise the need for strategic decision making. In recent decades, tourism and research-related activities have continued to grow and expanded the human footprint in Antarctica (see Tin et al. 2013). As noted above, the implementation of the Antarctic EIA process has demonstrated significant generic limitations in the assessment of both, tourism and research-related activities (Hemmings and Kriwoken 2010; Roura and Hemmings 2011). These limitations are particularly noteworthy as the coherence and clarity of the provisions of the Madrid Protocol as well as the consistency with which the Protocol is applied to human activities are concerned.

While strategic thinking is applied less often on the scale of the Antarctic as a whole, individual ATCPs may use strategic thinking and tools in their operations and in the regions they are active in. One example is the development of the Deception Island Antarctic Specially Managed Area (ASMA) in the South Shetland Islands (Pertierra et al. 2013; Roura and Hemmings 2011). It was established in 2005 and was developed (1) collectively by five ATCPs (Argentina, Chile, Norway, Spain and the UK), (2) in consultation with stakeholders (from the tourism industry and environmental groups), (3) taking into consideration the protection of different values (natural, scientific, historic) and (4) in anticipation of future development in human activity. Examples of the use of other strategic tools in Antarctic environmental management can be found in Tables 14.2 and 14.3. In most cases, they have been applied by individual NAPs for their own operations.

14.3 Applying Environmental and Sustainability Assessment Tools to Antarctic Environmental Management

Despite the lack of a consistent, strategic approach to Antarctic environmental management, strategic thinking for environmental management and sustainability has been discussed and adopted widely in recent decades in the rest of the world. In this context, it has been described in terms of three interrelated but distinguishable dimensions: strategy process, strategy context and strategy content (Baumgartner and Korhonen 2010; De Wit and Meyer 2004; see also Roura and Tin 2013). *Strategy process* refers to the procedure of strategy development, including steps that need to be followed, the main characteristics of these steps (i.e. subordinate processes) and an identification of the main actors and timing (i.e. who should be involved and when). *Strategy context* represents contextual conditions that have an impact on an organisation's activities and performance, such as the larger socio-economic, regulatory, or environmental context. *Strategy content* focuses on the output or result of strategic activities, such as their contribution towards sustainability (Baumgartner and Korhonen 2010).

With regards to environmental and sustainability assessment tools, a corresponding distinction is made between procedural tools (i.e. those tools that address the *strategy process*) and analytical tools (i.e. tools that address *strategy context and content*) (Finnveden and Moberg 2005; De Ridder et al. 2007). Procedural tools focus on decision-making processes regarding environmental issues, whereas analytical tools enable the technical assessment of an environmental system or one of its components. Analytical tools can be used separately or be part of a larger procedural tool (Finnveden and Moberg 2005; De Ridder et al. 2007).

Following the categorisation outlined above, we examine a range of environmental and sustainability assessment tools which have been adopted in Antarctic environmental decision making to varying degrees, and categorise them into *strategy process*, *context* and *content* tools (see Tables 14.1, 14.2 and 14.3 respectively). While this list is not exhaustive (e.g. Sheat and Partidárioc 2010; De Ridder et al. 2007; Finnveden and Moberg 2005; Rotmans 1998), it represents a first attempt at compiling and conceptualising an overview of global environmental and sustainability assessment tools considered in an Antarctic context. Furthermore, this list outlines the wealth of different approaches that could be applied to Antarctic environmental governance in order to introduce a distinctive strategic approach.

The use of *strategy process* tools in Antarctic environmental decision making has been minimal (Table 14.1). Even though the use of Strategic Environmental Assessment (SEA) has been discussed for more than a decade, it has never been implemented (e.g. ASOC 2000; Hemmings and Roura 2003; Roura and Hemmings 2011). Risk Assessment and Cost-Benefit Analysis are the most commonly used tools in Antarctic environmental governance. A few other tools have been used in a more sporadic manner, e.g. Scenario Analysis, Indicator

Table 14.1 Selected *strategy process* tools and their relevance to Antarctic environmental management

Tool	What is it?	How has it been used?	How can it be used in the Antarctic context?
Strategic environmental assessment	A systematic process for evaluating the environmental consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and appropriately addressed at the earliest stage of decision making (Sadler and Verheem 1996)	Around the world in city planning, natural resources extraction, national policies on energy and on genetically engineered organisms (Therivel 2010)	Could be used to extend EIAs and the designation of protected areas within the ATS by transcending the current boundaries of EIAs across certain types of activities or across certain environments or regions rather than focusing on individual projects (Roura and Hemmings 2011; Marsden 2011)
Strategic planning	A planning process that clarifies mission and values, develops a vision for the future, analyses external challenges and opportunities, assesses internal strengths and weakness, develops strategic goals, develops and evaluates alternative strategies and action plans (Poister and Streib 2005)	Around the world in public, private and civic organisations on all levels, predominantly by local governments, businesses and non-profit organisations to multi-national companies and non-governmental organisations (Bryson 2004; Mintzberg 1994)	Could be used by ATCPs to structure policy processes. The CEP has used elements of a strategic planning process to help prioritise its work since 2005. Strategic planning has been on the agenda of the ATCMs since 2010
Integrated sustainability assessment	An integrated systems analysis and participatory process to develop a shared interpretation among stakeholders of the sustainability of a particular system, to transform these into a shared vision of a sustainable future and to explore various solutions for a transition towards sustainability (Weaver and Rotmans 2006)	Research has examined possible application to natural resource use in Europe	Could be used as a framework for addressing persistent problems by including the multiple perspectives of stakeholders, developing a vision of a sustainable future for the whole entire Antarctic continent or parts thereof and for testing scenarios and exploring trade-offs

Table 14.2 Selected *strategy context* tools and their relevance to Antarctic environmental management

Tool	What is it?	How has it been used?	How can it be used in the Antarctic context?
Scenario analysis	Tools and methods for the exploration of possible future developments. Scenarios can be defined as coherent descriptions of alternative hypothetical futures that reflect different perspectives on past, present and future developments, which can serve as a basis for action (Van Notten et al. 2003; Bishop et al. 2007)	Widely used in the private and public sector contexts to envision and explore alternative developments or to identify ethically desirable or undesirable futures. Different approaches (e.g. forecasting, back-casting, horizon scanning) have been developed to meet different objectives	Can be used to inform decisions for existing activities that are evolving rapidly (e.g. tourism, shipping, fishing) and for activities that have potential in the future but are either very limited or are not taking place at all at the moment (e.g. bioprospecting, mineral extraction, iceberg harvesting). Has been used in the Antarctic context with regard to tourism development (Amelung and Lamers 2006; Lamers et al. 2010)
Risk assessment	Tools and methods for the determination of the quantitative or qualitative value of risk related to a concrete situation (e.g. accidents) or a recognised threat (e.g. chemical substances)	Widely used across the world in the private and public sector to assess financial, ecological or health risks of projects and incidents	Applied in fuel spills, area management, human health and safety (e.g. COMNAP 2008; IAATO 2010; Germany 2008). Can be extended into other areas, such as non-native species (New Zealand 2009) and diseases in wildlife (Kerry and Riddle 2009)
Recreation opportunity spectrum (ROS); Limits of acceptable change (LAC)	Development of standards to achieve a compromise between various types of visitor uses and other natural resource uses, and environmental protection in natural areas by zoning (Clark and Stankey 1979; Cole and Stankey 1998)	Used in tourism planning and visitor management in national parks, especially in the USA and Australia	Has been analysed from an academic perspective with regard to Antarctic tourism management (Davis 1999; Lamers et al. 2008). Can be used to specify and measure the impacts of tourism activities on a set of indicators, to define acceptable limits of change in different zones and to manage environmental impacts in these zones (see Pertierra et al. 2013)

Table 14.3 Selected *strategy content* tools and their relevance to Antarctic environmental management

Tool	What is it?	How has it been used?	How can it be used in the Antarctic context?
Indicator inventories	Development of databases or maps of resources (e.g. undeveloped areas far from human infrastructure, certain species of wildlife) and footprint analyses of energy consumption or polluting substances (e.g. greenhouse gas emissions of human activities)	Inventories of undeveloped lands and rivers used in the USA and Australia; ecological footprint analyses performed worldwide; greenhouse gas inventories adopted by most countries party to the UN Framework Convention on Climate Change (e.g. Lesslie et al. 1995; Ewing et al. 2008; UNFCCC 2011)	Used in the Antarctic tourism context to estimate the use of greenhouse gas emissions (Amelung and Lamers 2007; Farreny et al. 2011; Shirsat and Graf 2009). Can be used to map the locations of human infrastructure and activities in Antarctica and the Southern Ocean. Comparison and benchmarking of NAPs and tour operators will be made possible, for example on energy consumption
Cost-benefit analysis	Tools and methods for the evaluation of expected positive and negative impacts (usually in monetary terms) of a policy or project, which can be used to support or reject proposed actions	Globally used across the public and private sector on all levels (e.g. small businesses, large organisations, state authorities) to review the monetary consequences of policy alternatives	Used widely by individual NAPs, such as in construction of renewable energy sources (Baring-Gould et al. 2005) or logistical infrastructures (USA 2004). Could be extended to multi-national collective decision-making processes
Systematic conservation planning	Methodology that assists in the design of a protected areas system that comprehensively represents the biodiversity of each region, through the achievement of well-defined objectives (Margules and Pressey 2000; Ardron et al. 2008)	Has been used to develop conservation plans for threatened terrestrial and marine habitats such as the California Channel Islands, Milne Bay Province in Papua New Guinea and European wetlands	Used in the designation of the South Orkneys Marine Protected Area (UK 2009). With sufficient data, it can be used to improve the representativeness of the Antarctic protected areas network (SCAR 2010; Terauds et al. 2012)
Life-cycle analysis	Tools and methods to assess the environmental impacts and resources throughout the life of a product or service, including raw material acquisition, production, use and disposal (Horne et al. 2009)	Employed around the world to assess industrially produced items, water resources, agricultural products, waste management and environmental labelling (Jensen et al. 1997)	Can be used to expand current EIAs to integrate impacts associated with the production of equipment used in the Antarctic, the transport of these products and their use in the Antarctic

Inventories, Systematic Conservation Planning, while some tools that have not been applied in an Antarctic context thus far have clear potential, such as Life-Cycle Analysis and Limits of Acceptable Change (Tables 14.2 and 14.3). We argue that applying these innovative analytical tools (to take care of *strategy context and content*), as well as employing a more programmatic approach aided by procedural tools (to take care of the *strategy process*), is essential for strategic collective decision making by state and non-state actors over the vast Antarctic territory and its resources.

For a more in-depth look into how strategic tools can be applied to Antarctic environmental management, we explore one tool from each of the three dimensions of *strategy process*, *strategy context* and *strategy content* in greater detail. Since it is our aim to encourage innovation in Antarctic environmental governance, we focus on the relatively new (only to the Antarctic context) tools of Strategic Environmental Assessment, Scenario Analysis and Indicator Inventories to examine their applicability to Antarctic environmental management.

14.3.1 Strategic Environmental Assessment

14.3.1.1 Background

Decision making is often conducted in tiers, with the decisions with the largest scope and furthest implications made earliest. Policies, plans and programmes are 'high-tiered' decisions. Once a programme has been decided, decisions are then made about the individual projects at 'lower tiers' within the programme. Strategic Environmental Assessment (SEA) is closely related to the Environmental Impact Assessment (EIA) whilst addressing different tiers of the decision-making process (e.g. Therivel 2010; Nooteboom 2000; ASOC 2000). Both SEA and EIA identify and assess environmental impacts of a proposal and examine alternative options. EIA examines the proposal of an individual project or action (at a lower tier). SEA examines the proposal of a policy, plan or programme of projects at the higher tier and generally takes place earlier in the decision-making process. Consequently, SEA can potentially shape the approach taken to development in a region as well as the type and number of projects to be permitted. SEA can address the cumulative and synergistic impacts of multiple activities leaving it to EIAs to resolve how individual projects should be carried out (ASOC 2002). Several dozen countries worldwide, including many Antarctic Treaty Parties, have established domestic legal requirements for SEA. SEA has been applied in preparation of plans and programmes in the fields of land-use, transport, waste and water management, energy and other sectors, and has also been used by the World Bank as a decision-aiding tool (Therivel 2010; Dalal-Clayton and Sadler 2005; Runhaar and Driessen 2007).

14.3.1.2 Use in Antarctic Context

In the Antarctic context, the utilisation of SEAs was suggested first in 1999 by the Antarctic and Southern Ocean Coalition (ASOC), an environmental non-governmental organisation (ASOC 1999). ASOC proposed that Antarctic SEAs could take either a sectoral approach by focussing on a range of activities or issues such as waste or fuel management, or a regional approach. A regional SEA would involve all the nations operating in a certain area who would agree on a vision for the future, for instance by deciding not to allow new permanent science facilities to be built or tourism landing sites to be developed. The next stage of the SEA process would involve compiling a database of all past, present and foreseeable future human activities in the region, and a summary of the state of the knowledge of the regional environment. Based on this information, national operators would develop a strategy for future activities in the region following the lines of the agreed vision. Each individual human activity, such as a scientific project or a tourism operation, would still require a project-level EIA under the requirements of the Madrid Protocol, but activities potentially causing environmental impacts deemed unacceptable in this region by the SEA would be blocked right away (ASOC 2000). It has been proposed that SEA should be employed when assessing the exploration of Antarctic subglacial lakes, effectively applying it over an activity type (drilling) and a specific environment (subglacial) (SALEGOS 2001). The formulation of the Management Plan for Deception Island—a region with several active research stations and a high level of tourism activity—has followed a process with some elements based on SEA procedures (ASOC 2001). Although 'consideration of the application of SEA in the Antarctic' has appeared annually on the CEP's 5-year work plan since 2007, no SEA in the Antarctic context has been conducted so far (Roura and Hemmings 2011).

14.3.1.3 Opportunities and Constraints

SEA could supplement the existing EIA process and help address environmental issues raised by increasing tourism and other activities in a tiered and more proactive approach (Amelung and Lamers 2006; Bastmeijer and Roura 2004; Molenaar 2005; ASOC 2009; Roura and Hemmings 2011). It would facilitate the assessment of cumulative impacts and allow strategic issues, such as the expansion of the human footprint and development of further tourism destinations and facilities, to be addressed. Complex political arrangements within the ATS, diverging national interests and the lack of unique and accepted sovereignty complicate the implementation of an Antarctic SEA. There have been proposals that avoid the adoption of new legal instruments and use the existing instruments for EIAs and designation of protected areas to address strategic environmental needs for particular regions, environmental domains, or activity typologies (Roura and Hemmings 2011). On the other hand, the adoption of a SEA Annex to the Madrid Protocol has also been proposed (Marsden 2011).

14.3.2 Scenario Analysis

14.3.2.1 Background

Scenario analysis is a well-established tool used to explore the implications of a wide range of possible future developments (Bishop et al. 2007; Ringland 1998; Schoemaker 1995; Van Notten et al. 2003). The creation of a diverse set of plausible scenarios examines the uncertainties inherent in future studies and the societal consequences arising from these uncertainties, so that these can be addressed. In addition, the use of scenarios allows for policy measures and other plans to be 'tested' under a variety of circumstances.

Scenarios can be differentiated according to the project goal, the process design and the scenario contents (Bishop et al. 2007; Van Notten et al. 2003). In relation to the goal of the scenarios, a distinction is made between exploratory and decision-support scenarios. Whereas exploratory scenarios are aimed at learning and investigating the interaction of societal processes, decision-support scenarios have a strong normative aspect in that they examine alternative paths to a desirable point in the future (e.g. through envisioning and back-casting techniques). The design of the scenario development process can range from intuitive to formal. Intuitive designs strongly depend on qualitative insights, while formal approaches often include quantitative modelling. Finally, scenarios can be grouped by the complexity of their contents. While simple scenarios may be limited to extrapolations of isolated trends, complex scenarios consider a network of interrelated causes and effects.

14.3.2.2 Use of Scenarios in the Antarctic Context

Since the birth of the Antarctic Treaty in 1959, academic and professional papers and books on the future of Antarctica have indicated an increasing interest in exploring potential developments in this region. First, these publications focussed primarily on the exploitation of minerals, hydrocarbons and the drafting of the Madrid Protocol in the late 1980s and early 1990s (e.g. OTA 1989; Cook 1990). Later, a focus on sectoral activities, such as science operations (e.g. COMNAP 2003) and tourism (e.g. Snyder 1997; Kershaw 1998; Landau 2000; Bauer 2001), reflected concerns about the rapid increase of human operations and the associated risks. Visions of the combined future of science and tourism activities were developed in workshop reports (e.g. Tetley 1998), in entrepreneurial proposals (e.g. Rohde 1990) and in science fiction novels (e.g. Robinson 1998). In most of these publications, single scenarios were created based on perspectives of individuals. These scenarios rarely went beyond the Business-As-Usual perspective and did not build on a systematic or collective process of a diverse group of stakeholders.

An exploratory and participatory scenario process has only been used once in the Antarctic context and resulted in the drafting and analysis of a diverse set of Antarctic tourism scenarios informed by a broad group of stakeholders and

Table 14.4 Scenarios developed at Antarctic tourism workshop

Scenario	Orientation	Summary
'The sky is the limit'	Globalisation/market	Opportunities for tourism are optimal but also for the development of other resource-related activities. The resulting infrastructural developments drive the expansion of land-based tourism serviced by air links along with an expansion of ship-based tourism operations
Business-As-Usual	Globalisation/ environment	Climate change drives tourism activities in the Polar Regions and activities remain largely ship-based. International emission mitigation policies increase the barrier of entry and stricter Antarctic tourism regulations result in a minimisation of tourism impacts
'Cold hostage'	Fragmentation/market	National interests in resource exploitation in Antarctica overshadow international cooperation. Tourism activities continue for elite groups in places away from resource exploitation activities
'Special interest tourism'	Fragmentation/ environment	Wider-scale interest in Antarctica fades and a diversity of smaller-scale ship-based and land-based niche tourism products remains

by leading global scenario studies (Amelung and Lamers 2006; Lamers et al. 2010). The scenarios were developed in three participatory workshops in the Netherlands and New Zealand and can be characterised as exploratory, intuitive and complex (Amelung and Lamers 2006). Scenarios were drafted based on assumptions derived from two sets of relevant global scenario studies: the Fourth Global Environmental Outlook report (GEO-4) (UNEP 2007) and the Millennium Ecosystem Assessment (Carpenter et al. 2005). The resulting four scenarios differ along the lines of geographical orientation (i.e. globalisation vs. fragmentation) and ethical orientation (i.e. market vs. environment). In each of the four resulting scenarios, Antarctic tourism develops in different ways regarding the scale and form of activities and control over these activities by institutions (see Table 14.4). Generally, workshop participants considered the continued growth and diversification of tourism activities as most plausible and inevitable, but disliked many of the extreme developments, such as large-scale operations and land-based infrastructures. The scenario analysis demonstrated the openness and volatility of the global Antarctic tourism system (Lamers et al. 2010).

14.3.2.3 Opportunities and Constraints

Scenario analysis is instrumental in understanding aggregated levels of long-term environmental and political challenges and can consequently play an important role in developing a strategic vision. Using scenarios in Antarctic policy development allows stakeholders to identify future uncertainties and threats and contributes to proactive and adaptive policy-making. Participatory scenario analysis, for example in intersessional work, can also stimulate social learning among different stakeholders. The limited use of scenario analysis in Antarctic policy so far indicates the existence of constraining factors. Formal processes to develop scenarios in the Antarctic context is likely to be difficult because of diverging policy priorities of participating states, the resources needed for organising such a process and the relatively weak institutionalisation of Antarctic governance to guide and organise such a process (Lamers et al. 2012). Issues surrounding disputed sovereignty in Antarctica could be at the core of these obstacles.

14.3.3 Indicator Inventories

Underlying SEA and scenario analysis, and in fact, all strategic decisions, is the need to have a clear understanding of the present situation, such as where and what type of human activities are taking place, the amounts of energy consumed, the different types and volumes of emissions and resources being extracted (e.g. fish, environmental values), as well as the outcomes and effectiveness of strategic decisions. Indicator inventories provide a quantitative picture of the world. Such information is necessary for understanding the present state of the environment, to predict environmental impacts of present as well as future activities, and may be used in decision-making processes (e.g. Klein et al. 2008; Lynch et al. 2010). A greenhouse gas inventory is an established tool that is used worldwide to provide a baseline picture of energy consumption and their global environmental impact (UNFCCC 2011). Another type of indicator, the wildlands inventory, has been used in parts of the world to compile information to assist in the designation of protected areas, the development of management options and the prediction of the impacts of development on wilderness values (e.g. Lesslie et al. 1995; Lacate 1996). Contrary to global practice, no comprehensive inventories of human activities, energy use, or emissions exist in the Antarctic (with exception of Amelung and Lamers 2007; Farreny et al. 2011; Shirsat and Graf 2009). Information is collected and maintained by NAPs, fishing and tourism companies, the Commission of the Convention on the Conservation of Antarctic Marine Life (CCAMLR) and other authorities, but this information is often incomplete and not publicly available in most cases. No mechanism or entity exists to centralise or collate this information so that it can be used for the planning of human activities and management of the environment of the Antarctic region as a whole (Summerson and Tin 2011; Hughes et al. 2011). Without this information, it will continue to be difficult to assess cumulative environmental impacts and to make fact-based strategic decisions on how to protect Antarctica's wilderness values or which areas in the Antarctic are still untouched.

14.4 The Need for Strategic Thinking in Antarctic Governance

Governance requires ‘coordination between actors’ (Rose and Milligans 2010, p. 42), which is only possible if the actors involved have compatible goals to a certain extent (Ibid). In the Antarctic context, diverging interests, especially with regard to commercial for-profit activities such as tourism and fishing, make co-ordination and long-term planning a challenge. A governance system also needs institutional arrangements for decision making, the implementation and enforcement of decisions and authoritative interpretations of contested meanings of decisions (Young 2011). Strategic governance in the Antarctic context includes the components of strategic thinking, planning, decision making, implementation and monitoring, which provides a continuous re-assessment of, or reflexive mechanism of feedback on, the goals that are set and the degree to which these goals have been reached (e.g. Loorbach 2007; Weaver and Rotmans 2006). The strategic thinking process results in visions, goals and action plans, the decision-making process engages the decision makers to commit the resources and the will necessary to implement the decisions, the monitoring process observes and reflects on the effectiveness of the policy actions. In practical terms strategic governance would:

- Address the subjective question of purpose and the often competing values that influence actions;
- Be oriented towards the future based on a thorough understanding of what has happened in the past and is happening at present, and an analysis of foreseen or predicted trends and scenarios of possible alternative futures;
- Be flexible and oriented towards the bigger picture (avoid being reductionist) by taking into consideration the different stakeholders and their values, a large geographical space and a long-time period;
- Integrate both qualitative and quantitative approaches;
- Require the candid confrontation of critical issues by key participants in order to build commitment to plans that will be implemented;
- Influence all areas of operations by becoming a part of the philosophy and culture in the regulation of the Antarctic (adapted from Lerner 1999; Poister and Streib 1999).

Under the current constitutive framework for the Antarctic, strategic governance can only succeed if undertaken collectively by all ATCPs and if it takes into consideration the entire Antarctic continent with its geological and ecological diversity as well as the different intensity levels of human activity. Strategic governance would help to improve decision making by reflecting on today’s decisions in light of their future consequences, such as avoiding unintended irreversible environmental impact. It would also help to avoid incremental decision making, or ‘muddling’ (Lindblom 1959), as it typically results in chronic sub-optimisation of organisational performance (Bryson 2004). Strategic governance would also help to avoid 'creeping degradation' where the effects of multiple small decisions produce a cumulative effect that leads to significant degradation of a place, its values or resources (Landres 2005). Incremental decision making is prevalent in policy contexts in which a reactive approach is taken, for example, in the case of Antarctic tourism. Proper strategic thinking and planning would take into consideration a range of possible future developments and identify the most desirable future vision and methods to reach this vision. Strategic governance would be particularly useful in dealing with rapidly changing circumstances prevalent in the Antarctic due to climate change and globalisation. As Hemmings (2009) argued, 'globalism now denies us the capacity to treat anywhere differently and thereby disables the principle of Antarctic exceptionalism upon which international governance of the region was predicated' (Hemmings 2009, p. 55). Without the protective cushion of Antarctic exceptionalism, which dominated Antarctic governance so far and shielded it from developments in the rest of the world, it is even more pressing to clear the path for the adoption of strategic thinking and the implementation of strategic environmental assessment tools. As demonstrated in the previous section, these tools are already widely applied in other parts of the world, and if globalisation implies a loss of Antarctic exceptionalism, it will be wise to catch up with global environmental governance practices.

Individual states (ATCPs) as well as non-state actors (e.g. companies, non-governmental organisations) already apply strategic thinking and tools in their operations and in the joint management of areas in which they are active (see for example Scully 2008). These experiences represent exemplars that can be adopted by other state and non-state actors at sectoral, national, or regional levels, or even scaled up to be applied collectively to the Antarctic region as a whole. At the moment, the lack of undisputed sovereignty, consensus decision making, and the relatively limited institutionalisation of Antarctic governance (e.g. when compared to United Nations agencies), represent barriers to adopting a strategic approach to environmental management of the region as a whole. Agreement on a long-term vision and goals, genuine commitment to their implementation, and the co-ordination of actors and activities across the multiple dimensions of human engagement with the Antarctic environment will be necessary. Co-ordination of actors requires a high level of transparency with regard to the interests, values and activities of actors. Such transparency can be facilitated through further institutionalisation and proper reporting structures to guarantee sufficient buy-in by all stakeholders (Ostrom 2005). This is currently not the case, as illustrated by the lax attitude with which ATCPs seem to approach reporting requirements (Huber 2011). Similarly, effective environmental governance involves strong enforcement, compliance and monitoring to successfully pursue an agreed upon vision (Ostrom 2005). Currently, the inventorying and monitoring of the impacts of human activities in Antarctica is inconsistent and, in many cases, absent (Hughes 2010). The science community could propel, inform and manage the continuous monitoring and assessment of human impacts (Berkman 2002), but sufficient resources and a strong political mandate need to be given to the science community if it were to take on the important role of translating science into policy.

14.5 Conclusions

Strategic environmental assessment tools are used in the Antarctic governance context, but in a fragmented and incidental manner. For example, some ATCPs have engaged in strategic thinking for their own NAPs and for the regions in which they are active. Data necessary for the use of strategic thinking and tools exist, but are often incomplete, and are simply not collated or used for the environmental management of the Antarctic region as a whole. Diverging interests and priorities between different ATCPs and other stakeholders may explain the observation that strategic thinking, insofar as it concerns long-term, large-scale perspectives, appears to be either still largely reserved for meeting national or sectoral interests or lacking altogether. In view of the growing global interests in Antarctic activities and resources, the loss of Antarctic exceptionalism, and the challenges that the Antarctic regulatory regime faces, a more collective, structural and strategic approach to Antarctic governance is ever more needed to guarantee the future sustainability of the region.

We argue that a more strategic approach to environmental governance in Antarctica should consist of different components, including strategic thinking (resulting in visions, goals and action plans), planning, decision making (engaging decision makers to commit the necessary resources to implement decisions), implementation and monitoring (observing and reflecting on the effectiveness of actions). As many different stakeholders have to align their approaches in the Antarctic context, and as suspended sovereignty claims are still influencing negotiations and decision making, the adoption and implementation of such a new collective, structural and strategic approach would be extremely challenging. State and non-state actors involved in the ATS would have to collectively show a stronger political commitment to the comprehensive protection of the Antarctic environment than is currently the case to make sure that the necessary resources for such an approach are available. Much experience has been generated, and many tools are available, from environmental governance processes outside of the Antarctic holding clear potential for the Antarctic context. In this chapter, we have only begun to open Pandora's box on this complex but essential next step in Antarctic environmental governance.

References

Amelung, B., & Lamers, M. (2006). Scenario development for Antarctic tourism: Exploring the uncertainties. *Polarforschung, 2–3*, 133–139.

Amelung, B., & Lamers, M. (2007). Estimating the greenhouse gas emissions from Antarctic tourism. *Tourism in Marine Environments, 4*(2–3), 121–134.

Antarctic Treaty System (1959). *Antarctic Treaty*. Washington: Cambridge University Press.

Antarctic Treaty System (1991). Protocol on Environmental Protection to the Antarctic Treaty. Buenos Aires: Antarctic Treaty Secretariat.

Ardron, J. A., Possingham, H. P., & Klein, C. J. (eds.) (2008). *Marxan Good Practices Handbook*. Vancouver: Pacific Marine Analysis and Research Association. www.pacmara.org.

ASOC (Antarctic and Southern Ocean Coalition). (1999). *Large Scale Antarctic Tourism*. Information Paper 121 presented at the XXIII Antarctic Treaty Consultative Meeting. Lima.

ASOC (Antarctic and Southern Ocean Coalition). (2000). *Antarctic Strategic Environmental Assessment: application to the growing Antarctic tourism industry*. Information Paper 10 presented at the Antarctic Treaty XII Special Consultative Meeting. The Hague.

ASOC (Antarctic and Southern Ocean Coalition). (2001). *Strategic needs and decision-making in Antarctica*. Information Paper 54 presented at the XXIV Antarctic Treaty Consultative Meeting. St. Petersburg: Russian Federation.

ASOC (Antarctic and Southern Ocean Coalition). (2002). *Strategic Environmental Assessment in Antarctica: a 'stepping stone' to Madrid Protocol objectives*. Information Paper 82 presented at the XXV Antarctic Treaty Consultative Meeting. Warsaw.

ASOC (Antarctic and Southern Ocean Coalition). (2009). *Key elements of a strategic vision for Antarctic tourism*. Information Paper 53 presented at the XXXII Antarctic Treaty Consultative Meeting. Baltimore.

Baring-Gould, I., Robichaud, R. & McLain, K. (2005). *Analysis of the use of wind energy to supplement the power needs at McMurdo station and Amundsen-Scott South Pole station, Antarctica*. National Renewable Energy Laboratory Technical Report NREL/TP500-37504.

Bastmeijer K. (2011). *Intergenerational equity and the Antarctic Treaty System: continued efforts to prevent 'mastery'*. Yearbook of Polar Law 3. Leiden/Boston: Martinus Nijhoff Publishers.

Bastmeijer, K., & Roura, R. (2004). Regulating Antarctic Tourism and the Precautionary Principle. *The American Journal of International Law, 98*(4), 763–781.

Bauer, T. G. (2001). *Tourism in the Antarctic: Opportunities, Constraints, and Future Prospects*. New York: The Haworth Hospitality Press.

Baumgartner, R. J., & Korhonen, J. (2010). Strategic Thinking for Sustainable Development. *Sustainable Development, 18*, 71–75.

Berkman, P. A. (2002). *Science into Policy: Global Lessons from Antarctica*. London: Academic Press.

Berkman, P. A., Lang, M. A., Walton, D. W. H., & Young, O. R. (2011). *Science diplomacy: Science, Antarctica, and the governance of international spaces*. Washington: Smithsonian Institution Scholarly Press.

Bishop, P., Hines, A., & Collins, T. (2007). The current state of scenario development: An overview of techniques. *Foresight, 9*(1), 5–25.

Bryson, J. M. (1988). A Strategic Planning Process for Public and Non-profit Organisations. *Long Range Planning*, *21*(1), 73–81.

Bryson, J. M. (2004). *Strategic planning for public and non-profit organizations* (3rd ed., p. 2004). San Francisco: Jossey-Bass Publishers.

Carpenter, S., Pingali, P., Bennet, E., & Zurek, M. (2005). *Ecosystems and human well-being: Scenarios*. Washington DC: Islands Press.

CCAMLR (Convention on the Conservation of Antarctic Marine Living Resources) (2007). *Workshop on Bioregionalisation of the Southern Ocean*. SC-CAMLR-XXVI/11. Brussels, 13–17 August 2007.

Clark, R. N. & Stankey, G. H. (1979). *The Recreation Opportunity Spectrum: A Framework for Planning, Management, and Research*. General Technical Report PNW-98 Pacific Northwest Forest and Range Experiment Station, U.S. Department of Agriculture and Forest Service.

Cole, D. N., & Stankey, G. H. (1998). Historical development of limits of acceptable change: Conceptual clarifications and possible extensions. In S. F. McCool & D. N. Cole (Eds.), *Limits of Acceptable Change and related planning processes: Progress and future directions*. Ogden: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

COMNAP (Council of Managers of National Antarctic Programs). (2003). *'Worst Case' & 'Less than Worst Case' Environmental scenarios*. Paper presented at the XXVI Antarctic Treaty Consultative Meeting. Madrid.

COMNAP (Council of Managers of National Antarctic Programs). (2008). *COMNAP Fuel Manual. Version 1.0*. Hobart: COMNAP Secretariat.

Cook, G. (1990). *The Future of Antarctica: Exploitation versus preservation*. Manchester: Manchester University Press.

Cullen, R. (1994). Antarctic minerals and conservation. *Ecological Economics, 10*, 143–155.
Davis, P. (1999). Beyond guidelines: A model for Antarctic tourism. *Annals of Tourism Research, 26*(3), 516–533.
Dalal-Clayton, B., & Sadler B. (2005). *Strategic Environmental Assessment, a source book and reference guide to international experience*. London: Earthscan.
De Wit, B., & Meyer, R. (2004). *Strategy: Process, Content, Context* (3rd ed.). London: ITP Press.
De Ridder, W., Turnpenny, J., Nilsson, M., & Von Raggamby, A. (2007). A framework for tool selection and use in integrated assessment for sustainable development. *Journal of Environmental Assessment Policy and Management, 9*(4), 423–441.
Ewing, B., Goldfinger, S., Wackernagel, M., Stechbart, M., Rizk, S. M., Reed, A., et al. (2008). *The ecological footprint Atlas 2008*. Oakland: Global Footprint Network.
Farreny, R., Oliver-Solà, J., Lamers, M., Amelung, B., Gabarrell, X., Rieradevall, J., et al. (2011). Carbon dioxide emissions of Antarctic tourism. *Antarctic Science, 23*(6), 556–566.
Finnveden, G., & Moberg, A. (2005). Environmental systems analysis tools—An overview. *Journal of Cleaner Production, 13*, 1165–1173.
Germany. (2008). Final Report on the Research Project 'Risk assessment for Fildes Peninsula and Ardley Island and the development of management plans for designation as Antarctic Specially Protected or Managed Areas'. Information Paper 30 presented at the XXXI Antarctic Treaty Consultative Meeting. Kyiv, Ukraine.
Hemmings, A.D. and Roura, R. (2003). A square peg in a round hole: fitting impact assessment under the Antarctic Environmental Protocol to Antarctic tourism. *Impact Assessment and Project Appraisal*, *21*, 13–24.
Hemmings, A. D. (2009). From the new geopolitics of resources to nanotechnology: Emerging challenges of globalism in Antarctica. *Yearbook of Polar Law, 1*, 55–72.
Hemmings, A. D., & Kriwoken, L. K. (2010). High level Antarctic EIA under the Madrid protocol: State practice and the effectiveness of the comprehensive environmental evaluation process. *International environmental agreements: Politics, law and economics, 10*(3), 187–208.
Horne, R., Grant, T., & Verghese, K. (2009). *Life cycle assessment: Principles, practice and prospects*. Melbourne: CSIRO Publishing.
Huber, J. (2011). The antarctic treaty: Toward a new partnership. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, Science and the Governance of International Spaces* (pp. 89–95). Washington, DC: Smithsonian Institution.
Hughes, K. A. (2010). How committed are we to monitoring human impacts in Antarctica? *Environmental Research Letters, 5*(4), 3.
Hughes, K. A., Fretwell, P., Rae, J., Holmes, K., & Fleming, A. (2011). Untouched Antarctica: Mapping a finite and diminishing environmental resource. *Antarctic Science, 23*(6), 537–548.
IAATO (International Association of Antarctica Tour Operations). (2010). *Developing a Risk Assessment Framework for IAATO Passenger Vessels*. Information Paper 60 presented at the XXXIII Antarctic Treaty Consultative Meeting. Punta del Este.
Jabour, J. (2013). Strategic management and ` Antarctic tourism. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.) *Antarctic futures: human engagement with the Antarctic environment*. Dordrecht: Springer-Verlag.
Jensen, A.A., Hoffman, L., Moller, B. & Schidt, A. (1997). *Life cycle assessment (LCA): A guide to approaches, experiences and information sources*. Environmental Issues Series no. 6. Copenhagen: European Environment Agency.
Joyner, C. C. (1998). *Governing the frozen commons: The Antarctic regime and environmental protection*. Columbia: University of South Carolina Press.
Kemp, K., Loorbach, D., & Rotmans, J. (2007). Transition management as a model for managing processes of co-evolution towards sustainable development. *International Journal of Sustainable Development & World Ecology, 14*(1), 78–91.
Kershaw, A. (1998). Destination Last Wilderness. In: G. Tetley (Ed.). *Antarctica 2010: A Notebook*. Proceedings of the Antarctic Futures Workshop 28–30 April 1998. Christchurch: Antarctica New Zealand.

Kerry, K. R., & Riddle, M. (2009). *Health of Antarctic wildlife: a challenge for science and policy*. Berlin-Heidelberg: Springer-Verlag.

Klein, A. G., Kennicutt, M. C., Wolff, G. A., Sweet, S. T., Bloxom, T., Gielstra, D. A., et al. (2008). The historical development of McMurdo station, Antarctica, an environmental perspective. *Polar Geography, 31*(3–4), 119–144.

Lacate, D. S. (1996). Wildland inventory and mapping. *The Forestry Chronicle, 42*, 184–194.

Lamers, M., Haase, D., & Amelung, B. (2008). Facing the elements: Analysing trends in Antarctic tourism. *Tourism Review, 63*(1), 15–27.

Lamers, M., Amelung, B., & Stel, J. (2010). Business as (Un)Usual: Integrated scenario analysis for tourism in Antarctica. In C. M. Hall & J. Saarinen (Eds.), *Tourism and change in polar regions: Climate, environment and experiences* (pp. 247–262). London: Routledge.

Lamers, M., Haase, D., & Amelung, B. (2012). Strategic challenges of tourism development and governance in Antarctica: Taking stock and moving forward. *Polar Research, 31*, 1–13.

Landau, D. (2000). *Tourism scenarios. Proceedings of the Antarctic tourism workshop*. Christchurch: Antarctica New Zealand.

Landres, P., Boutcher, S., Merigliano, L., Barns, C., Davis, D., Hall, T., Henry, S., Hunter, B., Janiga, P., Laker, M., McPherson, A., Powell, D.S., Rowan M., Sater, S. (2005). *Monitoring selected conditions related to wilderness character: A national framework*. Gen. Tech. Rep. RMRS-GTR-151. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.

Lerner, A. L. (1999). *A strategic planning primer for higher education*. Retrieved from http://www.sonoma.edu/aa/planning/Strategic_Planning_Primer.pdf.

Lesslie, R., Taylor, D., & Maslen, M. (1995). *National Wilderness Inventory's Handbook of Procedures, Content and Usage*, Second Edition. Australia: Australian Government Publishing Service.

Lindblom, C. E. (1959). The Science of 'Muddling Through' *Public Administration Review, 19*, 79–88.

Loorbach, D. (2007). *Transition management. New mode of governance for sustainable development. Dutch research institute for transitions (DRIFT)*. Utrecht: International Books.

Lynch, H. J., Crosbie, K., Fagan, W. F., & Naveen, R. (2010). Spatial patterns of tour ship traffic in the Antarctic Peninsula region. *Antarctic Science, 22*, 123–130.

Marsden, S. (2011). Introducing strategic environmental assessment to the Madrid Protocol: Lessons from international experience. *Polar Journal, 1*(1), 36–50.

Margules, C. R., & Pressey, R. L. (2000). Systematic conservation planning. *Nature, 405*, 243–253.

Miller, D. G. M. (2013). Antarctic marine living resources—'the future is not what it used to be'. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.) *Antarctic futures: human engagement with the Antarctic environment.* Dordrecht, Netherlands: Springer-Verlag.

Mintzberg, H. (1994). *The Rise and Fall of Strategic Planning: Reconceiving the Roles for Planning, Plans, Planners*. New York: The Free Press.

Molenaar, E. J. (2005). Sea-Borne tourism in Antarctica: Avenues for further intergovernmental regulation. *International Journal for Marine and Coastal Law, 20*(2), 247–295.

New Zealand (2009). *IP 36 A framework for analysing and managing non-native species risks in Antarctica*. Baltimore: Information Paper presented at the XXXII Antarctic Treaty Consultative Meeting.

Nooteboom, S. (2000). Environmental assessments of strategic decisions and project decisions: Interactions and benefits. *Impact Assessment and Project Appraisal, 182*(1), 151–160.

Ostrom, E. (2005). *Understanding institutional diversity*. Princeton: Princeton University Press.

OTA (1989). *Polar prospects: A minerals treaty for Antarctica*. Darby: Diane Publishing Company.

Pertierra, L. R., Tejedo, P. & Benayas, J. (2013). Looking into the future of Deception Island: Current status, drivers of change and policy alternatives. In T. Tin, D. Liggett, P. T. Maher, & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment.* Dordrecht: Springer-Verlag.

Poister, T., & Streib, G. (1999). Strategic management in the public sector: Concepts, models, and processes. *Public Productivity and Management Review, 22*(3), 308–325.

Poister, T., & Streib, G. (2005). Elements of strategic planning and management in municipal government: Status after two decades. *Public Administration Review, Jan/Feb, 2005*, 45–56.

Ringland, G. (1998). *Scenario planning*. Chichester: John Wiley & Sons.

Robinson, K. S. (1998). *Antarctica*. New York: Bantam Books.

Rohde, H. F. (1990). *Engineering: An essential means for conserving Antarctica and achieving cost-effective built infrastructure*. Proceedings of the First Pacific/Asia Offshore Mechanics Symposium, Seoul: The International Society of Offshore and Polar Engineers.

Rose, G., & Milligan, B. (2010). Law for the management of Antarctic marine living resources: From normative conflicts towards integrated governance? *Yearbook of International Environmental Law, 20*(1), 41–87.

Rotmans, J. (1998). Methods for IA: The challenges and opportunities ahead. *Environmental Modelling and Assessment, 3*(3), 155–179.

Roura, R. M., & Hemmings, A. D. (2011). Realising strategic environmental assessment in Antarctica. *Journal of Environmental Assessment Policy and Management, 13*(3), 483–514.

Roura, R. M., & Tin, T. (2013). Strategic thinking and the Antarctic wilderness: Contrasting alternative futures. In T. Tin, D. Liggett, P. T. Maher and M. Lamers (Eds.) *Antarctic futures: human engagement with the Antarctic environment.* Dordrecht: Springer-Verlag.

Runhaar, H. A. C., & Driessen, P. P. J. (2007). What makes strategic environmental assessment successful environmental assessment? *Impact Assessment and Project Appraisal, 25*(1), 2–14.

Sadler B. & Verheem R. (1996). *Strategic environmental assessment: status, challenges and future directions*. Report 53. The Hague: Ministry of Spatial Planning and the Environment.

SALEGOS (Subglacial Antarctic Lake Exploration Group of Specialists) (2001). *Report of the subglacial Antarctic lake exploration group of specialists (SALEGOS) Meeting*, Bologna, Italy, 29-30 November 2001. Retrieved from http://salegos-scar.montana.edu.

Sánchez, R. A. & Njaastad, B. (2013). Future challenges in environmental management of National Antarctic Programs. In T. Tin, D. Liggett, P.T. Maher, and M. Lamers (Eds.) *Antarctic futures: human engagement with the Antarctic environment*. Dordrecht: Springer-Verlag.

SCAR (Scientific Committee on Antarctic Research). (2010). *Biodiversity-based evaluation of the Environmental Domains Analysis*. Working Paper 3. XXXIII Antarctic Treaty Consultative Meeting, 3-14 May, 2010, Punta del Este.

Schoemaker, P. J. H. (1995). *Scenario planning: A tool for strategic thinking* (pp. 25–40). Winter: Sloan Management Review.

Scully, T. (2008). *Chairman's report from the Miami meeting (March 17-19, 2008) on Antarctic tourism. Information* Paper 19. XXXI Antarctic Treaty Consultative Meeting. 2-13 June, Kiev.

Sheat, W. R., & Partidárioc, M. R. (2010). Strategic approaches and assessment techniques—Potential for knowledge brokerage towards sustainability. *Environmental Impact Assessment Review, 30*(4), 278–288.

Shirsat, S. V., & Graf, H. F. (2009). An emission inventory of sulfur from anthropogenic sources in Antarctica. *Atmospheric Chemistry and Physics, 9*, 3397–3408.

Snyder, J. (1997). *Alternative future for tourism to Antarctica: And a preliminary assessment of their resource management implications*. Littleton: Strategic Studies, Inc.

Steiner, G. (1979). *Strategic planning. What every manager should know*. New York: Free Press.

Stokke, O. S., & Vidas, D. (Eds.). (1996). *Governing the Antarctic. The effectiveness and legitimacy of the Antarctic Treaty System*. Cambridge: Cambridge University Press.

Summerson, R. & Tin, T. (2011). Protection of the wilderness and aesthetic values of Antarctica: Geographical Information Systems (GIS) as a tool. In: A. Watson, J. Murrieta-Saldivar, & B. McBride (Eds.) *Science and stewardship to protect and sustain wilderness values: Ninth World Wilderness Congress symposium*; November 6-13, 2009; Meridá, Yucatán, Mexico.

Proceedings RMRS-P-64. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Terauds, A., Chown, S. L., Morgan, F., Peat, H. J., Watts, D. J., Keys, H., et al. (2012). Conservation biogeography of the Antarctic. *Diversity and Distributions, 18*(7), 726–741.

Tetley, G. (1998). *Antarctica 2010: A Notebook*. Christchurch: Antarctica New Zealand.

Therivel, R. (2010). *Strategic environmental assessment in action* (1st ed.). London: Earthscan.

Tin, T., Lamers, M., Liggett, D., Maher, P. T., & Hughes, K. A. (2013) Setting the scene: Human activities, environmental impacts and governance arrangements in Antarctica. In T. Tin, D. Liggett, P. T. Maher & M. Lamers (Eds.), *Antarctic futures: Human engagement with the Antarctic environment*. Dordrecht: Springer-Verlag.

UK. (United Kingdom). (2009). *Pilot study on identifying important marine areas for conservation around the South Orkney Islands*. Information Paper 11, XXXII Antarctic Treaty Consultative Meeting, 6-17, April, 2009. Baltimore.

UNEP (2007). Global Environmental Outlook 4. London: Earthscan.

UNFCCC. (United Nations Framework Convention on Climate Change Secretariat). (2011). National greenhouse gas inventory data for the period 1990–2009. FCCC/SBI/2011/9. Bonn: UNFCCC Secretariat.

Van Notten, P., Rotmans, J., Van Asselt, M., & Rothman, D. (2003). An updated scenario typology. *Futures, 35*, 423–443.

Weaver, P., & Rotmans, J. (2006). Integrated sustainability assessment: What is it, why do it and how? *International Journal of Innovation and Sustainable Development, 1*(4), 284–303.

Part III
Actors and Sectors

Summary

Different individuals and organisations (actors) undertaking different activities (sectors) in the Antarctic context elaborate their visions of future human engagement with the Antarctic environment in Chaps. 10–14.

In Chap. 10, Neufeld et al. discuss the common threads that emerge from four multi-national studies that examine the values attributed to Antarctica by members of the general public that have and have not been to Antarctica. A consistent theme that emerges from the surveys is that most people value the Antarctic as a wilderness and express a desire to see it protected. The authors depict a Business-As-Usual future in which sovereignty and national economic interests will remain the main driving values behind the decision-making process of Antarctic Treaty parties. Reactive wait-and-see attitudes de facto support the attrition of Antarctica's wilderness and aesthetic values. Two alternative scenarios are also discussed. The 'Antarctic Sanctuary' scenario envisages strong commitment by all actors to the protection of the intrinsic values of Antarctica. A transcultural ethic is established where Antarctica is valued independently of human presence and is considered as common heritage, as a common gift shared by all. The 'World (Resources) Bank' scenario imagines a world where national economic and territorial interests dominate and the Madrid Protocol is modified or the Antarctic Treaty System collapses. Antarctic resources and values are sold to the global consumer society, as commodities, experiences or concepts.

In Chap. 11, Roura and Tin reiterate the long-standing views of environmental non-governmental non-profit organisations, valuing Antarctica as a global commons for the heritage of future generations of humans and wildlife, for its intrinsic, wilderness and environmental values. They argue that Antarctic Treaty parties need to ensure that the vision of the Madrid Protocol is effectively put into action, noting that the level of strategic thinking of the Committee for Environmental Protection has been relatively limited in extent and scope. An aspirational vision for the future of the Antarctic wilderness is rendered: one where Antarctica remains a large contiguous wilderness area with little evidence of human presence,

scientific efforts are focused on those that are globally significant for the benefit of humankind, and human activities in the Antarctic (chiefly science and use of ecosystem services) follow the precautionary principle, adopt an ecosystem approach and minimise their environmental impacts and footprint.

In Chap. 12, Jabour considers the management of Antarctic tourism, a commercial enterprise that has grown steadily from the early 1990s to 2008. It is expected that the good will of the tourism industry to keep their destination unspoiled and the desire of the Antarctic Treaty Consultative Parties to protect Antarctica has the potential to see Business-As-Usual Antarctic tourism remain sustainable. The author asserts that it is not inconceivable to imagine a future scenario of slow and steady growth in Antarctic tourism, adversely affected by economic factors such as increasing compliance costs but with new operators ready to fill the breach. She proposes the adoption of the concept of sponsoring states for tourism operators as a way to tighten the regulations surrounding tourism management. She also suggests that tourism operators could decide to become more proactive by designing and formalising their own voluntary regulatory scheme, although this would be unlikely to happen under positive and buoyant market conditions.

In Chap. 13, Sánchez and Njaastad explore the future challenges faced by National Antarctic Programs (NAPs) in their role as logistics providers for government-sponsored scientific activities and environmental managers. They postulate that challenges will be determined by a number of factors including (i) funding, (ii) oil prices, (iii) ownership, financing sources and objectives associated with NAP operations, (iv) technologies, (v) global policy frameworks, (vi) Antarctic Treaty System regulations, (vii) environmental change and (viii) pressure from science. They anticipate that the impact of these changes will vary greatly and associated institutional changes in NAPs are likely to gradually have mostly positive consequences on the Antarctic environment. The authors estimate that the number of land-based installations run by NAPs is not likely to increase by much. Technological advances and experience in the use of such technology are likely to lead to NAP operations with lower environmental impact. The authors conclude that overall progress in Antarctic environmental management can only be made if NAPs act collectively. Operational, environmental and cultural similarities and differences between NAPs can impede progress, on the one hand, or be used to facilitate cooperation, on the other hand.

In Chap. 14, Lamers et al. examine how environmental assessment tools (Strategic Environmental Assessment, strategic planning, integrated sustainability assessment, scenario analysis, risk assessment, Recreation Opportunity Spectrum, Limits of Acceptable Change, indicator inventories, cost-benefit analysis, systematic conservation planning, Life Cycle Analysis) are, and can be, used in Antarctic environmental governance. Based on their examination, the authors assert that experiences in the use of strategic thinking and strategic environmental assessment tools in and outside of Antarctica represent exemplars that can be adopted in an Antarctic setting and can be scaled up to the Antarctic region as a whole. In addition, they identify elements of a framework for strategic governance which would help to improve decision making by reflecting on today's decisions in light of their future consequences, avoiding incremental decision making and dealing with rapidly changing circumstances, such as is the case under the effects of globalisation and climate change. A more strategic approach to environmental governance in Antarctica should consist of different components, including strategic thinking (resulting in visions, goals and action plans), planning, decision making (engaging decision makers to commit the necessary resources to implement decisions), implementation and monitoring (observing and reflecting on the effectiveness of actions). Agreement on a long-term vision and goals, genuine commitment to their implementation, and the co-ordination of actors and activities across the multiple dimensions of human engagement with the Antarctic environment will be necessary.

Chapters 10–14 provide examples of the values, meanings and importance that different people attribute to Antarctica. To people who do not have direct experience of Antarctica, Antarctica is mostly valued as a wilderness and common heritage of humankind (see Chap. 10). Environmental groups desire to protect the Antarctic wilderness and intrinsic and environmental values associated with Antarctica and see Antarctica as a global commons that should be set aside for future generations (see Chap. 11). Antarctic natural resources have, to a certain extent, been protected from human overexploitation because of the continent's natural barriers such as its remoteness, hostile climate and inclement weather, allowing for a relatively pristine environment and a unique wilderness to survive into the twenty-first century. Tourism operators see Antarctica as a distinctive environment, with unique wildlife and scenic landscapes, which provide opportunities for paying tourists to have exceptional and novel experiences (see Chap. 12). NAPs have the dual mandate of providing logistics support to scientific activities and effectively protecting the Antarctic environment (see Chap. 13) and associated values, including 'its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment' [Madrid Protocol Article 3(1)]. From an academic perspective, Antarctica represents a special, potentially visionary, case of environmental governance which necessitates the use of environmental assessment instruments, ideally embedded in a proactive and precautionary approach (see Chap. 14).

Seen from the perspective of their different actor groups and sectors, authors forecast different futures for the consequences of human engagement with the Antarctic environment. The majority of the chapters concur that a Business-As-Usual future is likely to contribute to the degradation of the once-pristine Antarctic environment and the attrition of Antarctica's unique values (see Chaps. 11, 12 and 14). Others forecast a relatively positive Business-As-Usual future, based on the current situation, with Antarctic tourism remaining sustainable (see Chap. 13) and changes in NAP operations having mostly positive effects on the Antarctic environment (see Chap. 14). Pragmatic and voluntary actions are proposed in Chaps. 13 and 14 to realise improvements in the in-situ implementation of environmental management tools to present-day policies and standards. The contributors to this part describe alternative scenarios that entail a strengthening of the monitoring and enforcement capabilities of the regulatory system. Some authors push the envelope and delineate aspirational visions where Antarctic governance and the relation between humankind and nature are different from those that are currently in practice (see Chaps. 11, 12 and 14).

Part IV
Conclusions

Chapter 15
Conclusion: Multiple Dimensions of Human Engagement with the Antarctic Environment

Daniela Liggett, Machiel Lamers, Tina Tin and Patrick T. Maher

Abstract The future scenarios developed by the contributors to this volume communicate a strong message. They concur that existing environmental management practices and the current system of governance are insufficient to meet the obligations set out under the Madrid Protocol to protect the Antarctic environment, let alone to address the challenges facing a warmer and busier Antarctic in the twenty-first century and beyond. However, not all is doom and gloom. A variety of environmental protection provisions have already been agreed. Reassertion and full compliance to their objectives, as well as wider use of existing environmental management tools (e.g. monitoring, information sharing, systematic designation of protected areas) can significantly increase the protection of the Antarctic environment. Notwithstanding, contentious and strategic issues need to be addressed urgently and proactively. Long-term and large-scale considerations need to permeate throughout all the steps of planning, decision making, implementation, enforcement, monitoring and compliance. Decisions should be guided by long-term visions and goals that are supported by genuine commitment from all actors. Multiple dimensions and perspectives of human engagement with the Antarctic environment (e.g. time, space,

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individual and collective values, ecosystems) need to be taken into consideration. Effective Antarctic environmental governance can only exist within the context of a stable and supportive governance regime that is invested with genuine political will and necessary resources. This ultimately depends on how much Antarctic Treaty Parties or, in fact, humankind in general, want to protect the Antarctic environment. The future of human engagement with the Antarctic environment draws on basic human values that underlie all decision making. We strongly recommend continued and coordinated studies into the values that different publics and Antarctic Treaty Party members actually associate with Antarctica and into how these values manifest themselves in human behaviour in Antarctica as well as in its governance. Finally, the Antarctic exists within a global context, and its environment cannot be protected through efforts within the Antarctic only. The sustainability of the Antarctic environment also depends on the preservation and broadening of agreed provisions within the Antarctic Treaty System (ATS), links between the ATS and other relevant global environmental agreements and global environmental initiatives.

Keywords Future scenarios • Strategic planning • Antarctic environmental governance • Human values

15.1 Introduction

Humans interact (or engage) with the multiple components of the Antarctic environment at different times and locations, through various means, driven by diverse motivations resulting in a variety of outcomes. This book is an exploration of some of the aspects (or dimensions) of this engagement. Contributors began by examining the dimensions of environmental impacts of human activities, future scenarios and strategic planning needs, while other dimensions emerged organically during the course of the project. These include the dimensions that divided the chapters into three sections:

- health of species and ecosystems;
- places of engagement and
- human individuals and organisations (actors) engaging in a variety of activities (sectors).

The consideration of future scenarios and strategic planning further treated the dimensions of:

- time and
- environmental management practices and regulatory mechanisms.

Implicit to, and underlying the discussions in all the chapters, are the critical dimensions of:

- Antarctic governance and
- motivations behind human engagement with the Antarctic.

In this concluding chapter we aim to provide a synthesis of the preceding chapters and an overall picture of the various dimensions of human engagement with the Antarctic environment that emerged. We follow a narrative that is guided by the following questions:

(1) What futures await the Antarctic environment, and are existing environmental management practices and regulatory mechanisms adequate for ensuring the future conservation of the Antarctic environment?
(2) If not, what strategic planning actions could help ensure continued conservation of the Antarctic environment?

While this narrative brings together what has been written in the preceding chapters, we believe that questions need to be asked that go beyond the daunting problem of whether current practices and governance are sufficient for addressing the challenges ahead. We also have to ask who and what drives decision making (or the lack thereof) in the governance regime, what 'chaos' (in the form of unpredictable changes and global forces) may affect the regime, and what role do the most fundamental drivers of human behaviour—individual as well as collective values—play. In the Antarctic context, the framework of governance has been critically analysed by a range of scholars (Dodds 2010; Joyner 1998; Stokke and Vidas 1996; Young 1998, 2011; Young and Osherenko 1993), but the drivers of human engagement with the Antarctic have so far been neglected. Therefore, we finish this chapter with a consideration of:

(3) Human motivations in engaging with the Antarctic and
(4) Future challenges to current Antarctic governance.

Antarctic futures, governance, values and environmental management are vast subjects. In no way do we claim that this is a definitive piece of work in all these fields. What we do hope is that, in this chapter, we can build on the comprehensive body of work developed by the experts who have so generously contributed to this volume. By bringing together common threads from the preceding chapters, we want to call attention to the future that we are heading towards and how we might steer towards a version that is more sustainable if we so desire. In this way, we hope to make a small contribution to Antarctic environmental management and governance.

15.2 What Futures Await the Antarctic Environment?

Contributors were invited to consider future scenarios for the Antarctic environment, notably the Business-As-Usual scenario, where currently perceived trends are extrapolated into the future and alternative future scenarios. In order to create a synthesis of the scenarios examined, we map out their commonalities and

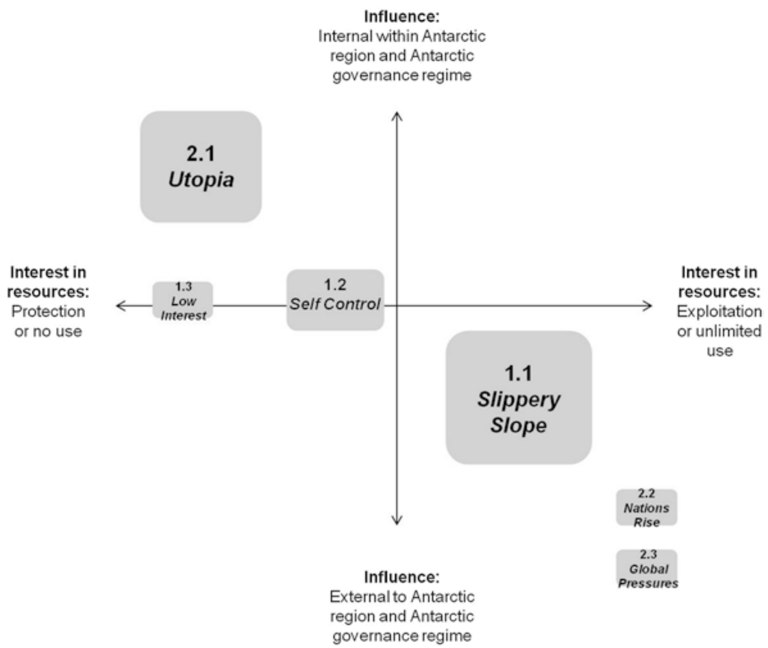

Fig. 15.1 Synthesis of future scenarios examined in this volume according to: (1) interests of actors in Antarctica's natural resources; (2) source of influence on decisions made over the Antarctic environment. Relative sizes of squares approximately reflect the relative number of scenarios within each cluster

differences following two criteria. The first criterion refers to the interests of actors in Antarctica's natural resources. This can be depicted along a continuum stretching from preservationist attitudes that support no resource use or resource protection (left end of horizontal axis in Fig. 15.1) to utilitarian attitudes that support unlimited resource use or resource exploitation (right end of horizontal axis in Fig. 15.1). In scenario studies, typically a difference is made between internal and external factors. Internal factors refer to those factors that are controllable by actors in a particular context, and external factors are those that largely lie outside the scope of influence of the actors (Börjeson et al. 2006). We use this as the second criterion to map out the scenarios. One end of the continuum includes only internal influences (top end of vertical axis in Fig. 15.1). This includes controllable influences that come from within the Antarctic context (e.g. human activities, environmental impacts within the region and the Antarctic governance regime). The other end of the continuum includes only external influences (bottom end of vertical axis in Fig. 15.1), such as global environmental change, global market demands, technological changes, globalisation. More information on the technique used for scenario mapping can be found in Lamers et al. (2010), or Van't Klooster and Van Asselt (2006).

Scenarios described in the preceding chapters fall into three clusters of Business-As-Usual scenarios that we have labelled 'Slippery Slope', 'Self Control' and 'Low Interest'. Alternative scenarios also fall into three clusters: 'Utopia', 'Nations Rise' and 'Global Pressures'. Their key characteristics are summarised in Table 15.1.

The vast majority of Business-As-Usual scenarios anticipate more human activities and more people in the Antarctic, often linked to global processes. Most of these scenarios also recognise global environmental change as an external driving factor that will potentially amplify the consequences of future environmental impacts. A large proportion of Business-As-Usual scenarios fall into the cluster labelled 'Slippery Slope'. Current environmental management practices and regulatory mechanisms are not considered robust or flexible enough to address the challenges arising from the expansion of human activities and global change, particularly when Antarctic Treaty parties continue to avoid contentious and strategic issues and address environmental issues in an ad-hoc, reactive and piecemeal manner. Current environmental management practices are seen to be unable to meet the obligations set out under the Madrid Protocol, let alone raise the bar of environmental protection in the future.

Chapters 12 and 13, focussing on the activities of tourism and National Antarctic Programs (NAPs) respectively, form a stand-alone cluster of Business-As-Usual scenarios. The cluster labelled 'Self Control' depicts an increase of human activities or a reduction in the resources available for environmental management and management of human activities. Scenarios within this cluster believe that, with proactive regulatory actions initiated within the Antarctic governance regime, it is possible to use Antarctica sustainably (in this case, for tourism and scientific research), without compromising its environment.

Chapter 4 stands alone under the Business-As-Usual scenario of 'Low Interest'. Whaling is unique among the human activities examined in this volume in the sense that it has had a long-standing history and has elicited deep emotional responses from people globally. There is little global interest in the resumption of widespread whaling and current agreed regulatory mechanisms appear to be sufficient to keep the few active whaling operations to a limited level. This is the only Business-As-Usual scenario where maintaining the *status quo* will result in resource protection.

The vast majority of alternative scenarios fall under the cluster labelled 'Utopia', where decision making is dominated by influences within the Antarctic region and Antarctic governance regime actors are more interested in resource protection than exploitation. This cluster of scenarios anticipates sophisticated levels of implementation of, and compliance with, regulatory mechanisms, combined with proactive governance that incorporates a collective future vision, resulting in little or no resource use. A combination of strong influences from outside the Antarctic and a dominant interest in resource exploitation produces two other clusters of alternative scenarios. Chapter 4 (focussing on whale conservation) and Chapter 10 (focussing on values attributed to Antarctica) depict an alternative scenario labelled 'Nations Rise' where national interests start to dominate and current

Table 15.1 Overview of the key characteristics of the scenario clusters

Themes	Chapters
1. Business-As-Usual scenario clusters	
1.1 'Slippery slope'	
Strong external influence + dominant interest in resource exploitation	
Expansion of human activities	2, 3, 5, 6, 7, 8, 10, 11, 14
Over long term, management practices unable to address environmental challenges arising from expansion of human activities and global change	2, 5, 6, 7, 8, 10, 11, 14
Decision making remains ad hoc, non-binding, reactive, piecemeal and based on limited available information. Contentious and strategic issues avoided	11, 14
Decision making over the Antarctic and its environment motivated predominantly by sovereignty and economic interests, with scientific research and environmental protection remaining important motivations. Intrinsic values not taken into consideration	2, 3, 6, 10, 11
1.2 'Self control'	
Internal and external influences in balance + dominant interest in resource protection	
Expansion of human activities	12
Reduction in available resources for environmental management and management of human activities	13
Improvements are made due to the goodwill of certain NAPs and tourism operators and proactive regulation involving Antarctic Treaty parties	12, 13
1.3 'Low interest'	
Internal and external influences in balance + dominant interest in resource protection	
Little global interest in resource. Agreed regulatory mechanisms sufficient to limit resource use	4
2. Alternative scenario clusters	
2.1 'Utopia'	
Strong internal influence + dominant interest in resource protection	
Increased implementation and compliance of environmental protection provisions. Comprehensive monitoring systems providing data that is taken into consideration in decision making. Wider adoption of environmental management practices raise overall environmental standards	2, 3, 4, 6, 8, 10, 12, 13, 14
Resource use is banned or limited	2, 3, 4, 7, 8, 10, 11
Decision making guided by strategic vision that takes precautionary approach, recognises importance of intrinsic values and uses Antarctica to serve the global benefit of mankind and not for nationalistic or commercial interests	2, 3, 10, 11, 14
2.2 'Nations rise'	
Strong external influence + dominant interest in resource exploitation	
Amendments to current regulatory mechanisms. Domination of national economic and territorial interests	4, 10
2.3 'Global pressures'	
Strong external influence + dominant interest in resource exploitation	
Environmental management practices adopted within Antarctic context insufficient to address environmental impacts of actions arising under strong external influences	5

regulatory mechanisms (International Convention for the Regulation of Whaling and Madrid Protocol in Chapters 4 and 10 respectively) are amended in order to allow resource uses that support national interests. Chapter 5 (focussing on non-native species) depicts an alternative scenario of 'Global Pressures' where global influences dominate. Global market demands lead to the development of land-based tourism and/or mineral resource exploitation. A lack of climate change mitigation policies in populated states results in the continuation and intensification of global change. Subsequently, environmental management practices adopted and implemented within the Antarctic context are insufficient to ensure the successful mitigation or minimisation of human impacts on the Antarctic environment.

The Business-As-Usual scenarios reflect that current Antarctic environmental management is more or less ad hoc and has not been implemented sufficiently with a long-term or proactive view. The alternative scenario of 'Utopia' emphasises the need for a more strategic approach that can take into account the temporal dimension. Decisions need to be guided by a vision of a desirable future. Assessment of environmental impacts needs to incorporate impacts accumulated from past, present and anticipated future human activities. Neglecting the temporal dimension is likely to lead to unpleasant surprises: the effects of multiple small decisions that are seemingly harmless today can accumulate and lead to significant degradation of the environment tomorrow.

The future scenarios examined in this volume communicate a strong message. They concur that existing environmental management practices and the current system of governance are insufficient to meet the obligations set out under the Madrid Protocol, let alone able to address the challenges facing a warmer and busier Antarctic in the twenty-first century and beyond.

15.3 What Strategic Planning Actions Could Help Ensure Continued Conservation of the Antarctic Environment?

In addition to examining future scenarios for the Antarctic environment, contributors explored strategic planning needs that would ensure continued conservation of the Antarctic environment. Acknowledging that the term 'strategic' can have a broad range of applications, its use in this chapter follows its usage in Chapters 11 and 14. We use it in the context of Antarctic environmental management; and broadly speaking, strategic actions are those that take into consideration large geographical areas, long timescales and interactions between different sub-systems, components and stakeholders. The strategic planning needs proposed by contributors roughly comprise (Table 15.2):

- actions that can be taken within the Antarctic context;
- actions that can be taken to improve the interaction between actors in Antarctic and global contexts;

Table 15.2 Overview of strategic planning needs

Themes	Chapters
Internal within Antarctic context	
Wider deployment of existing environmental management tools	2, 5, 6, 7
Preserve, broaden and implement agreed provisions in the ATS	2, 3, 11
Linking between Antarctic and global contexts	
Strengthen links between ATS environmental protection provisions and other relevant global instruments	3
Bring in instruments and tools from outside the Antarctic. Adapt and implement them for the Antarctic context	2, 11, 12, 13, 14
External to Antarctic context	
Global environmental and research initiatives	2, 3, 10
Bringing it all together strategically, proactively, holistically	
Long-term and large-scale considerations including visions and goals need to permeate throughout all the steps of planning, decision making and implementation	2, 11, 14

- actions that can to be taken outside the Antarctic context;
- holistic and strategic actions that bring all the above actions together.

Few contributors argue for the need of new environmental legislations, as the development and adoption of international law is typically time-consuming and requires the difficult political task of consensus from all parties involved. These contributors highlight that, within the Antarctic Treaty System (ATS) and in particular under the Madrid Protocol, a variety of environmental protection provisions have been signed and a wealth of environmental management tools is available. The implementation of existing provisions and tools is uneven, with some actors in some areas choosing to apply higher environmental standards to their operations than others. Contributors propose that, without requiring new regulations or tools, maintenance of long-term monitoring programmes to generate policy-relevant knowledge, sharing of information (Chapters 2, 6 and 7), setting aside unimpacted areas and systematically designating Antarctic Specially Protected and Managed Areas (Chapters 5 and 7) can significantly improve the protection of the Antarctic environment.

The use of environmental management tools in the Antarctic is embedded within Antarctica's governance regime. Contributors also acknowledge that environmental management tools would not be effective without a stable and supportive governance regime. Some suggest that the ATS needs to be 'rebooted', in order to restore its original mission of preserving the unique nature of the Antarctic (Chapter 11). Others propose that Antarctic Treaty Parties need to adopt a real commitment to Antarctic environmental protection and acknowledge the tension that might exist between this commitment and national economic or strategic interests (Chapter 2).

Acknowledging the global context, contributors recommend that Antarctic Treaty Parties need to search for ways to strengthen links between ATS environmental conservation provisions and other relevant global instruments (Chapter 3).

Instruments, tools, legislations that are in use outside of the Antarctic can also be brought into, adapted to and implemented in the Antarctic context. These include managing Antarctica and peri-Antarctic islands under legal frameworks similar to those used for national parks (Chapter 2), introducing the concept of sponsoring states in the regulation of tourism (Chapter 12) and the use of Environmental Management Systems and strategic environmental assessment tools (Chapters 13 and 14).

The Antarctic does not exist in a vacuum. The Antarctic environment cannot be protected through efforts within the Antarctic only. Global environmental and research initiatives are also necessary to ensure the continued conservation of the Antarctic environment. Public awareness of global environmental change and contentious current issues related to the health of the Antarctic environment are starting points for any such initiatives, but what is needed is behavioural change in order to mitigate climate change, a reduction of global consumption and waste production (Chapter 2), an improvement in the effectiveness of the governance of ocean spaces (Chapter 3) and the understanding of the values that humans attribute to Antarctica (Chapter 10).

Last and most importantly, strategic actions internal and external to the Antarctic context need to be brought together holistically and proactively (Chapter 2). Long-term and large-scale considerations need to be reflected in all the steps of planning, decision making, implementation, enforcement, monitoring and compliance. Decisions should be guided by a long-term vision and goals that are supported by genuine commitment from all actors in order to prevent Antarctica becoming a 'paper park' (Chapters 11 and 14).

The strategic planning needs categorised in Table 15.2 broadly reflect the spatial dimensions of Antarctic environmental governance and include environmental management tools that can be used for the in-situ management of human activities in the Antarctic, that can be applied to Antarctic governance, or that are of relevance to global initiatives. As Antarctica is a continent with a diversity of ecosystems, the management of human activities needs to be context-specific—there is no one-size-fits-all with regard to Antarctic environmental management. This book explores different levels of governance and management based on species diversity and ecosystems (Chapters 2–6, grouped under Part I), an approach that also has been used in the delineation of Antarctic Conservation Biogeographic Regions (Terauds et al. 2012). Chapters 7–9 (Part II) pick up different regional case studies demonstrating the diversity with which human activities in different regions are managed. Like time, space is an important dimension that needs to be taken into consideration in Antarctic environmental governance—it determines ecosystem characteristics, types and scales of human activities and their management and the appropriate strategic planning response. This is reflected in the frequently suggested notion of zoning (Bertram and Stonehouse 2007; Davis 1999; Hall and Wouters 1994; Harris 1998; Kriwoken and Rootes 2000; Tracey 2001). Annex V of the Madrid Protocol also provides a framework to protect areas with 'outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values', or ongoing or planned scientific research.

15.4 Motivations Behind Human Engagement with the Antarctic

In addition to Annex V of the Madrid Protocol, Article 3(1) 'Environmental Principles' of the Madrid Protocol also refers to the protection of values:

> The protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area.

In order to govern human activities in the Antarctic effectively, it is necessary to take into consideration not only the peculiarities and impacts of the types of activities taking place but also the interests, motivations and values driving these particular activities. This is not only because the Madrid Protocol mandates the protection of certain values. On a much more fundamental level, it is because of the fact that human engagement with the Antarctic environment is not value-free (Chapter 10 provides a more in-depth discussion). The future of human engagement with the Antarctic environment draws on basic human values that underlie all decision making. The term 'value' is used in a range of different contexts and is associated with a variety of meanings (Rescher 1966) but is commonly used to relate to something desirable, worthy or simply something good. In sociology and psychology, the concept of value is closely linked to human behaviour, which is considered to be guided by basic values (Rokeach 1973; Schwartz 2005). A difference is made between intrinsic values which refer to something that is good in and of itself (Zimmerman 2001) and extrinsic or instrumental values that can be considered good for the sake of something else, i.e. as a means to a greater good (Rønnow-Rasmussen and Zimmerman 2005; Sandler 2012).

Over time, humans have attributed different values to the Antarctic, which are reflected in different human activities and the legal instruments that states have agreed on. Table 15.3 summarises the values that humans have attributed to the Antarctic environment as featured in the preceding chapters and in the international legal instruments that have direct jurisdiction with regard to Antarctic environmental governance.

The 1959 Antarctic Treaty enshrined the twin values of peace and science. It recognises that it is in the interest of all mankind for peace to continue forever in the Antarctic. While it might seem that the original Antarctic Treaty signatories valued Antarctica for present and future generations, Elzinga (2011) and Beck (2010) pointed out that the success of the Antarctic Treaty was not a result of altruism. National claims to territorial sovereignty, commercial and financial opportunities as well as national prestige have been long-standing considerations in state's engagement with the Antarctic (Triggs 2011; Roots 2011). These values are touched on in Chapters 3, 10 and 12,

Table 15.3 Categories of values addressed in the different chapters

What is valued (or type of value attributed)?	Chapters/[conventions]
Ecosystem health and services, including:	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14 [CCAS, CCAMLR, Protocol, ACAP]
– native terrestrial and marine ecosystems, their biodiversity and unique biological assemblages	
– quality and quantity of wildlife	
– landscapes and spaces for themselves (intrinsic value) and as present or former habitat	
– integral component of the Earth's climate system	
Economic values of natural resources, including:	3, 10, 12 [ICRW, CCAMLR]
– fisheries	
– tourism	
– potential future resource exploration and exploitation	
Scientific value:	5, 6, 7, 8, 10, 11, 13 [AT, Protocol]
– Antarctica as a laboratory, producing research for the benefits of humankind	
Historic, educational or cultural values	8 [Protocol, ACAP]
National interests	10
Peace	[AT, Protocol]
Intrinsic value:	10, 11 [Protocol]
– Value that Antarctica has in and of itself independent of its use to anyone or whether anyone exists to value it	
Aesthetic value	8, 12 [Protocol]
Symbolic values:	10, 11
– symbolic place where humankind can express their highest ideals	
– common heritage of all humankind	
Wilderness value:	6, 8, 10, 11, 13, 14 [Protocol]
– Values of landscapes and environment that have little imprint of humankind	
Moral obligations	5
Present and future generations	11 [ICRW, AT, ACAP]

Legend of acronyms

ACAP	2001 Agreement on the Conservation of Albatrosses and Petrels
AT	1959 Antarctic Treaty
CCAS	1972 Convention for the Conservation of Antarctic Seals
CCAMLR	1980 Convention on the Conservation of Antarctic Marine Living Resources
ICRW	1946 International Convention for the Regulation of Whaling
Protocol	1991 Protocol on Environmental Protection to the Antarctic Treaty

addressed by two conventions (Table 15.3) and, in the late 1980s, led to the negotiation of the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) that never came into force (Berkman 2002, pp. 189–196). However, through the Madrid Protocol, Antarctic Treaty Parties articulated the wish to protect Antarctica's ecosystems, as well as its wilderness, aesthetic, intrinsic and scientific values. The relatively pristine nature of the Antarctic environment has long been a principal resource for science and society (Berkman 2002, p. 184). Notably, nearly all chapters as well as four international agreements address, to some extent, the issue of the health of Antarctica's ecosystems and any services that they may provide (Table 15.3). Antarctica, with its transcendent majesty and beauty, is sometimes considered as a mythic, timeless landscape, set apart from the ordinariness of life, and a place where humans can rise above national and personal ambitions and pursue the highest human aspirations (Chapters 10, 11, e.g. Leane 2005; Spufford 2007; Glasberg 2008). Its wilderness and aesthetic values have also been used as powerful attractions for tourists (Chapter 12; Liggett 2011), which tourists themselves may or may not buy into (see Maher 2007 and Maher 2010), and in global commercial advertisement (Glasberg 1998).

Are the values enshrined under international agreements cherished in practice? What values do the various actors (public and private) attribute to the Antarctic? Is there a tension between where actors want to drive the Antarctic environment and where international agreements commit nations to go? More fundamentally, how does humankind in general value Antarctica? It is likely that different groups attribute different values to Antarctica at different times. How can this diversity be taken into consideration in the management of human activities in Antarctica?

Only detailed examination of human motivations and activities in the Antarctic can fully answer these questions. However, reviewing the rather sombre discussions surrounding future scenarios, we see that the Antarctic environment and the values enshrined under the Madrid Protocol are likely to be degraded under a Business-As-Usual future. It may be reasonable to conclude that the values embraced by many of the actors currently active in the Antarctic are different to those protected under the Madrid Protocol.

This discussion brings back the importance of space and time dimensions in Antarctic governance. Values that humans attribute to a place change with time. For example, whaling was considered a legitimate financial pursuit at one time and deemed barbaric at others. Values drive human behaviour at a place, be it at a field camp in Antarctica or at the meetings of the ATS. This discussion highlights the relevance of the dimension of culture to Antarctic environmental governance. Different cultures embrace different values, which drive their behaviours. Chapter 12 speculates that cultural differences could explain why NAPs vary in the ways they implement new environmental standards. Chapter 10 surveys people from a number of countries and cultures and focuses on groups that have no direct experience of Antarctica. For these people, Antarctica exists only in their imagination, unlike the intimate experiences many scientists and researchers who contributed to this volume bring along. The natural sciences and the social sciences examine Antarctic subjects from different viewpoints using different methods; people from developing and developed countries embody different life experiences; commercial, governmental and environmental organisations are motivated by different priorities.

15.5 Future Challenges to Antarctic Governance

Until we can better understand what values individuals and cultures attribute to Antarctica and how they are translated into the way human activities in the Antarctic are governed, values as motivators of human behaviour and decision making will remain wildcards in Antarctic environmental governance. However, these are not the only challenges that Antarctic environmental governance has to face. It has been frequently emphasised that climate change will be a significant challenge to Antarctic environmental governance (French and Scott 2009; Joyner 2011; Orheim et al. 2011; Rothwell and Nasu 2008). Other challenges include shrinking budgets for NAPs and limited resources for environmental management (see Chapters 5, 8 and 13), technological advances that can bring challenges as well as improvements (see Chapters 5, 8, 10 and 13) and the lack of leadership, vision and flexibility in environmental governance (see Chapters 5, 7, 8, 12, 13 and 14).

It is important to recognise that effective Antarctic environmental governance can only exist within the context of a stable and supportive governance regime. Triggs (2011) contended that terrorism and conflict may represent significant external challenges for the ATS in the coming decades. Even more importantly, threats to the stability of the ATS also arise from within itself, such as through:

- the contentious issue of scientific whaling (Joyner 2011; Rothwell and Nasu 2008; Scott 2010; Triggs 2011);
- the unresolved question of bioprospecting as a commercial pursuit (Jacobsson 2011; Joyner 2008, 2011; Leary 2008, 2009; Rothwell and Nasu 2008);
- illegal, unreported and unregulated fishing in the Southern Ocean (Dodds 2010; Hemmings 2008) or
- submissions to the UN Commission on the Limits of the Continental Shelf (Dodds 2010; Hemmings 2008; Jacobsson 2011; Joyner 2008; Triggs 2011; Weber 2011).

At the heart of many of these issues lies the difficult problem of unresolved and suspended sovereignty (Dodds 2010), which still drives ATS politics and the contributions made to decision making by individual nations. Scholars (e.g. Hemmings 2008; Scott 2010) have strongly recommended the abandonment of the colonial notion of sovereignty and a move to a post-territorial Antarctica. However, it does not seem likely that claimant states will surrender their territorial claims easily. Without strong economic and political motivations that would imply greater benefits for them by giving up their claims than they would obtain from retaining them, it might not be considered in their national interests to do so. Furthermore, even though resource extraction is currently not allowed, amendments or exemptions to existing agreements can be made (e.g. as has been done in the case of scientific whaling). This opens the way to resource extraction (Chown et al. 2012), potentially favouring those states with territorial claims. Roots (2011, p. 69) noted that the history of Antarctic exploration involves the interplay of 'personal ambition, greed, drive for national prestige and impulse to control'. It is important to recognise that geopolitics has and is likely to continue to play a decisive role in human engagement with the Antarctic environment.

15.6 Concluding Thoughts: Towards 'Utopia'

The future scenarios developed by the contributors to this volume draw a near unanimous and sobering picture. Under a Business-As-Usual future, human activities are likely to expand. Current environmental management practices and regulatory mechanisms will not be sufficient to address the environmental challenges in a warmer and busier Antarctic in the twenty-first century and beyond. The objectives of the Madrid Protocol—drafted in the 20th century—will not be met. The Antarctic environment and the values that are given protection under the Madrid Protocol are likely to be degraded.

How important is environmental protection to actors who are active in the Antarctic, especially Antarctic Treaty Parties? Actors (governmental, commercial and non-profit) come from different cultures and embrace diverse values. Budgets are shrinking. Environmental protection competes with national prestige, sovereignty and economic advantage for limited resources. If not all individuals, let alone institutions, share the same ideas about the need to protect the Antarctic environment, what does the future hold for the Antarctic environment? The Madrid Protocol designated Antarctica as a 'natural reserve'. Does this designation offer any real protection? Can it still offer protection to the Antarctic environment as human interests in the region continue to grow (see also Chown et al. 2012)?

The experts who contributed to this volume have suggested strategic actions that could help to better ensure the future of the Antarctic as a 'natural reserve' over the long term. These include:

- wider use of existing environmental management tools and fuller compliance with existing regulatory mechanisms;
- preserving, broadening and implementing agreed provisions in the ATS;
- strengthening links between ATS environmental protection provisions and relevant global instruments;
- bringing in instruments and tools from outside the Antarctic, adapting and implementing them for the Antarctic context;
- global environmental initiatives;
- last and most importantly, bringing it all together through strategic, proactive and holistic planning and implementation, taking into consideration as many dimensions (e.g. time, space, human values, ecosystems) and perspectives (e.g. experience, culture, behaviour, systems; cf. Esbjörn-Hargens and Zimmerman 2009, p. 6) as possible.

This would help create an effective and nested system of multi-actor and multi-level governance. It would require action by different actors (public and private) on different levels (local, continent-wide, global) over different timescales. Links to other international environmental agreements and organisations will be paramount (Hooghe and Marks 2003; Newig and Fritsch 2009; Ostrom 2005). Regulations and governance regimes alone cannot protect a 'natural reserve'. They need to be invested with genuine political will and necessary resources, which ultimately depends on how much Treaty Parties or, in fact, humankind in general, want to protect the Antarctic environment.

Strategic environmental governance provides pathways that could lead us away from the Business-As-Usual scenarios towards a different future, one that we have given the label of 'Utopia'. 'Utopia' often has connotations of an imaginary perfection that does not exist in reality and might be understood as impractical, unattainable and irrelevant to the real world. However, we concur with McFague (1993, p. 72) that utopian visions are necessary. They provide a goal that humans can aim towards, and they beckon us not to rest in what is but to strive for what might be, could be and should be. It is here where we aim to make a strong contribution and where we hope this book will encourage further work.

References

Beck, P. J. (2010). Fifty years on: putting the Antarctic Treaty into the history books. *Polar Record, 46*(236), 4–7.

Berkman, P. A. (2002). *Science into policy: Global lessons from Antarctica*. San Diego: Academic Press.

Bertram, E., & Stonehouse, B. (2007). Tourism management for Antarctica. In J. Snyder & B. Stonehouse (Eds.), *Prospects for polar tourism* (pp. 285–309). Oxon: CABI Publications.

Börjeson, L., Höjer, K., Dreborg, H., Ekvall, T., & Finnveden, G. (2006). Scenario types and techniques: Towards a user's guide. *Futures, 38*, 723–739.

Chown, S. L., Lee, J. E., Hughes, K. A., Barnes, J., Barrett, P. J., Bergstrom, D. M., et al. (2012). Challenges to the future conservation of the Antarctic. *Science, 337*(6091), 158–159.

Davis, P. B. (1999). Beyond guidelines: A model for Antarctic tourism. *Annals of Tourism Research, 26*(3), 516–533.

Dodds, K. (2010). Governing Antarctica: Contemporary challenges and the enduring legacy of the 1959 Antarctic Treaty. *Global Policy, 1*(1), 108–115.

Elzinga, A. (2011). Origin and limitations of the Antarctic Treaty. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science, and the governance of international spaces* (pp. 59–67). Washington, D.C.: Smithsonian Institution Scholarly Press.

Esbjörn-Hargens, S., & Zimmerman, M. E. (2009). *Integral ecology. Uniting multiple perspectives on the natural world*. Boston: Integral Books.

French, D., & Scott, K. (2009). International legal implications of climate change for the polar regions: Too much, too little, too late? *Melbourne Journal of International Law, 10*(2), 631–654.

Glasberg, E. (1998). The last place on Earth: Antarctica and virtual capitalism. *PoLAR. Political and Legal Anthropology Review, 21*(1), 65–76.

Glasberg, E. (2008). Who goes there? Science, fiction, and belonging in Antarctica. *Journal of Historical Geography, 34*(4), 639–657.

Hall, C. M., & Wouters, M. (1994). Managing nature tourism in the Sub-Antarctic. *Annals of Tourism Research, 21*(2), 355–374.

Harris, C. M. (1998). Science and environmental management in the McMurdo Dry Valleys, Antarctica. In Priscu, J. (Ed.), *Ecosystem processes in a polar desert: the McMurdo dry valleys, Antarctica* (Vol. 72, Antarctic Research Series, pp. 13.). Washington, DC: American Geophysical Union.

Hemmings, A. D. (2008). Beyond claims: Towards a non-territorial Antarctic security prism for Australia and New Zealand. *New Zealand Yearbook of International Law, 6*, 76–91.

Hooghe, L., & Marks, G. (2003). Unraveling the central state, but how? Types of multi-level governance. *American Political Science Review, 97*(2), 233–243.

Jacobsson, M. (2011). Building the international legal framework for Antarctica. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science, and the governance of international spaces* (pp. 1–15). Washington, D.C.: Smithsonian Institution Scholarly Press.

Joyner, C. C. (1998). *Governing the frozen commons: The Antarctic regime and environmental protection*. Columbia: University of South Carolina Press.

Joyner, C. C. (2008). Challenges to the Antarctic Treaty: Looking back to see ahead. *New Zealand Yearbook of International Law, 6*, 25–62.

Joyner, C. C. (2011). Potential challenges to the Antarctic Treaty. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science, and the governance of international spaces* (pp. 97–102). Washington, D.C.: Smithsonian Institution Scholarly Press.

Kriwoken, L. K., & Rootes, D. (2000). Tourism on ice: Environmental impact assessment of Antarctic tourism. *Impact Assessment and Project Appraisal, 18*(2), 138–150.

Lamers, M., Amelung, B., & Stel, J. H. (2010). Business as (Un)usual: Integrated scenario analysis for tourism in Antarctica. In C. M. Hall & J. Saarinen (Eds.), *Tourism and change in the polar regions: Climate, environment and experiences*. London: Routledge.

Leane, E. (2005). Antarctic travel writing and the problematics of the pristine: Two Australian novelists' narratives of tourist voyages to Antarctica. In Lester, L. & Ellis, C. (Eds.), *Proceedings of Imaging Nature: Media, Environment and Tourism, Cradle Mountain*, June 27–29 2004.

Leary, D. (2008). Bi-polar disorder? Is bioprospecting an emerging issue for the arctic as well as for Antarctica? *RECIEL, 17*(1), 41–55.

Leary, D. (2009). Looking beyond the international polar year: What are the emerging and re-emerging issues in international law and policy in the polar regions? *Yearbook of Polar Law, 1*, 1–19.

Liggett, D. H. (2011). *Economy world and its peoples* (Vol. 10 (Australia and Antarctica), pp. 1430–1433). New York: Marshall Cavendish.

Maher, P. T. (2007). Advocating for Antarctic wilderness: Short-term visits and human values. In Watson, A., Sproull, J. & Dean, L. (eds.) *Science and stewardship to protect and sustain wilderness values: Eighth World Wilderness Congress symposium. Proceedings RMRS-P-49*. Fort Collins, USA: US Department of Agriculture, Forest Service, RMRS.

Maher, P. T. (2010). *Footsteps on the ice: Visitor experiences in the Ross Sea region*. Antarctica: Lincoln University.

McFague, S. (1993). *The body of God: An ecological theology*. Minneapolis: Augsburg Fortress.

Newig, J., & Fritsch, O. (2009). Environmental governance: Participatory, multi-level—and effective? *Environmental Policy and Governance, 19* 197–214.

Orheim, O., Press, A., & Gilbert, N. (2011). Managing the Antarctic environment: The evolving role of the committee for environmental protection. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science, and the governance of international spaces* (pp. 209–221). Washington, D.C.: Smithsonian Institution Scholarly Press.

Ostrom, E. (2005). *Understanding institutional diversity*. Princeton: Princeton University Press.

Rescher, N. (1966). Practical reasoning and values. *The Philosophical Quarterly, 16*(63), 121–136.

Rokeach, M. (1973). *The nature of human values*. New York: Free Press.

Rønnow-Rasmussen, T., & Zimmerman, M. J. (Eds.). (2005). *Recent work on intrinsic value*. Dordrecht: Springer.

Roots, E. F. (2011). Background and evolution of some ideas and values that have led to the Antarctic Treaty. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science, and the governance of international spaces* (pp. 69–72). Washington, D.C: Smithsonian Institution Scholarly Press.

Rothwell, D. R., & Nasu, H. (2008). Antarctica and international security discourse: A primer. *New Zealand Yearbook of International Law, 6*, 3–23.

Sandler, R. (2012). Intrinsic value, ecology, and conservation. *Nature Education Knowledge, 3*(3), 4.

Schwartz, S. H. (2005). Basic human values: An overview. 1–20. Retrieved 10 March 2012 from http://segr-did2.fmag.unict.it/Allegati/convegno7-8-10-05/Schwartzpaper.pdf

Scott, K. N. (2010). Managing sovereignty and jurisdictional disputes in the Antarctic: The next fifty years. *Yearbook of International Environmental Law, 20*(1), 3–40.

Spufford, F. (2007). Introduction. In Spufford, F. & Kolbert, E. (Eds.). The Ends of the Earth: The Antarctic, vol.2 of *The Ends of the Earth. An Anthology of the finest Writing on the Arctic and the Antarctic*. (pp. 1–11). New York: Bloomsbury.

Stokke, O. S., & Vidas, D. (Eds.). (1996). Governing the Antarctic. The effectiveness and legitimacy of the Antarctic Treaty System. Cambridge, United Kingdom: Cambridge.

Terauds, A., Chown, S. L., Morgan, F., Peat, H. J., Watts, D. J., Keys, H., et al. (2012). Conservation biogeography of the Antarctic. *Diversity and Distributions, 18*(7), 726–741.

Tracey, P. J. (2001). *Managing Antarctic tourism.* PhD thesis, the University of Tasmania, Hobart, Tasmania, Australia.

Triggs, G. (2011). The Antarctic Treaty System: A model of legal creativity and cooperation. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science, and the governance of international spaces* (pp. 39–49). Washington, D.C.: Smithsonian Institution Scholarly Press.

Van't Klooster, S. A., & Van Asselt, M. B. A. (2006). Practising the scenario-axes technique. *Futures, 38*, 15–30.

Weber, M. (2011). *The strength to continue: A case study approach to examining the robustness of polar governance in the era of environmental and energy security.* Unpublished PhD thesis, University of Tasmania, Hobart, Australia.

Young, O. R. (1998). The effectiveness of international environmental regimes: A mid-term report. *International Environmental Affairs, 10*(4), 267–289.

Young, O. R. (2011). Governing international spaces: Antarctica and beyond. In P. A. Berkman, M. A. Lang, D. W. H. Walton, & O. R. Young (Eds.), *Science diplomacy: Antarctica, science, and the governance of international spaces* (pp. 287–294). Washington, DC: Smithsonian Institution.

Young, O. R., & Osherenko, G. (Eds.) (1993). *Polar politics: Creating international environmental regimes*. Ithaca and London: Cornell University Press.

Zimmerman, M. J. (2001). *The nature of intrinsic value*. Lanham: Rowman & Littlefield.

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