Non-native Species in the Antarctic

PROCEEDINGS

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*Editor*

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Map of the Antarctic continent, the subantarctic islands and the Southern Ocean. The dashed line is the approximate location of the polar front/Antarctic convergence. Data from Antarctic Digital Database (ADD). Cartography by I. Jones, (Gateway Antarctica).
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Invasive non-native species are one of the most significant threats to the ecological and economic well-being of the planet. Such species have caused enormous damage to biodiversity and natural agricultural systems upon which we depend. And the damage can often be irreversible.

Continuing globalization, with increasing trade, travel, and transport across borders, has brought tremendous benefits. But it has also exaggerated the rapid spread of non-native species and the development of invasiveness by many of them.

Invasive species occur in all major taxonomic groups, and all habitats and environments can be affected. It is becoming increasingly clear that the Antarctic region is not immune. Less than 200 years ago no human had set foot on Antarctica. Today over 40,000 people visit the continent annually, arriving in a variety of ships and aircraft from numerous countries around the world. Antarctica is no longer an isolated and remote continent. This increasing visitation coupled with a changing, more benign climate in certain parts of Antarctica, mean that the risks of non-native species invasions are becoming more significant.

At risk are the loss of natural Antarctic biodiversity, and equally importantly, the value of Antarctica as a continent for scientific research.
At present, only a few non-native species are known in Antarctica, but their very existence needs to set alarm bells ringing. Immediate action needs to be taken to manage the risks and to put preventative measures in place. Preventing the importation of invasive alien species to Antarctica, or at worst, coordinating timely and effective responses to actual invasions, requires urgent and significant co-operative effort among Antarctic Treaty Parties, non-governmental organisations, and international experts.

A variety of response and management mechanisms need to be considered and developed including, risk assessments, guidelines, protocols, response plans, awareness-raising opportunities, further research and accessible databases.

The Non-native Species in Antarctic Workshop, held in Christchurch in April 2006, was seen as a first step to address this global challenge in an Antarctic context. We were delighted with the attendance at, and outcomes to, the workshop which are captured in this publication. We therefore commend these proceedings to all those with an Antarctic interest, including Antarctic Treaty Parties and the Committee for Environmental Protection, and hope that the workshop assists in stimulating further discussion and action to address this significant problem.

Maj De Poorter
Neil Gilbert
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Convenors
INTRODUCTION

MAJ DE POORTER, NEIL GILBERT,
MICHELLE ROGAN-FINNEMORE & BRYAN STOREY

The natural biogeographical barriers of oceans, mountains, rivers and deserts have provided the isolation in which species and ecosystems evolved. Worldwide, these barriers have increasingly lost their effectiveness as economic globalisation and the resulting trade, travel & transport contributes to an exponential increase in the intentional or unintentional movement of organisms from one part of the world to another (McNeely et al. 2001; Carlton 1999).

We define a non-native species (sometimes called alien species) as a species that has been introduced to an ecosystem either intentionally or unintentionally, where introduction is used to indicate the movement, as a direct or indirect result of human activity, of species into an area where they are not native. While many introductions of species into new ecosystems are beneficial to people, providing food, building materials and other economic benefits, nevertheless, tremendous damage results from those non-native species that become detrimental.

In this publication, we use the term invasive non-native species for non-native species whose introduction and/or spread threaten biological diversity. Invasive non-native species are one of the most significant threats to biological diversity on a global scale (McKinney & Lockwood 1999; Sala et al. 2000; Courchamp et al. 2003). They have affected native biota in virtually every ecosystem type on earth. The
ecological cost includes the loss of native species and ecosystems, ecosystem services and livelihoods (OTA 1993; Mack et al. 2000; McNeely et al. 2001). In view of the significance of the global threat, several international legal instruments address aspects of non-native species introductions and the risks of subsequent biological invasion, including, the Convention on Biological Diversity 1992, the United Nations Convention on the Law of the Sea 1982 and the Ballast Water Convention 2004 (not yet in force).

Native biodiversity on subantarctic islands has been heavily impacted by invasive non-native plants and vertebrates (Bonner 1984; Cooper 1995; Chapuis 1995; Frenot et al. 2005). While the Antarctic continent itself has, so far, escaped the ravages of biological invasion, non-native organisms, including terrestrial invertebrates and plants, and a marine crustacea have been found in the Antarctic Treaty region (Australia 1995; Japan 1996; Olech 1996; Tavares et al. 2004).

The Antarctic Treaty System (ATS) recognised the importance of non-native species as early as 1964 in the Agreed Measures for the Conservation of Antarctic Fauna and Flora. The Protocol on Environmental Protection to the Antarctic Treaty 1991 has not expanded upon those early provisions and little has been done to elaborate upon them through practical guidance. Further, the non-native species provisions of the Protocol are largely aimed at intentional introductions of non-native species. The need for parties to address the issue of unintentional introductions is not explicitly stated in the Protocol, though it can be inferred from a number of its Articles. For example, Article 4 of Annex II to the Protocol:

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- prohibits the introduction of non-native species except in accordance with a permit;
- places restrictions on what can be permitted;
- provides an exemption for food;
- requires that permitted species must be removed or destroyed;
- requires precautions to be taken to prevent the introduction of microorganisms not present in the native fauna and flora.

Recently, however, a heightened interest has been developed by the Antarctic Treaty System (ATS). For instance, Working Paper 28 (ATCM XXVIII) on measures to address the unintentional introduction and spread of non-native biota and disease to the Antarctic Treaty area noted that no formal assessment had been undertaken of the risks associated with non-native species in the Antarctic context, and that increasing visitation and a changing, more benign, climate in certain parts of the Antarctic is likely to be increasing these risks. The Committee for Environmental Protection (CEP) has been discussing the issue and has recently declared this issue of the highest priority.

In this context, a three-day workshop was hosted by Gateway Antarctica, the Centre for Antarctic Research and Studies at the University of Canterbury, on “Non-native Species in the Antarctic Region”, on 10, 11 and 12 April 2006. The Workshop was jointly convened by Dr. Maj De Poorter (Centre for Biodiversity and Biosecurity, University of Auckland), Dr. Neil Gilbert (Antarctica New Zealand) and Professor Bryan Storey (Gateway Antarctica, University of Canterbury), with Michelle Rogan-Finnemore (Gateway Antarctica,
University of Canterbury) as Workshop project manager. The Workshop was attended by 42 people from six countries: Australia, France, Italy, New Zealand, UK and USA (see Appendix 4 for list of participants). The final report of the workshop and the individual powerpoint presentations can be found at www.anta.canterbury.ac.nz.

The aim of the Workshop was to bring together relevant national and international experts to discuss conservation, management and research issues relating to the introduction of non-native species in the Antarctic in order to foster increased understanding and awareness of:

- The relevance of non-native species introductions to conservation of Antarctic environmental and other values;
- Pathways for intentional and unintentional introductions of non-native species;
- Best practice and management tools (practical as well as legal);
- Identification of gaps (knowledge, methods, regulatory);
- Requirements to address these gaps (including research, implementation, regulatory, awareness-raising).

The geographic focus of the workshop included all habitats in the Antarctic region (below 60° South). This was not meant to exclude the subantarctic region, it was simply a way to focus the discussions to the Antarctic Treaty area. The scope included comprehensive coverage of biota, and the emerging issue of diseases; terrestrial and marine environments; internal (site-to-site) introductions and external (inter-continental) considerations.
The workshop highlighted key lessons learned globally and confirmed the significance of non-native species issues in the Antarctic context. Based on the presentations and discussions, participants put forward several conclusions and recommended actions to maximise the lessons learned worldwide and to improve practical measures to address the non-native species issue in the Antarctic context. These are summarised below as workshop outcomes in two headings, those outcomes in reference to non-native species in a global context, and those outcomes in reference to non-native species in the Antarctic context.

Non-native species in the global context

- Invasive alien species (IAS) are contributing significantly to a global biodiversity crisis. For several groups, IAS represent the second or third major threat to their survival;
- In the marine environment, IAS are recognised as the fifth biggest threat to global marine biodiversity;
- Invasive alien species are found in all taxonomic groups and all ecosystem types are at risk from the impacts of IAS. Isolated and island ecosystems are particularly at risk due to the high degree of endemism found in such communities;
- Ongoing increases in global trade and travel are causing an exponential increase in the movement of species outside of their natural range;
- With regards to non-native species, the key lesson from elsewhere in the world is that in view of the complexity of ecological effects, non-native species issues need a
preventative and precautionary approach. That is, prevention of introduction must be a priority and we must consider any species "guilty until proven innocent";

> Key components of management are prevention, surveillance and rapid response:

- **Prevention** is the most effective means of avoiding or minimizing impacts caused by invasive non-native species;
- **Surveillance** can be passive (waiting for things to appear in the native environment) or targeted (an active programme of identifying potential alien species) - good baseline data on native fauna and flora present is required;
- **Rapid response** requires a quick assessment of the feasibility, and desirability of eradicating an alien species - if eradication is not an option then control and/or containment need to be considered;

> To assist with the management of non-native species, a number of risk assessment tools are continuing to be developed. However, such tools require adequate data and are likely to remain inadequate for data poor areas such as the Antarctic;

> A critical component of management is awareness-raising at multiple levels to multiple audiences (from decision makers at international and national levels to personnel in the field and crews on ships). This should include awareness-raising on the risks posed by non-native species and on the need to prevent their introduction;
No non-native species management programme can be 100% successful. There is a need to focus on the key risks and pathways, to develop a coordinated approach and to ensure adequate research and monitoring is in place.

Non-native species in the Antarctic context

- IAS have already significantly affected the subantarctic islands, with around 200 known alien plants and animals established;
- There is a strong correlation between introduced species and human activity on the subantarctic islands with most alien species being of European origin;
- Introductions of non-native species into the Antarctic resulting from human activity far outweigh natural dispersal of species;
- Whilst Antarctica has natural environmental advantages (remoteness and a harsh climate), these are not enough to stop invasive species, pests and diseases and there are several examples of non-native species occurring in Antarctica;
- Several marine species that are found in Antarctic waters (notably bryozoans and ascidians) are found elsewhere in the world. It may not be appropriate to assume that marine species found in the Antarctic are native;
- Increased human activity on the continent also risks transferring species across natural biogeographic boundaries with the subsequent breakdown of regional endemism, and genetic distinctness. Antarctica is one of the few areas of the
planet where such boundaries and regions still hold. Two examples of high risk areas are:

- Charcot Island which has no springtails (an otherwise ubiquitous species) in its terrestrial ecosystem, which is scientifically highly significant. The introduction of species to Charcot Island would compromise the scientific value of the island; and

- Ellsworth Land nunataks which contain the simplest known multitrophic terrestrial ecosystems on the planet comprising only tardigrades and rotifers. The potential for pre-adapted taxa to invade these systems is high with human activity in the region;

- Increased human activity in the Antarctic also means increased ship and aircraft activity. Aircraft pose particular risks by reducing the transport time for alien species from days or weeks to just a few hours (thus increasing the chances of transport survival). Hull fouling of vessels is likely a pathway for marine introductions to the Antarctic;

- Increased links between Antarctica and the Arctic increases the potential for introductions of species with survival;

- A changing more benign climate, particularly in the Antarctic increases the risks of alien species establishing themselves;

- There is a pressing need for increased and coordinated survey, monitoring and research across the continent and Southern Ocean. Good baseline information should be developed for all taxa and all environments, with special emphasis on closing the gaps in knowledge on microbes and on marine environments;
Antarctic Treaty parties have not ignored the issue of non-native species, but provisions, have been largely aimed at intentional introductions of non-native species. The Antarctic Treaty’s Committee for Environmental Protection (CEP) is well placed to take action. Consideration could be given to making non-native species issues a separate agenda item;

All the values in Article 3 of the Protocol need to be protected from non-native species introductions - the Antarctic requires the highest standard of protection;

National Antarctic Programmes have demonstrated a mixed response to the management of non-native species. It will be important to ensure that practical measures are implemented consistently among all operators in the Antarctic. In addition to the consideration of new or additional procedures to address non-native species, existing procedures, such as Environmental Impact Assessment (EIA) and protected areas management should incorporate, as appropriate, components to address non-native species concerns. Information sharing should be encouraged and maximised on practices and/or procedures used. Interagency cooperation will be beneficial;

The principle components of any management programme are prevention, surveillance and rapid response, with prevention being the most effective means of minimising any impact;

Increasing awareness on the risks posed by non-native species and on the need to prevent their introduction is a key requirement for successful management.
The Proceedings are a follow up from the Workshop and reflect the discussions and presentations from April 2005. The CEP continues to discuss the issue of non-native species in the Antarctic at its annual meetings.

REFERENCES


Mick Clout is the founding Chair of the Invasive Species Specialist Group (ISSG) of the World Conservation Union (IUCN). He is Professor and Director of the Centre for Biodiversity and Biosecurity at the University of Auckland and Chair of the Biosecurity Ministerial Advisory Committee. He is a vertebrate ecologist and has published widely on the ecology and conservation of native wildlife and the management of invasive alien species. Through his role as Chair of ISSG, he is involved in a range of international biosecurity initiatives to prevent, eradicate and manage invasive species.

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Yves Frenot has more than 20 years experience in the terrestrial ecology of the subantarctic islands. His PhD was conducted on the soil characteristics and the earthworm fauna of Ile de la Possession, Crozet Islands. After his PhD his field of research moved to the colonisation processes on the glacier forelands at Kerguelen Islands.
More recently his research has focused on the impact of climate change and human activities on subantarctic biodiversity. This work was carried out under the umbrella of the SCAR RiSCC programme. He is currently Deputy-Director of the French Polar Institute (IPEV) and, in 2005, he was elected vice-chair of the Committee for Environmental Protection (CEP).

Neil Gilbert (convenor) has worked on polar matters for the last 22 years. In 1985 he joined the British Antarctic Survey (BAS) as a research scientist completing his PhD on near-shore marine ecology in 1991. For the field component of his research, he spent 2.5 years living and working at the BAS’s Signy Island research station. Between 1991 and 1994, Neil continued his association with Signy as permanent Base Commander for the station. In 1997 he was appointed to the position of Deputy Head of the Polar Regions Unit in the Foreign and Commonwealth Office. In that capacity, he represented the UK at meetings of the Antarctic Treaty and its Committee on Environmental Protection (CEP). In 2003, he immigrated to New Zealand joining Antarctica New Zealand as Environmental Manager. In this capacity he has continued to attend meetings of the CEP as New Zealand’s representative. In 2006 he was elected to the Chair of the Committee.

Tom Maggs has been with the Australian Antarctic Division (AAD) since 1979, wintering twice at Mawson Station and at Casey as Station Leader in 1988. He is currently the Manager of Environmental Policy and Protection at the AAD, a position he has held since 1996. He is also the Australian contact point for the Committee for Environmental Protection (CEP).

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Bryan Storey (convenor) is Professor in Antarctic Studies and Director of Gateway Antarctica, the Centre for Antarctic Studies and Research at the University of Canterbury. Bryan worked for the British Antarctic Survey (BAS) for 25 years before taking on the role of Director of Gateway Antarctica. He is currently the Chair of the New Zealand University Antarctic Alliance (NZUAA), Secretary of the SCAR Standing Scientific Group on Geosciences (SSG – GS), and is a Polar Medal recipient.

Sue Worner is a senior lecturer and researcher at Lincoln University and a project leader in the biosecurity theme of the Bio-Protection Centre, a Centre of Research Excellence (CoRE) hosted by Lincoln University. Her experience is in ecological data analysis and modelling, particularly modelling climatic and other influences on invasive insect populations to predict potential distribution, abundance and spread. This work has resulted in many invited international conference presentations and international publications. Dr Worner currently leads, or is involved in, several international projects in Biosecurity research.
INTRODUCTION: INVASIVE ALIEN SPECIES—A GLOBAL ISSUE

The natural biogeographical barriers of oceans, mountains, rivers and deserts provided the isolation in which species and ecosystems evolved. Increasingly these barriers have lost their effectiveness – as economic globalisation has resulted in an exponential increase in the movement of organisms from one part of the world to another. (McNeely et al. 2001; Carlton 1999). Pathways for intentional introductions of alien (non-native = introduced) species\(^3\) include forestry, agriculture, horticulture, aquaculture, erosion control, aid programmes, pet trade, gardening, research etc. In many instances, however, introductions are unintentional: such as contamination of seeds or other agricultural produce, pests on plants, timber products, organisms inside ships (ballast water) or on the outside of ships (hull fouling), “hitchhikers” in containers, construction equipment or luggage, organisms in soil of dirty shoes, tenting or hiking equipment, etc (see e.g. Wittenberg & Cock 2001; Shine et al. 2000).

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\(^2\) Invasive Species Specialist Group (ISSG) of the Species Survival Commission (SSC) of IUCN – the World Conservation Union. Also see Appendix B at end of paper.
\(^3\) For further definitions of terminology see Appendix A at end of paper and the Introduction section of this volume.
While many of the deliberate movements of species into new ecosystems are beneficial to people, providing food, building materials and other economic benefits, nevertheless tremendous damage results from alien species that become detrimental. The IUCN World Conservation Union defines an alien species as a “species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce.” An “Invasive Alien Species” (IAS) is defined as an “alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity” (IUCN 2000).

IAS are found in all taxonomic groups: they include introduced viruses, pathogens and other micro-organisms, fungi, algae, mosses, ferns, higher plants, invertebrates including insects, molluscs and crustaceans, bryozoans, fish, seaweeds, amphibians, reptiles, birds and mammals (e.g. Lowe et al. 2000; UNEP 2001; and see www.issg.org/database). IAS have invaded and affected terrestrial, freshwater and marine ecosystems from deserts to forests, lakes, wetlands, grasslands, estuaries, rocky shores or coral reefs, to name only a few. Virtually every ecosystem type in almost any region in the world has been affected to some extent (UNEP 2001; Matthews & Brand 2004; Matthews 2004, 2005).
Biological invasions are now considered one of the main factors in biodiversity loss and endangered species listings worldwide (OTA 1993), and almost certainly the worst factor in biodiversity loss on islands (Clout 1999; Clout & Lowe 2000). In the marine environment, IAS has been rated as one of the four greatest threats to the world’s oceans. The *Millennium Ecosystem Assessment* confirms it as a main driver of biodiversity loss over the last 50 to 100 years, globally, and the trend in the impact is estimated to continue or increase in all biomes (UNEP 2005a, 2005b). The ecological cost includes the loss of native species and ecosystems, ecosystem services and livelihoods (OTA 1993; Mack *et al.* 2000; McNeely *et al.* 2001).

It should be noted that “alien” refers to ecological boundaries, rather than political ones. Within a country for instance, a species can be native in one part, but alien and even invasive, in another part of the same country if it has been moved across a biogeographical boundary (e.g. from mainland to island, from one watershed to another, across a mountain range, or, in case of the Antarctic for instance, across a vast ice sheet from one nunatak region to another).

**ECOLOGICAL IMPACTS FROM INVASIVE ALIEN SPECIES**

**Invasive alien species and the Red List: global extinctions and threats**

The *Global Species Assessment* (based on the 2004 IUCN Red List) contains information on extinctions and “extinctions in the wild” since
1500 AD. For birds, relatively good data exists indicating that invasive species are being associated with the extinction of at least 65 species. Predation by introduced rats and cats, and diseases caused by introduced pathogens have been, overall, the most deadly contributing to the extinctions of 30, 20, and ten bird species respectively. For freshwater fish globally, preliminary analysis points to IAS as a growing threat, having contributed to over 50% of species extinctions (Baillie et al. 2004). For invertebrates, Baillie et al. 2004 contains an illustrative case study: seventy-two percent of the Partula snail species native to the Society Islands (French Polynesia) are now extinct since the 1970s as a result of the introduction of the predatory wolf snail (*Euglandina rosea*).

Amphibian species have been reported as declining since the 1970s, and in many of them, the fungal disease chytridiomycosis is implicated. Moreover, eight out of nine recorded amphibian extinctions since 1980, as well as many of the more than 100 possible extinctions, are also thought to be the result of this fungal disease, probably operating in conjunction with climate change (Baillie et al. 2004). Not only is the pathogen itself an IAS (Weldon et al. 2004), but its spread across the globe is facilitated by vectors that are invasive alien amphibians such as the African clawed frog (*Xenopus laevis*), the American bullfrog (*Rana catesbeiana*) and cane toad (*Bufo marinus*) ([www.issg.org/database](http://www.issg.org/database), De Poorter in press).

In the Global Species Assessment, IAS have been identified as a major threat faced by globally threatened birds and amphibians, affecting 30% (326 species) and 11% (212 species) of them. Island
species are particularly vulnerable: 67% of oceanic-island globally threatened birds are affected by IAS (Baillie et al. 2004). IAS are also generally accepted to be one of the major issues in the conservation of freshwater ecosystems, and the very high value of freshwater ecosystems that are still free of alien species has been highlighted (Saunders et al. 2002).

**Impacts of invasive alien species on populations, species and ecosystem functioning**

There is a growing body of literature on the epidemiology of biological invasions, their impacts on populations, species, communities and ecosystem functioning, and interactions with other factors of global change (see e.g. Mack et al. 2000; McNeely et al. 2001; Macdonald et al. 1989; Mooney & Hobbs 2000; UNEP 2001).

At the level of populations, impacts can be categorised into:

- **Predation**: for instance, by feral cats, rats and even mice which has depleted or extirpated breeding populations of seabirds or endemic land birds (Figures 1 and 2) in a variety of locations spread over the world (e.g. Tershy et al. 2002; Cooper & Glass 2006).

- **Herbivory**: for instance, by goats and rabbits which have been responsible for damage to native plants through grazing or browsing, including extinctions of endemic plants (Figure 3).

- **Competition**: for resources such as light, nutrients, prey, space and niches within a habitat. The North American grey squirrel (*Sciurus carolinensis*), for instance, is replacing the native red
squirrel (*Sciurus vulgaris*) in Britain by more efficient foraging, and threatens to do so eventually on the European continent (Genovesi & Bertolino 2001). In New Zealand, two alien invasive wasp species successfully outcompete the threatened parrot, the Kaka (*Nestor meridionalis septentrionalis*) during the autumn peak of wasp density, by using up to 95% of the honeydew produced by native scale insects in the southern beech forests (Beggs 2001).

- **Pathogens:** Disease causing organisms (and/or their vectors) can have significant impacts on plants as well as animals. For example, the chestnut blight fungus (*Cryphonectria parasitica*) arrived in the USA (on nursery stock) early in the 20\textsuperscript{th} century and within a few decades it had spread throughout the eastern third of the USA destroying almost all American chestnuts (*Castanea dentata*) within its native range (Macdonald & van Wilgen 2002). Avian malaria was introduced to Hawaii in exotic birds kept by settlers; with the introduction of the southern house mosquito (*Culex quiquefasciatus*) in water barrels of a sailing ship in 1826, it acquired a vector and has since contributed to the extinction of at least ten native Hawaiian birds and threats to many more (Lowe *et al.* 2000).

- **Hybridisation of alien species with native species:** hybridisation with alien mallards threatens the existence – at least as distinct species – of the New Zealand grey duck (*Anas superciliosa superciliosa*) as well as the Hawaiian duck (*Anas wyvilliana*) (Lever 2005).
Of course, these impact types are not mutually exclusive, and in addition, effects at species level will have ramifications at the community and ecosystem levels. Some authors consider the biggest ecological threat posed by IAS to be the disruption of entire ecosystems, often by invasive plants. Such biological invasion by plants can result in dense stands excluding or smothering other vegetation (Figure 4), lowering of water tables, changing fire regimes, increasing nitrogen in soils, etc. Such changes can, in turn, favour even more alien invasive plants (see Mack et al. 2000 for examples). Impacts on native species, communities and ecosystems, are likely to directly or indirectly impact on livelihoods (and poverty alleviation) through affecting ecosystem services, sustainable use of biodiversity or other values (Figure 5).

A complicating factor is that direct and/or indirect impacts on biodiversity or ecosystem functioning, caused by IAS, are often more complex and more surprising than the impacts of agricultural weeds on crops. For instance, in the South African St. Lucia protected area, *Chromolaena odorata*, an invasive plant, has been linked to Nile crocodiles’ sex ratio changes (Leslie & Spotila 2001). In the New Zealand subantarctic Enderby Island, not only did feral cows (*Bos taurus*) adapt to seaweed as part of their diet, but introduced rabbits (*Oryctolagus cuniculus cuniculus*) became a threat to the endangered Hooker’s sea lion (*Phocarctos hookeri*). Possibly up to 10% of Hooker’s sea lion pups had died annually by being trapped and suffocated in rabbit burrows (Torr 2002) (Figure 6). Invasion by an alien species facilitates and accelerates further invasion by other species. The combination of indirect and secondary effects and
facilitation of further invasion by other aliens can sometimes reach a level where “invasional meltdown” is triggered (Box 1).

**Box 1 An example of “invasional meltdown”**

Alien crazy ants, *Anoplolepis gracilipes*, have formed extensive super colonies on Christmas Island (Australia) since the mid-1990s, most of them in the Christmas Island National Park. Red crabs (*Gecarcoidea natalis*) are very vulnerable, and mortality has been high. This has had further consequences for the dynamics and structure of the native forest, including changes in seedling recruitment, seedling species composition, litter breakdown and density of litter invertebrates. Due to the crab’s migratory nature, effects also occur in areas not (yet) invaded by the crazy ant. In addition, mutualism between the crazy ant and a scale insect and facilitation of invasion into native rainforest by the giant African land snail (*Achatina fulicata*), woody alien weeds and alien cockroaches (Green *et al.* 2001), has vastly increased scope and complexity of impacts – leading to invasional meltdown.

It is not always possible to clearly prove IAS impact on biodiversity – often the resources are not available to carry out research and baselines are often not known. Demonstration of environmental impacts can be difficult because of the complexity of ecosystems. In many cases it may not be feasible to quantitatively determine indirect or cumulative impacts, and even direct biodiversity impacts may be hard to quantify, especially in the case of impacts on plant species, which often do not lead to species extinction, but rather to ecological dysfunction. Rather than being unimportant, such hard to measure effects can be pervading and insidious.
Figure 1 One of many cat-killed Xantus's murrelets (*Synthliboramphus hypoleucus*) in north-west Mexico. Photo: Island Conservation.
Figure 2 Tristan albatross on Gough Island, severely wounded after being attacked nightly by house mice; it died soon after. Photo: Ross Wanless, © Angel/Wanless, reproduced with permission.
**Figure 3** Herbivory by introduced goats, Galápagos archipelago. Photo: Josh Donlan.
Figure 4 Invasive merremia vine (*Merremia peltata*) in the village of Fagaitua, American Samoa. Photo: Tavita Togia.
Figure 5 Livelihood impacts by water hyacinth (*Eichhornia crassipes*), Uganda. Photo: Fen Beed, © International Institute of Tropical Agriculture (IITA), reproduced with permission.
Figure 6  Feral cows (main photo) and introduced rabbits (inset) on the New Zealand subantarctic Enderby Island (now both eradicated). Photos: Pete McClelland.
Likely future trends?

In general, globalisation will increase the risks for biological invasions. Increasing volume of trade, travel and tourism has led to more species than ever before being moved around the world, on land, in the air and by sea. A billion tons of ballast water per year with at least 10,000 species per day in the ballast water is being transported around the world (Carlton 1999).

The number of visitors to an area has been shown to be associated with the numbers of IAS (e.g. see MacDonald et al. (1989) for vascular plants in South African reserves, and Chown et al. (1998) for subantarctic islands). Increased numbers of visitors means increased numbers of introductions of alien species and hence an increased risk that some of the introduced species will be able to become invasive.

PATTERN OF INVASION

Most alien species do not trigger new biological invasions. Invasion is indeed only one of the possible outcomes of a multi-stage process that starts when organisms are transported from their native range to a new ecosystem. Especially with unintentional introductions, first of all, many will not survive the transport, and if they succeed in reaching a new site, many, if not most, of the new immigrant organisms are likely to be destroyed. Some, however, are likely to survive and reproduce. A fraction of those will establish persistent populations and/or spread, and a fraction of those will be harmful in natural or semi-natural...
environments (invasive). Scientists have tried to mathematically calculate what these proportions may be, but, so far, a general rule has remained elusive (contra e.g. Williamson 1996).

While there is no general rule that can be applied to estimate the likelihood that once alien organisms have arrived in a new region they will result in biological invasion, there is much more agreement on what the pattern is, in time, for those that do (Figure 7). After introduction, an alien species may be dormant and show no signs of being invasive for years or decades, and then, turn invasive rapidly. For instance, the spread of invasive trees in the Florida Everglades was delayed until the area became more prone to anthropogenic disturbance and/or hurricanes (Crooks & Soulé 1999). Even without any complicating factors, the usual pattern of invasion starts with a lag phase, during which the alien species is low in abundance and impacts are not noticeable. The lag phase can be short or last over a century. Eventually the population reaches a phase where it increases rapidly – the “explosion phase” – and the impacts usually become very apparent. Following the explosion phase, the population levels out as it reaches the carrying capacity. The lag phase of a future invader is often indistinguishable from the slow rate of spread displayed by alien non-invasive species in a new range, and this makes it particularly challenging to identify future invaders during this phase when they can be relatively easily eradicated (Mack et al. 2000). By the time that impacts are noticeable, the invasion has usually reached a stage where management is very difficult and/or very costly. For this reason, effective and efficient protection of biodiversity against impacts from invasive species means that management action needs to be taken
before invasiveness is noticeable in an alien species – and so the crucial question is how to predict which alien species are likely to become problems and which would remain innocuous if they are introduced.

**WHAT ECOSYSTEMS ARE AT RISK FROM INVASIVE ALIEN SPECIES?**

Ecological communities all over the planet have been invaded to a greater or lesser degree (UNEP 2005a, 2005b; UNEP 2001). But the question arises whether remoteness, relative undisturbedness or a harsh polar climate would convey sufficient protection against biological invasion in the Antarctic.

As a general rule, disturbance increases the risks of biological invasion, but undisturbed habitats, ecosystems or sites are not necessarily safe from biological invasion. For example, the relatively undisturbed New Zealand South Island *Nothofagus* forest has suffered severe alteration of its ecosystem processes, as a result of the combined effect of alien Vespulid wasps (which colonised in the 1970s) and other IAS (Clout & Lowe 2000; Beggs 2001). In the oak woods of Killarney, Ireland, the replacement of *Ilex* by *Rhododendron* is another example of the successful invasion of an undisturbed community by an alien species (Usher 1988). Usher bluntly states: “The concept of invasion of undisturbed communities being rare is no longer tenable. Either this is because undisturbed communities are not resistant to invasion, or it is incorrect because all communities on this
planet are now disturbed, at least slightly. The reason is unimportant since nearly all areas of the planet have invasive species” (Usher 1988).

Being far away from the main centres of civilisation is no protection against biological invasion either. For instance, Stirling Range National Park in Australia contains a number of isolated mountain peaks which are biodiversity hotspots containing 1,517 plant species, some being endemics with narrow ecological ranges. The main threat to the alpine floral communities in this park is a plant disease caused by the introduced pathogen *Phytophthora cinnamomi*, also known as dieback disease. It appears that it is spread by transport of infected soil, mainly by foot access (Watson & Barret 2003).

Mittermeier *et al.* (2003) analysed 24 wilderness areas – each larger than one million hectares, more than 70% intact and with human densities of less than, or equal to, five people per km$^2$. All continents (except Antarctica) were included. Their analysis found IAS as a threat in 15 of the 24 wilderness areas, including areas in the tropical humid forests (2), tropical dry forests (2), temperate forests (5), wetlands (1), deserts (4) and tundra (1).

High latitude is no impediment to biological invasion either, as illustrated by the case of the Red King crab (*Paralithodes camtschaticus*), introduced from the North Pacific into the Soviet Barents Sea. After an initial lag period, this crab has rapidly expanded westward and northward into Norwegian waters, including North Cape. Its spread is continuing and some have predicted it may eventually
reach Svalbard. Here, management options are controversial, as some would like to see management focus on the species’ invasiveness while others want to focus on the species value for fishing (Jørgensen 2006).

In the Southern Ocean, biological invasions of mammals, invertebrates and plants, have been devastating on the subantarctic islands in spite of their remoteness (see e.g. Sanson & Dingwall 1995; Cooper 1995a, 1995b; Chapuis 1995; Cooper & Glass 2006; Clark & Dingwall 1985; Poncet 2006; Springer 2006; Torr 2002; Bonner 1984; Frenot et al. 2005).

FIGHTING BACK AGAINST INVASIVE ALIEN SPECIES

Prevention

Prevention is the first line of defence (see e.g. Wittenberg & Cock 2001). It is the most cost effective approach to protecting biodiversity and other values, and, in addition, it is a sine qua non of future proofing them, especially in the face of global change. Pathogens may be transferred by tourists in clothing or on boots, seeds of invasive plants may be brought on construction equipment, animals may be “hitchhiking” in people’s belongings, vessels or vehicles. These pathways can be addressed through requirements such as boot cleaning, equipment cleaning, de-ratting certificates before allowing access to islands, etc. In Stirling Range National Park, prevention measures now include the provision of boot-cleaning stations.
designed to reduce the spread of the pathogen via trampers (Watson & Barret 2003).

**Early Detection and Rapid Response**

The second line of defence, and high priority, is the early detection of an introduced, potential IAS, allowing for rapid response (e.g. eradication before numbers have become too big, or the area of spread too vast). That way, even if a species has arrived and has survived there, it will not be able to become well established and spread. Any potential invasion can be "nipped in the bud" – avoiding impacts on biodiversity and livelihoods, and saving management resources. Many invasive species may be almost impossible to manage once they are well established, but they can be successfully eradicated at this early stage. Figure 8 illustrates the exponential rise in costs for management of IAS plants, with time since establishment. While this particular graph referred to plant invasives in the New Zealand Conservation estate (Timmins 2002), the same principle applies more generally to taxa anywhere.

**Eradication**

Even if an IAS has established itself, eradication may still be possible, especially on islands where the bulk of successful eradication of introduced vertebrates has been carried out (see e.g. Clout & Russell 2006; Tershy *et al.* 2002; Genovesi 2005). Figure 9 illustrates the increasing size of islands from which Norway rats have been eradicated in New Zealand. Successful eradication, however, is not
Figure 7 Usual pattern of biological invasion.
Figure 8 Management costs as function of time since establishment of IAS plant. (Based on weed management in the New Zealand Conservation estate.) After Timmins 2002.
Figure 9 Increasing size of New Zealand Islands from which Norway rats (*Rattus norvegicus*) have been eradicated. The diamond symbol represents the recent eradication on Campbell Island (Clout & Veitch 2002).
Figure 10 Management options to address invasive alien species (IAS). ED = Early detection; RR = Rapid response.
limited to islands, vertebrates, or certain regions – many IAS, including plants (Mack & Lonsdale 2002; Rejmánek & Pitcairn 2002), insects (Genovesi 2005) and marine species (Bax et al. 2002) have been eradicated worldwide.

A topic which merits greater attention when planning is that of ecosystem response to eradication of well established populations of IAS. This can be very complex, especially where sites are affected by multiple invaders. Moreover, there may be unexpected (and sometimes unwanted) consequences of eradications, such as the ecological release of invasive plants when an introduced herbivore is removed, or irruptions of prey species after the removal of a predator. Addressing such effects needs to be included in planning and implementing eradications (Zavaleta et al. 2001; Zavaleta 2002). Another challenge with eradications of established populations is that they can require a significant amount of resources – the 11 year programme to successfully eradicate coypu (*Myocastor coypus*) from East Anglia (UK), for instance, cost as much as five million Euro (Baker 2006).

Nevertheless, where eradication is methodologically feasible and desirable from the ecological point of view (because it will result in biodiversity gains), it should be seriously considered, as the financial and environmental costs will usually be even larger if ongoing control rather than eradication is used (Genovese 2005), or if no management action is taken. Commitment of resources, as well as political and public support need to be assured, because without them failure is very likely (Genovesi 2005; Genovesi & Bertolino 2001; Veitch & Clout
2002). In many circumstances, especially where large areas and invasive plants are the issue, eradication will not be possible, and control will need to be considered instead.

Eradication should never be carried out for the sake of it, but always in order to obtain specific biodiversity or livelihood gains. The positive consequences for native biodiversity, and ecosystem restoration successes resulting from eradictions of invasive species are increasingly well documented (Genovesi 2005; Lorvelec & Pascal 2005; Veitch & Clout 2002; Scalera & Zaghi 2004). Two subantarctic examples are presented in Box 2.

Box 2 Positive biodiversity outcomes from eradication

Subantarctic Case Study One. The rarest duck in the world, the Campbell Island teal (Anas nesiotis) has been classified as critically endangered, and it was almost driven to extinction following the accidental introduction of Norway rats (Rattus norvegicus) to these New Zealand subantarctic islands. In 2001, the New Zealand Department of Conservation successfully coordinated the eradication which cleared the 11,300 hectare island of R. norvegicus. Once the island was rat free, birds were returned from a captive breeding site and it is expected that the Campbell Island teal should spread to occupy its entire former range on the island. Further benefits of the rat eradication project are demonstrated by the recent return of 30 individuals of the Campbell Island snipe (Coenocorypha aucklandica. norv. sp), also endemic to the region. The snipe once lived on Campbell Island, but had recently been restricted to a neighbouring small offshore island.

Subantarctic Case Study Two. The eradication of R. norvegicus, from Grass Island in Stromness Bay off South Georgia, was declared a success in 2002. The first South Georgia pipit, one of the most southerly breeding passerines in the world, returned in 2003, followed by the nesting of a pair in 2005-06 (Poncet 2006).
Control

Where eradication is not feasible, long-term control or containment should be considered. Several strategies for control exist, including the use of biological control agents and integrated pest management (Wittenberg & Cock 2001), and for weeds (IAS that are plants) manual eradication, mechanised removal, use of fire and herbicides. No single method is perfect and each case needs careful planning. As with eradication, the desired outcome of control should be to achieve gains for native biodiversity and/or livelihoods. As with eradication, there needs to be both management and political commitment to spend the resources required over the long term (McNeely et al. 2001). The benefits for biodiversity and livelihoods can once again be demonstrated with a case study of an endangered bird – this one in the tropics. In 1989 the Kakerori or Rarotonga flycatcher (Pomarea dimidiata) was one of the world’s rarest birds (29 individuals). The Takitimu Conservation Area (Rarotonga, Cook Islands) was created and is now managed by traditional owners of the area. The ship rat (Rattus rattus) is controlled in the area, and, as a result, in 2002 more than 250 birds were alive and well and the area is now a flagship for income-generating activities such as ecotourism (UNDP 2002).

Progression of management options

IAS are a form of biological pollution. Unlike other pollution, however, they are not diluted with time but, on the contrary, expand in numbers, density and geographic spread – and often exponentially. While addressing established populations is often possible, it is never easy
or cheap. Control requires ongoing efforts and costs. Eradication is possible under certain conditions, but often not affordable or feasible. The key management approach is to apply prevention of new invasions: first by preventing new introductions of potential IAS, and second, by implementing early detection and rapid response as a second line of defence. The progression of management options (and increasing costs and difficulty) with time since introduction are illustrated in Figure 10.

**Prediction and precaution**

A match of climate and habitat may help in predicting invasiveness, but species are known to expand to other habitat types once outside their native range. For instance, while the colonisation probability for alien marine species in its new area is higher when salinity and temperature are similar to those in their native range, this does not mean that colonisation and harmfulness are ruled out if those variables in the “recipient” region do not match the “donor” region (Gollasch 2007). Moreover, non-native species, over time, may exhibit evolutionary adaptation to their new environment (Cox 2004; Phillips *et al.* 2006).

Characteristics of the species itself in its native range (including reproductive and dispersal mechanisms, tolerance to environmental factors, such as shade or salinity, life form or habit, such as climbing vine or an aquatic species, and adaptive mechanisms, such as the ability of a plant to fix nitrogen) are not accurate risk predictors for prevention although they are somewhat more useful for predicting rate
and extent of spread if prevention failed and the alien species is already established. For use in prediction of invasiveness, especially of a species not yet present, only one factor has a consistently high correlation with invasiveness: whether or not the species is invasive elsewhere (Wittenberg & Cock 2001).

The uncertainty surrounding the prediction of invasiveness is compounded by the ecological complexity of biodiversity impacts, which adds additional uncertainty on what the impacts may be to the uncertainty on whether impacts would be caused. This reinforces the need to apply the precautionary principle where any alien species must be considered "guilty until proven innocent". In other words, unless there is a reasonable likelihood that an introduction of a species in an alien ecosystem will be harmless, it should be treated as likely to be harmful (see Shine et al. 2000 and IUCN 2000 for more details).

**SIGNIFICANCE OF THE ALIEN SPECIES ISSUE FOR THE ANTARCTIC TREATY AREA**

How significant is the issue of alien species in the Antarctic Treaty area? This depends on the one hand on how likely alien species are likely to “arrive” in the Antarctic Treaty area and on the other hand whether it would matter if they did. In other words, the questions to be answered relate to vectors for human-mediated transport of living organisms (for details on vector science and integrated vector management see e.g. Carlton & Ruiz 2005) and to the likelihood of
organism survival and species developing invasiveness. The questions we will address here include: What are the vectors that can bring alien species into the Antarctic? Are there routes followed that connect the Antarctic recipient area with a donor area that is likely to contain species that will survive in the Antarctic? Is the “travel time” along these routes such that survival is likely? If alien organisms arrive in the Antarctic, are they likely to survive? If alien organisms survive in the Antarctic, would they be (or likely become) harmful to Antarctic environmental values?

**What are the vectors that can bring alien species into the Antarctic?**

For marine species, a range of vectors exist that can bring alien species into the Antarctic Treaty area. Vectors include hull fouling, ballast water and marine debris. In the case of the Antarctic, all of these vectors have been found to have potential to transport alien species to the Antarctic Treaty area, (Barnes 2002; Lewis et al. 2003, 2004) even though the relative contributions of each type may still be under discussion (Lewis et al. 2005). It needs to be noted that several different actors are associated with these including National Antarctic Programmes, tourist and fishing companies.

Ships also potentially carry many terrestrial alien organisms on board in containers as well as in the ship itself. Shipping, cargo operations, aircraft activities, fresh produce, hydroponic operations, and waste management practices are all potential pathways for transporting alien terrestrial organisms. Antarctic visitors themselves have been found to
carry propagules with them in clothing, luggage and scientific or other personal equipment. Human contact with wildlife can also transfer organisms (see e.g. Potter 2006; Fortune 2006; New Zealand 2007; Hughes 2006).

Invertebrate as well as vertebrate animals, plants or plant seeds can be transported to the area south of 60°S (Potter 2006; Fortune 2006; New Zealand 2007; Smith 1996). In fact, Potter states, “the discovery of two cane toads (Bufo marinus) aboard a polar research and resupply vessel preparing to sail from Tasmania suggests that there are few import [sic.] scenarios that should be dismissed as inconceivable.”

Are there routes followed that connect the Antarctic recipient area with a donor area that is likely to provide species that will survive in the Antarctic? Is the travel time along these routes such that survival is likely?

Transport to the Antarctic is increasing, including an increase via fishing vessels, research vessels and tourist vessels that also spend time in the Arctic. Unintentional introductions of Arctic species would be expected to have higher chances of naturalising and potentially becoming invasive in Antarctic conditions (Gollasch 2007). Moreover, vessels may carry out stopovers in the subantarctic before entering the Antarctic Treaty area, and the potential to pick up organisms there must also be taken into consideration. This includes species native in the subantarctic, as well as species that are alien in the subantarctic and survived there, and possibly even adapted already to harsher conditions than in their native range.
The use of equipment in bipolar research programmes, and the use of airplanes in the Arctic as well as the Antarctic, also creates additional routes connecting Arctic species with the Antarctic region. Importantly, air transport significantly reduces travel times and, as such, increases the chances that an associated organism is in relatively good condition upon arrival in the Antarctic region.

**Are alien species able to survive in the Antarctic Treaty area?**

There are by now many examples of alien species that have survived inside station buildings, such as in the soil of greenhouses and in hydroponic systems (Smith 1996). Much more relevant, however, there are several examples of individuals of alien species occurring outside of stations in the Antarctic environment and surviving. Experimental introductions or “transplant experiments” resulted in many instances where plants survived one or more winters at Antarctic localities (Smith 1996). Unintentional introductions of plants have also resulted in survival over one or more winters. These include *Poa trivialis* which has survived in Antarctic soils near Syowa Station (Japan 1996) and *Poa annua* which has survived over a decade in Antarctic soils and has increased in density around Arctowski Station (Olech 1996). *P. annua* as well as *P. spreepratensis* were recorded from several sites in the Antarctic Treaty area in the 1940s, 50s and 60s (Smith 1996), while grasses and other vascular plants of northern hemisphere origin have been observed recently in (and removed from) the Larseman Hills (Australia 1995; Potter 2006). Several invertebrate alien species, including earthworms, mites, fly larvae and adult moths were found in soils that had been discarded in the Schirmacher Oasis.
(Lewis Smith pers. comm.). In the marine environment, there has been a record of the North Atlantic spider crab (*Hyas araneus*) in samples taken from the northern Antarctic Peninsula region (Tavares & De Melo 2004).

**Would alien species be harmful to Antarctic environmental values?**

The Antarctic itself has so far escaped the ravages of biological invasion that have impacted on biodiversity elsewhere in the world. On the marine side, however, a high proportion of alien marine species that are associated with hull fouling of vessels departing to Antarctica from ports of call outside the Antarctic such as Hobart have become invasive in other parts of the world (Lewis *et al.* 2003), and have thereby shown that they definitely have the capacity to develop invasiveness. As far as terrestrial species go, organisms of many alien taxa have already been found surviving in the Antarctic, and increasing travel and transport of goods together with shorter transport times and increasing direct links between Arctic and subantarctic locations and Antarctica increase the likelihood of invasiveness being developed by at least some alien species in future. Future changes in the climate are likely to exacerbate such risk.

In the context of the Antarctic, it must be noted that alien species that are not impacting native biodiversity and hence are not, strictly speaking, “invasive alien species” according to the IUCN definition, nevertheless are a threat to Antarctic values including wilderness value, existence value, and science value. IUCN has argued that the threshold at which action must be taken against alien species in the
Antarctic should be lower than elsewhere in the world in order to reflect the full range of Antarctic values (IUCN 2005).

**ANTARCTIC TREATY CONSULTATIVE MEETINGS RESPONSE**

The Antarctic Treaty System recognised the importance of non-native species as early as 1964 in the Agreed Measures for the Conservation of Antarctic Fauna and Flora (Agreed Measures) and the Protocol on Environmental Protection to the Antarctic Treaty 1991 (Protocol) maintained those provisions (see Mansfield & Gilbert in this volume for fuller discussion). These focus on regulating the intentional introductions of non-native species and do not explicitly state the need to address the issue of unintentional introductions, although it can be inferred from a number of provisions such as those relating to the importation of un-sterilised soil. IUCN has included the issue of potential threats caused by alien species in the Antarctic Treaty area, and the need to develop further management to address it, in its contributions to the Antarctic Treaty Consultative Meetings (ATCMs) since 1998 (IUCN 1998, 2005, 2006, 2007). With growing understanding of the potential threats by alien species to biodiversity in general, the Committee of Environmental Protection (CEP) has now given high priority to this issue.

Specific challenges in dealing with alien species in the Antarctic context will include:

- All taxa, all vectors, and all actors need to be included in measures to address the issue. This means that not only the
CEP and ATCM but also the Convention on the Conservation of Antarctic Marine Living Resources 1980 (CCAMLR) will also need to recognise the importance of addressing this issue.

- Awareness and understanding of the processes of biological invasion and of the need to be precautionary are not equally well understood yet by all Treaty parties, and especially other actors, such as fishing interests may still lag behind in understanding of the issue and acceptance of the need to act in a precautionary way.

- In addition to addressing introductions of alien species into the Antarctic Treaty area, it is also necessary to deal with introductions within the Antarctic itself (e.g. from one location to another). The Antarctic can also be a donor region for introductions into other parts of the world, and this needs to be addressed.

- Awareness of the issue, and of the need to take certain measures, needs to be widespread – effective implementation can only happen if not only decision makers, but also all personnel, understand what is required and why.

CONCLUSIONS

While many of the movements of species into new ecosystems do not result in ecological damage, biological invasions are now nevertheless considered one of the main factors in biodiversity loss and endangered species listings worldwide. Invasive alien species are found in all
taxonomic groups and they have invaded and affected virtually every ecosystem type in almost every region of the world to some extent. Remote, undisturbed, or very cold areas do not provide immunity to the threat of biological invasion. While no alien species has become invasive yet in the Antarctic Treaty area, alien organisms have regularly arrived and survived there, and increasing transport and travel, coupled with global climate change will increase the chances for invasiveness, even in the Antarctic. The ATS is in the unique position of being able to take proactive measures and to learn from the biological invasion disasters that have happened elsewhere in the world. The main lessons learned elsewhere are first that prevention is the key management option, followed by early detection and rapid response; and second, that with regards to the risk of invasiveness, any alien species must be considered "guilty until proven innocent".

**APPENDIX A: GLOSSARY**

Terminology relating to invasive alien species (IAS) has developed independently in different sectors such as agriculture, health, and conservation, and in the key international instruments that address them, reflecting their different mandates. This glossary explains the terminology used (in the invasive alien species context and/or in the protected areas context) in this publication.

**Invasive alien species (IAS):** in the context of the Convention on Biological Diversity (CBD), invasive alien species means an "alien species whose introduction and/or spread threaten biological diversity", whereas IUCN defines them as: “an alien species which
becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity”. For operational reasons, conservation managers and practitioners will often express invasiveness in terms of impacts caused, in the case on animal IAS, and in terms of establishment, spread and (sometimes) abundance for IAS that are plants.

**Alien species:** a species, subspecies or lower taxon, *introduced* outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce (CBD 2002). Synonym to “non-native species” which is the terminology used in the Antarctic Treaty System.

**Control:** a specific type of *IAS management*, reducing the density or distribution (or both) of an IAS population to below a pre-set acceptable threshold.

**Early detection:** a specific type of *IAS management*, using surveys, fortuitous detection etc., to find and identify known or potential future invasive alien species as early as possible; the aim is to allow for *rapid response*.

**Eradication:** a specific type of *IAS management*, namely the extirpation of the entire population of an alien species in a managed area, eliminating the IAS completely.

**Establishment:** the process of a species in a new habitat successfully reproducing at a level sufficient to ensure continued survival without infusion of new genetic material from outside the system.

**Introduction:** the movement, by human agency, of a species, subspecies or lower taxon outside its natural range (past or present). The CBD and IUCN use similar concepts (CBD 2002, IUCN 2000) This movement can be either within a country from a location where the species is native to a location within the same country where it is not native, or the movement can be between countries (or even continents).

**Management (of IAS):** includes prevention, early detection, rapid response, eradication, control and mitigation.
**Prevention**: particular type of *IAS management*. It refers to the keeping IAS out of particular sites (or out of specific locations within a site), at country level, keeping IAS out of a country (e.g. through import restrictions, border control etc). Prevention includes: 1) the prevention of intentional *introductions* of any alien species unless they have been determined to be acceptable (e.g. through *risk assessment*), and 2) the minimisation of unintentional *introductions* of alien species (See IUCN 2000; Shine *et al.* 2001)

**Rapid response**: a particular type of *IAS management*, consisting of a systematic effort to *eradicate*, or *control* invasive or potentially invasive alien species at an early stage, before they are *established* and/or widely spread.

**Risk assessment**: evaluation of the likelihood of invasiveness for an alien species, including an estimate of the nature and magnitude of potential impacts, and a judgement of their significance. Note: the aim of such assessment is not to produce an ecological model, but simply to support management decisions.

**Threat**: we consider an invasive alien species as a threat either when an impact has been identified or otherwise observed, or when a relevant risk has been determined through risk assessment; Future threats result from species already present that, while not invasive yet, will likely become so in future; future threats also result from risk-species not present yet but likely to be introduced in future.

**APPENDIX B: ISSG INFORMATION**

The Invasive Species Specialist Group (ISSG) is a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN). The goals of ISSG are to reduce threats to natural ecosystems and the native species they contain by increasing awareness of alien invasions and of ways to prevent, control or eradicate them.
The IUCN “Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive species” can be accessed on line

Objectives of these guidelines include:

- to increase awareness of alien invasive species as a major issue affecting native biodiversity in all regions of the world.
- to encourage prevention of alien invasive species introductions as a priority issue requiring national and international action.
- to minimise the number of unintentional introductions of alien species
- to prevent unauthorised introductions of alien species.
- to encourage the development and implementation of management action to address alien species that naturalised (and/or established and/or spread) and that have detrimental environmental effects

The Global Invasive Species Database (GISD) (www.issg.org/database) is a free, online public resource of authoritative information about Invasive Alien Species (IAS). The GISD aims to increase public awareness about invasives and to facilitate effective prevention and management activities by disseminating specialist’s knowledge and experience globally. It receives 75,000 hits (1100 unique visitors) per day. At this point in time it contains information on the ecology, impacts, distribution and pathways of more than 430 IAS, along with the contact details of experts that can offer further advice, and most importantly, information on prevention and management options. Location-specific records for the subantarctic are already included to some extent and can be searched.

**Aliens-L Listserver:** IUCN administers the globally active Aliens-L list server. Listservers offer an important contribution to empowerment and "horizontal" information transfer (practitioners helping each other). Moreover, they have great flexibility and are able to deal quickly with time-critical issues.

**Aliens Newsletter:** bi-annual newsletter of the Invasive Species Specialist Group. Its role is to put researchers, managers and/or practitioners in contact with each other and to publish information and news of invasive alien species and issues. Contributions focus on
conservation and livelihood issues rather than economic, health or agricultural aspects of alien invasions.

**The Global Register of Invasive Species (GRIS)** aims to identify all invasive species that negatively impact biodiversity by accessing and analysing checklists generated by national and regional collection an observation databanks around the world, as well as information not formally published elsewhere. Access to the original source of information, along with metadata will be provided. A prototype version has been developed and presented in July 2007.

**Global Invasive Species Information Network (GISIN):** The development of GISIN will provide a platform through which IAS information from hundreds of databases and web sites can be accessed ([http://invasivespecies.nbii.gov/gisin.html](http://invasivespecies.nbii.gov/gisin.html)). Tools being developed for GISIN include a model invasive species database that will be offered at no cost to users. ISSG’s contributions to development of the GISIN, such the IAS profile schema currently being developed, are based on expertise gained in the development of the Global Invasive Species Database. This ensures future compatibility of all GISD records with GISIN.

For further information, see www.issg.org or contact: issg@auckland.ac.nz

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ANTARCTIC AND SUBANTARCTIC BIOLOGICAL INVASIONS:
SOURCES, EXTENTS, IMPACTS AND IMPLICATIONS

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ABSTRACT

This paper draws to a large extent on the recent benchmark review by Frenot et al. (2005) of the presence and status of non-indigenous (alien) species, carried out under the auspices of the RiSCC (Regional Sensitivity to Climate Change in Antarctica) programme of the Scientific Committee on Antarctic Research (SCAR). The aim of the review was to document the current state of knowledge on alien species in terrestrial, marine and freshwater ecosystems of continental Antarctica, and the subantarctic in terms of extent, impact and implications, and taking into account contemporary changes in climate

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and patterns of human activities in these regions. The present paper summarises this information, providing additional detail in several examples of alien establishment. We highlight the main conclusions of the review, with particular attention to possible management approaches required to minimise the risks and impacts of future introductions.

INTRODUCTION

Biological invasions are widely recognised as being one of the most significant threats to biodiversity (McKinney & Lockwood 1999; Sala et al. 2000; Courchamp et al. 2003). Their occurrence and impacts are expected to increase with two major contemporary processes affecting the planet at global scales – environmental change and the globalisation of human activities (Dukes & Mooney 1999; Hughes 2000; Smith et al. 2000; McKinney 2001; Prinzing et al. 2002; Walther et al. 2002; Frenot et al. 2005; Convey et al. 2006). Historically, Antarctica and the outlying subantarctic islands in the Southern Ocean have, until the last two hundred years, been immune from the pervasive ecosystem impacts that human activities have brought to all other continents, protected through geographical isolation and harsh environmental conditions. Despite this isolation, however, and since their discovery and the establishment of human contact, invasions have taken place. As elsewhere on the planet, some have already had considerable impacts on the indigenous biota of the Antarctic region which, through high levels of endemism, is of considerable global conservation significance. Furthermore, contemporary rapid climate
change in parts of the Antarctic region, especially when combined with large increases in human activity, will increase both the opportunities for new biological introductions to occur, and subsequently, the likelihood of newly established alien species then becoming invasive (Greenslade 1987; Frenot et al. 1997; Chown et al. 1998; Bergstrom & Chown 1999; Chown & Gaston 2000; Convey 2001a; Convey et al. 2006).

In this paper we use the term “Antarctic” to include the main continental landmass, the Antarctic Peninsula and associated archipelagos (South Shetland, South Orkney, South Sandwich Islands), and the isolated Southern Ocean subantarctic islands that lie near to the Polar Frontal Zone. This approach is rationalised and justified through the following reasoning. First, there are strong biological connections between Antarctic and subantarctic ecosystems, both in terms of long-term biogeographical relationships and direct biological interdependence (Chown et al. 1998; Greve et al. 2005). For instance, recent studies on the feeding habits of Southern elephant seals (*Mirounga leonina*) from Îles Kerguelen (Kerguelen Islands) have demonstrated that these animals make a journey of more than 2000 km in March in order to reach the Antarctic coastline where they remain for up to two months before returning to Kerguelen in June (Bailleul et al. 2007). Second, the same human agencies (government and scientific national operators, cruise and airplane operators) are generally responsible for logistic, scientific or tourism programmes across these regions. In practical terms, the same vessels are used throughout each operator’s area of operations, thereby providing opportunity to act as vectors for the movement of
biota (Lee & Chown 2007). Finally, the existing status and impact of alien species on the subantarctic islands may in effect provide a model or "early warning system" for the risks and changes likely to challenge Antarctic continental ecosystems, especially under current scenarios of climate change and changing human activity patterns.

ANTARCTIC ECOLOGICAL CONTEXT

In order to understand how alien species may constitute a serious threat to the Antarctic, it is appropriate to reiterate some of the general characteristics of the continent’s ecosystems. Antarctic ecosystems are characterized by strong geographical and historical isolation. Although varying widely across the continental scale in terms of the intensity and variability of environmental stresses experienced (Peck et al. 2006), it is clear that climatic constraints are fundamental in the biology of these ecosystems which, at the extreme, include habitats at the limit for life on the planet. By contrast with Antarctic marine (particularly benthic) ecosystems where biodiversity and biomass are relatively high (Clarke & Johnston 2003; Peck et al. 2006), diversity is extremely low in terrestrial ecosystems (Convey, 2001b), although in both, levels of endemism are high (Clarke & Johnston 2003; Chown & Convey 2006, 2007). Antarctic terrestrial ecosystems are also much simplified in comparison with those of lower latitudes, typically lacking representatives of many higher taxonomic and ecological functional groups (Block 1984; Convey 1996, 2007). In particular, there are no indigenous terrestrial mammals, reptiles or amphibians (and very few non-marine birds), or fish. Within the invertebrates, communities are
dominated by decomposers, true herbivores are unusual and indigenous predators virtually absent.

These characteristics, in combination with the recent history of human contact with the Antarctic, underlie the particular sensitivity of these ecosystems to processes of contemporary environmental change. The history of human contact can be separated into three phases (see Hull & Bergstrom 2006). Following initial discovery (commencing with the subantarctic islands in the late 17th century) and until the mid 20th century, human activity on the subantarctic islands and to a more limited extent the maritime Antarctic archipelagos, took the form of the land-based elements of sealing and whaling industries, and attempts to establish farming industries on some of the less extreme islands. This phase of contact saw the deliberate and accidental introduction of vertebrates (both herbivores and predators) to most subantarctic islands, along with the introduction of some of the more invasive flowering plants and most likely some invertebrates. The late 19th century saw the beginning of the “Heroic Era” and scientific exploration of the Antarctic continent, with 11 of the historic huts from this phase still remaining (Hull & Bergstrom 2006). This was followed by the last and continuing phase which commenced in the mid 20th century, with the International Geophysical Year (1957/58) and the signing of the Antarctic Treaty 1959. These events formed the catalysts for the initiation of intense scientific research activities on the Antarctic continent and some subantarctic islands which continue to this day. This phase saw the establishment of many permanent research stations, and also coincided with the effective end of the remaining onshore activities associated with the whaling industry. With the
exception of limited “scientific” whaling, there is no longer a pelagic whaling industry in the Southern Ocean. This region, however, still represents a fisheries resource within the global economy and, although the vessels involved have limited direct contact with land in the Antarctic and subantarctic, there remains both a risk of inadvertent introduction of alien biota through events such as shipwreck (as recently demonstrated on South Georgia) (Frenot et al. 2005), a risk of pollution through deposition of dispersal of marine debris into the littoral and nearby terrestrial environment (Gregory & Ryan 1997; Convey et al. 2002), and direct impacts (bycatch, fouling) to marine mammal and bird populations that come ashore to reproduce and moult, and contribute considerable nutrients into terrestrial ecosystems. The last three decades (since the early 1980s) has seen the rapid development of a further form of human contact with the Antarctic, through the tourism industry (Navareen et al. 2001). In numerical terms, this industry focuses its activities mainly around locations most rapidly or conveniently accessible to cruise vessels, in particular around the northern Antarctic Peninsula and Scotia Arc archipelagos, and the subantarctic island of South Georgia. Lower levels of tourism activity are also experienced by some other subantarctic islands, the historic sites associated with the early continental exploring expeditions in the Ross Sea region, and with the use of air support for visitors to explore the inland Ellsworth Mountains and to reach the South Pole. These changing patterns of human contact are inevitably likely to have influenced the flux of biological propagules reaching the region.
DEFINITIONS

Various terminology has been applied to invasive ecology (e.g. Richardson et al. 2000; Davis & Thompson 2000; Daehler 2001). Frenot et al. (2005) adopted the following definitions based on Greene (1964), Walton & Smith (1973) and Richardson et al. (2000) which are also used in the present paper:

*Alien (or non-native):* introduced to an ecosystem as a result of human activity. Includes species that arrive by natural means to a specific ecosystem but are alien to that biogeographical zone;

*Transient alien:* survive in small populations for a short time period but either die out naturally, or are removed by human intervention;

*Persistent alien:* survive, establish and reproduce for many years in a restricted locality, but do not expand in range from that location;

*Invasive alien:* spread into indigenous communities and displace indigenous species.

CURRENT KNOWLEDGE OF ALIEN SPECIES IN ANTARCTICA AND THE SUBANTARCTIC

Plants

The diversity of alien vascular plant species varies from 69 species at Kerguelen, to zero to two species in maritime Antarctic and one species on continental Antarctica (Frenot et al. 2005; Convey 2007).
On subantarctic islands including South Georgia, Marion Island and Îles Kerguelen and Crozet, there are now more alien than indigenous vascular plant species recorded in the contemporary biota. Examples from maritime and continental Antarctic (Poa pratensis, P. annua, P. trivialis) are currently of persistent alien status (Japan 1996; Olech 1996; Smith 1996), although there is some recent anecdotal evidence to suggest that P. annua has started to spread more rapidly around its core population close to Arctowski Station on King George Island (South Shetland Islands). By contrast, there are examples of plant species of all alien classes on several different subantarctic islands.

Most alien plant species in the subantarctic belong to four families (Poaceae, Asteraceae, Brassicaceae, Juncaceae), and six species are particularly widespread (Poa annua, Poa pratensis, Cerastium fontanum, Rumex acetosella, Stellaria media, Sagina procumbens). Most persistent or invasive alien species are long-lived, with about 75% being perennial. Even P. annua, a species characteristically with an annual life cycle at lower latitudes, tends to adopt a multi-year life cycle at Antarctic locations (Frenot et al. 2001), and such flexibility may underlie its success as an invasive. By contrast, about 65% of transient alien plant species recorded from Îles Kerguelen and Possession (Crozet archipelago) (species defined as those whose presence is cited in the literature but that were not observed during detailed survey work between 1996 and 2000) are annual or biennial (Frenot et al. 2001). It would appear that an (obligate) annual life cycle is not appropriate for species in these ecosystems (see Convey 1996), and that colonization or establishment abilities relevant to the sub-
antarctic environment may be better developed in alien perennial species.

A strong relationship between the establishment of alien species and human occupancy and activities has been clearly demonstrated (Chown et al. 1998, 2005; Frenot et al. 2001). On Crozet and Kerguelen (Frenot et al. 2001), early introductions are likely to have been associated with the activities of sealers and whalers, although scientific expeditions at the end of the 19th century recorded the presence of few alien species (Figure 1). Their species number drastically increased during the 1950s at Kerguelen and the 1960s at Crozet, corresponding with the timing of establishment of permanent stations. These data give no evidence of a decrease in this rate of introduction today. On Possession, all known alien species are present in the immediate vicinity of the island’s research station, while only seven species have yet spread away from this location. The rapid increase in distribution of one of the latter since the 1980s (when it was limited to the station area and the immediate vicinity of certain field huts), Sagina procumbens, is illustrated in Figure 2, and indicates that this species has now become an invasive alien on this island. The pattern of expansion after the species switched to invasive status continues to indicate the important contribution of human activity in its dispersal, with the new and expanded distribution records radiating out from the island’s tracks that are the major routes of human overland movement (M. Lebouvier et al. unpubl. data).
Figure 1 Changes in the number of alien vascular plant species at Ile de la Possession (Crozet archipelago, solid line) and Kerguelen archipelago (dotted line). Arrows indicate the date of establishment of permanent stations, Alfred Faure station on Ile de la Possession, Port-aux-Français on Iles Kerguelen. Modified from Frenot et al. (2001).
Figure 2 Changes in the distribution pattern of *Sagina procumbens* on Possession Island, Crozet archipelago, between 1989 and 2002. Solid lines inland indicate the tracks used by the walkers (scientists and logisticians) to reach the field huts from the permanent station Alfred Faure. Lebouvier and coll., unpubl. data.
A number of alien plant species were historically deliberately introduced to some subantarctic islands. For example, Bourzat & Monie (1977) reported that *Elymus repens, Dactylis glomerata, Festuca ovina, F. arundinacea, Lolium perenne, Poa pratensis* and *Phleum pratense* seeds had been sown in the 1970s at Îles Kerguelen on the islands where sheep were introduced (Île Longue, Île du Château). With changing attitudes to human environmental impact, we can assume that such deliberate introductions will not take place in future. By contrast, accidental introduction of plants continues to be the norm. On Gough Island (a South Atlantic cold temperate oceanic island) and subantarctic Marion Island the relative contributions of natural colonization processes and anthropogenic introductions have been estimated, with the latter being over two orders of magnitude greater than the former over the periods since each island’s discovery (Gaston *et al.* 2003; Gremmen & Smith 2004). Whinam *et al.* (2005) demonstrated that a large proportion of cargo items transported from Hobart to Australian Antarctic stations hosted a range of biological propagules, including spiders, plant material and viable seed. An encouraging sign, however, was that the percentage of cargo items found to be contaminated decreased over their study period (2000 to 2002), indicating some efficacy of newly introduced mitigation methods including new cleaning procedures and changes in cargo container design.

Cultivation in glasshouses that are associated with some research stations also facilitates the introduction and establishment of new species, not least as greenhouses can serve as transit areas facilitating the acclimatization of alien species, plants or invertebrates
(Hullé et al. 2003). Such a route might also be expected to facilitate the introduction of microbes and viruses, including disease-causing organisms, although, to date, rigorous data on these groups are not available.

**Invertebrates**

The level of knowledge of invertebrate fauna varies much more widely between taxonomic groups and locations. In particular, the physically smaller invertebrate groups, and those that form part of the soil ecosystem, are generally poorly known. The largest numbers of alien invertebrates are recorded from Kerguelen (30) and Macquarie Islands (28) (Chown et al. 1998; Frenot et al. 2005; Greenslade 2006), but comparable detail is not available for most other islands. The few persistent alien invertebrates known from maritime Antarctic are described by Convey (2007). Dartnall (2005) mentioned transient alien rotifers at Casey. As with the flowering plants, most alien invertebrates belong to a limited number of higher taxonomic groups, in particular the Diptera, Hemiptera and Coleoptera. Many of the species concerned share the significant biological trait of parthenogenetic reproduction (which obviously reduces the barrier to establishment as, in theory, arrival of a single viable individual is sufficient), and the two most widely distributed alien insects in the subantarctic (*Psychoda parthenogenetica* - Diptera, Psychodidae and *Rhopalosiphum padi* - Hemiptera, Aphididae) possess this characteristic.

There are few well-documented examples of invertebrate introductions (but see Slabber & Chown 2002; Lee et al. 2007). The case of
*Oopterus soledadinus* (Coleoptera, Carabidae) is important in a number of respects. It provides one of the few examples of establishment of a non-European alien species in the subantarctic region, being accidentally transported from the Falkland Islands or southern South America to both South Georgia and Kerguelen. At the latter, it was most likely introduced in the early 20th century with sheep and forage exported from the Falkland Islands as part of an attempt to establish farming, and its introduction took place in a single site, Port Couvreux (Jeannel 1940; Chevrier *et al.* 1997). The introduction on South Georgia is thought to have been more recent (the species was first recorded in 1963), and possibly happened on at least two separate occasions, as the species is known from two distinct locations while a separate closely related alien carabid (*Trechisibus antarcticus*) is only known from one (Darlington 1970; Ernsting 1993).

On Kerguelen, *O. soledadinus* is spreading both naturally and through human help, while *T. antarcticus* was also documented to be spreading rapidly on South Georgia during the 1990s (Ernsting *et al.* 1995). Unfortunately, more recent survey data are unavailable from this island. Both *O. soledadinus* and *T. antarcticus* are voracious predators of small insects and other invertebrates, and their arrival on these two subantarctic islands has deeply modified the food web equilibrium, in which no other comparable indigenous predators exist. After only a few years of the presence of *O. soledadinus* at a specific location at Kerguelen, almost all other large invertebrates are found to become locally extinct, including the endemic flightless dipteran *Anatalanta aptera*, a species that plays a major role in organic matter decomposition (M. Lebouvier *et al.*, unpubl. data). On South Georgia, *T. antarcticus* is similarly responsible for significant reductions in
populations of endemic herbivorous beetles and has also been implicated in a selective alteration of life cycle characteristics in these preys (Ernsting et al. 1999; Convey et al. 2006). Furthermore, on both islands, current climate warming trends might be expected to increase the rate of dispersal of both species, as well as the area of habitat environmentally suitable for their occupation, and hence their negative impact on the local fauna.

Prediction of changes in Antarctic terrestrial biodiversity is obviously a challenge for future decades. Here, the risk assessment approach developed by Greenslade (2002) for Collembola on Heard Island, one of the subantarctic islands to date least impacted by alien species, may be useful. Greenslade examined several criteria in order to determine the risk of introduction of several springtails as possible candidates for establishment in this island. These criteria included:

1. The origin of the species, its current distribution (including on other subantarctic islands);
2. Life history characteristics, in particular the mode of reproduction (parthenogenetic or sexual), length of life cycle, and feeding habits;
3. Habitat requirements and ecological plasticity;
4. Preferred climate range or envelope; and
5. Possession of appropriate dispersal mechanisms or opportunities, including human intervention (packing materials, plants, soil or food).
Greenslade (2002) concluded that the highest risk relates to species in the family Hypogastruridae, in particular *Hypogastrura viatica*. Several species in this family are known to be successful invasive species on a global scale, including two (*H. viatica* and *H. purpurescens*) that have already been introduced to some subantarctic islands. *H. viatica* has also been recorded at some maritime Antarctic locations, although it is not clear whether it has become established at these (Greenslade 1995; Frenot *et al.* 2005). As mitigation measures (removal) of such species after establishment is likely to be difficult if not impossible (not least as establishment is unlikely to be noticed at an early enough stage before significant spread occurs), Greenslade suggested that practicable measures would need to take the form of quarantine controls such as various types of inspection, washing procedures and/or fumigation.

**Vertebrates**

Alien terrestrial and freshwater vertebrates are restricted to the subantarctic islands (Frenot *et al.* 2005). The greatest diversity is present on the Kerguelen archipelago, with 12 alien species. Some were introduced deliberately (sheep, mouflon, rabbit, cat, reindeer, salmonid fishes) and others accidentally (mouse, rat), while some have reached the islands through natural movement from alien populations on other southern hemisphere landmasses (birds, largely affecting Macquarie Island). The domestic cat, the only terrestrial vertebrate predator present on the subantarctic islands to which it has been introduced, has had considerable impacts, including drastic reductions and local extinctions of some seabird populations. The most widespread alien
vertebrate, the house mouse, present on five subantarctic islands, has a considerable and negative impact on indigenous insect fauna, and has even been observed predating on albatross chicks. Ship and brown rats, occurring on four islands, have wider impacts, affecting vegetation, invertebrates and birds. Of grazing mammals, the rabbit is responsible for drastic changes (loss of biomass and diversity) in the plant communities of some islands, while reindeer on South Georgia and Kerguelen have led to overgrazing and soil erosion, and also encouraged the spread of the alien invasive grass *Poa annua*. Mammals, being more easily visible, are obvious targets for eradication, and several such campaigns have been attempted (rabbits from Macquarie Island – Copson & Whinam 2001 – and from some small islands at Kerguelen – Chapuis *et al.* 2001; cats from Marion Island – Bloomer & Bester 1992), but some of these attempts themselves produced undesirable or unexpected effects. For instance, at Kerguelen eradication of rabbits from some small islands was seen to induce an increase in the abundance of alien plant species including *Taraxacum officinale*, a species whose spread was previously regulated by the herbivores. In the absence of this grazing, and now being further assisted by current climatic trends, this alien plant can now become dominant (Chapuis *et al.* 2004).

Macquarie Island currently is seeing a dramatic expansion of rabbit numbers and associated negative impacts on the ecosystem, with coastal slopes particularly being devastated, contributing to soil erosion and landslips. One such landslip has killed penguins in a colony below the slope. Three factors are thought to be interacting, resulting in an increase in rabbit numbers: one, the removal of feral
cats; two, built-up resistance to *Myxoma* virus with subsequent stopping of *Myxoma* virus use; and finally climate change resulting in increased rabbit winter survival and fecundity (Springer 2006).

**Microbes and diseases**

Very little is known about levels of diversity or endemicity in the various microbial groups present in the Antarctic, or of the presence or population trends of alien species (Convey 2007), and there have been few attempts to either quantify or minimise introduction risks, or to assess any impacts on indigenous microbial flora or other biota. There are several known examples of introduced fungi infecting indigenous plants on the subantarctic islands. For example, stands of the Kerguelen cabbage (*Pringlea antiscorbutica*) infected by *Albugo candida*, a fungus species probably transferred from fresh vegetables, has been noted on Kerguelen (Lebouvier & Frenot, unpubl. data).

One specific and high profile exception relates to plans to drill into Antarctic subglacial lakes such as Lake Vostok, where the danger of inadvertent introduction of microbes, and the various chemical components of drilling fluids, to an otherwise pristine environment has been clearly recognised (Gavaghan 2002). The Committee for Environmental Protection (CEP) of the Antarctic Treaty expressed concerns in 2003 over the continuation of drilling towards the lake ice boundary (CEP 2003) in the absence of appropriate clean technology, and concerns remain today.
Potential interactions between indigenous microorganisms and alien organisms are noteworthy. The recently identified Stilbocarpa Bacilliform Mosaic Virus (SBMV), a badnavirus causing bright yellow mosaic symptoms on leaves of the subantarctic megaherb *Stilbocarpa polaris* is recorded only from Macquarie Island, where it is widespread (Skotnicki et al. 2003). Badnaviruses are most often found associated with tropical and subtropical plants and are usually transmitted between plants by sucking insects. On Macquarie Island, it appears that the virus has been present for a very long time in *Stilbocarpa*, with an unknown indigenous transfer agent. It is likely that transfer between plants could now be undertaken by alien species of aphids.

Finally, human activity across the Antarctic has been identified as a potential source of disease in wildlife, primarily through the translocation of pathogens. There are several examples of evidence that Antarctic and subantarctic marine vertebrates have been exposed to some widespread disease organisms. These include Avian Paramyxoviruses (APMV) and antibodies to Newcastle Disease (NDV) reported from Macquarie Island Royal penguins (Morgan & Westbury 1981); five species of *Salmonella* isolated from continental Antarctic Adélie penguins (Morgan et al. 1978); antibodies to Lyme disease being found in King penguins; and the Lyme disease spirochete in the cosmopolitan tick, *Ixodes uriae* (Gauthier-Clerc et al. 1999). Such evidence does not, however, prove unequivocally that exposure has taken place in the Antarctic or that it is underlain by human activity, as other routes of infection certainly exist and may also be more plausible.
Marine introductions

There are very few records of alien species in the Antarctic marine environment. A recent report of a North Atlantic majid spider crab, *Hyas araneus* from the northern Antarctic Peninsula (Tavares & De Melo 2004), has received some publicity as being the first record of a benthic invasive species in this region, and it is certainly plausible that this species may have arrived in the Antarctic region via ships’ sea chests or ballast water. Other than the initial report, however, there have been no other records of this species either in the vicinity of the original trawl area or elsewhere, hence its true status in the region cannot be assessed. Lewis *et al.* (2006) documented the potential for introduction of marine organisms into subantarctic waters through data obtained from a barge used for ship-to-shore transfers at Macquarie Island (the presence of the fouling community was fortuitously detected en route from Tasmania to Macquarie Island, hence measures could be applied to ensure that no transfer took place on arrival). The fouling community included a total of 20 Tasmanian estuarine species, amongst which one invasive amphipod species, *Monocorophium acherusicum*, was very abundant – over 136,000 individuals including ovigerous females were calculated to be present. Although no transfer of alien species to Macquarie Island water took place on this occasion, this study demonstrated the ability of elements of the fouling community to survive on the barge on the ship’s deck over several months. More recently, sea chests of the supply ship SA *Agulhas* have been shown to house invasive Mediterranean mussels
(Mytilus galloprovincialis), that clearly survived repeated voyages to the Antarctic and subantarctic islands (Lee et al. 2007).

ORIGINS AND CORRELATES OF INVASION

Many alien species now present in the Antarctic are of European origin, although many are now effectively cosmopolitan and globally distributed having successfully invaded other temperate areas (e.g. Pyšek 1998; Prinzing et al. 2002). These species are often opportunistic “weeds”, and typically possess a large ecological range. The European influence is in part a reflection that the early exploration, colonization and exploitation activities of humans in the Antarctic originated largely from European ports (Headland 1989). As noted in the above example of the South American carabid beetle Oopterus soledadinus, exceptions to the pattern of introductions from Europe do exist. Furthermore, on the site of the introduction of O. soledadinus to Kerguelen, the grass Trisetum spicatum, a bipolar plant species growing in the Falkland Islands, is also recorded (Frenot et al. 2001).

Effort has been devoted to quantitative studies of the correlates of invasion on some of the subantarctic islands. Many successful colonists possess life history features that assist them in overcoming the “colonization filter” imposed by the large geographical isolation of these islands from source populations, and the “environmental filter” relating to environmental conditions typically being harsher. These include such features as parthenogenetic reproduction (as described
above) (Crafford et al. 1986), the ability to complete life cycles over extended periods, and flexibility in expression of stress tolerance capabilities. These features are also typical of the “adversity selected” life history strategies of many indigenous Antarctic terrestrial biota (Convey 1996). Subantarctic island biodiversity (both indigenous and alien species) is driven by a range of island features frequently identified in studies of island biogeography (Williamson 1996; Chown et al. 1998), including size and altitudinal range of islands (i.e. habitat heterogeneity), level of human occupancy, climate and energy availability (Chown et al. 2005), and diversity of different biological groups. Common features of Antarctic and subantarctic terrestrial ecosystems are low species richness and functional redundancy (i.e. vacant niches), both of which may render the subantarctic islands, and the island-like exposed land of the Antarctic continent, susceptible to alien colonization and invasion (Bergstrom & Chown 1999; Chown et al. 2000; Convey 2007). In the context of alien biota, the overriding influences on levels of introduction appear to be human patterns of use and climate matching. Changes in these variables are, therefore, likely to have the largest impact on further establishment and subsequent impacts of alien species in the Antarctic (Chown & Language 1994; Kennedy 1995; Chown & Gaston 2000).
CHANGING PATTERNS OF USE

Tourism

The first tourists visited Antarctica in 1956, flying over the continent from Chile. Commercial tours commenced in 1958. Tourist numbers remained very low for the two subsequent decades, but since the 1980s, and particularly over the last decade, there has been a consistent and rapid increase in tourism (Figure 3). During the 2005/06 summer season, approximately 40,000 people, including all touristic activities and crew members, visited the Antarctic in this way, in comparison with approximately 4000 National Antarctic Programme staff. Information from the International Association of Antarctica Tour Operators (IAATO) indicates that, numerically, tourism is predominantly based around the Scotia Arc islands and the Antarctic Peninsula (involving up to 98% of visitors), with a much smaller industry visiting the historic sites of the Ross Sea region, and the New Zealand shelf islands (which some authors include in a wider definition of the subantarctic islands). The most typical format of tourist visits are that they are cruise-ship based, visiting a sequence of sites over a short time period (two to four weeks), often progressing from warmer, higher biodiversity areas to cooler, lower biodiversity areas. This 'stepping stone' approach intuitively increases the risk of transfer of biota from one site to the next, although explicit and quantitative studies have not been attempted. Furthermore, such journeys highlight a further risk – that of transferring biota indigenous to one part of Antarctica (and thereby already adapted to the environmental extremes) into another (discussed in detail by Convey this volume).
Figure 3 1992-2007 Antarctic tourist trends (including ship and land-based passenger numbers; 1997-98 onwards includes commercial yacht activity). Source: www.iaato.org.
Other than private expeditions, the only possibility for tourists to visit inland regions of the Antarctic continent is presented through the air link of the operator Antarctic Logistics and Expeditions between Punta Arenas (Chile) and Patriot Hills (c. 80°S) in the eastern extension of the Ellsworth Mountains. Tourists using this opportunity then typically participate in trips to Vinson Massif (Antarctica’s highest mountain) or to the Geographic South Pole.

Frenot et al. (2005), drawing on data published by Navareen et al. (2001), identified four trends in tourism patterns likely to be of particular significance for the potential introduction and spread of alien organisms into and around the Antarctic. First, tourists (tour operators) are disproportionately attracted to sites of higher diversity. Second, the intensity of visitor use is increasing, as measured by such factors as the number of inflatable boat landings or the total number of people landing. Third, the most popular visitor sites change over time, meaning that potential human impacts are not contained to specific locations but vary as tourist trends or fashions change. Finally, the range of tourist activities available is expanding – in many cases it is no longer sufficient simply to land on beaches and observe immediately accessible wildlife, and operators are now offering options including extended walks, kayaking trips, climbing, diving, and even a competitive marathon on King George Island. The provision of “visitor facilities”, such as boardwalks, is starting to become an issue on some subantarctic islands. These have the advantage of reducing environmental damage and disturbance through control of human travel routes and trampling, but the disadvantage that they are themselves a fundamental alteration to the “pristine” state of these
environments, itself one of the major factors drawing tourists to the region.

**National Antarctic Research Programmes**

There are considerably fewer people involved in all aspects of running and supporting national research programmes in the Antarctic than in the tourism industry. For example, in the summer of 2005/06, 3760 National Antarctic Programme personnel visited Antarctica and the subantarctic islands, and this number is currently relatively stable year to year. In winter, the national programmes population drops to around 1000 personnel. Individual programme personnel spend longer periods in the Antarctic, and generally have a greater opportunity to visit more locations and move around than do tourists and most likely account for more “person days” than tourists (Hull & Bergstrom 2006). Stations or field camps are generally concentrated around the coast, which are by their very nature ice free and with higher relative biodiversity, hence areas of increased environmental sensitivity (Poland *et al.* 2003). In 2006, 82 stations had been established in the Antarctic (including the maritime islands). Of these, 37 were year round stations and twelve were significant seasonal stations (COMNAP 2006). The Antarctic Peninsula has a large proportion of the occupied stations due to its high degree of accessibility from South America (Hull & Bergstrom 2006) with the majority of stations, and almost half the personnel, located on the South Shetland Islands and northern Antarctic Peninsula, with a much lower density of stations further south on the Antarctic Peninsula and around the continental coastline. The second focus of station activity lies in the Ross Sea on
the Victoria Land coast – particularly due to the relatively large size of the US McMurdo Station, amounting to almost 1000 personnel there during the austral summer.

**Accessibility by air**

Although ships provide the bulk of logistic support and transport to Antarctic locations, several national programmes, tourist operators and a small number of non-governmental organisations use air transport. The practical advantages are obvious, in particular, in terms of faster and more efficient exchange of personnel and equipment. However, and to a much greater extent than the time-consuming reliance on ship transfer, this method also overcomes the “isolation barrier” that generally protects Antarctic locations, thereby allowing the rapid transfer of propagules, including even short-lived life stages. There are currently four points of departure for intercontinental flights to Antarctica carrying tourists or research staff (Punta Arenas, Chile; Stanley, Falkland Islands; Cape Town, South Africa; Christchurch, New Zealand), with a fifth route planned to commence operation from Tasmania. This means that, without effective quarantine measures, alien biota could be transported from all Southern Hemisphere continents to Antarctica within a three to nine hour time period. A further new development within the Antarctic Peninsula tourism industry is that, in order to accelerate the turnover of tourists on the Antarctic Peninsula and avoid the often unpleasant two day sailing across the Drake Passage, a “fly and sail” option is being made available, allowing tourists to reach the Antarctic (King George Island) by air and to board their cruise ship there.
CLIMATE CHANGE

Trends

Rapid temperature increases are well documented in maritime Antarctic, with increases in annual air temperatures of at least 1°C over the last 30-50 years reported at several locations (King et al. 2003; Turner et al. 2005a; Convey 2006). Warming trends have also been reported at some subantarctic and continental Antarctic locations (e.g. Adamson et al. 1988; Smith & Steenkamp 1990; Gordon and Timmis 1992; Frenot et al. 1997; Tweedie & Bergstrom 2000; Smith 2002; Jacka et al. 2004). By contrast, few long duration temperature fluctuations have been noted in the Dry Valleys region of Victoria Land. Changes in other climatic variables such as precipitation have also been documented, including increases in parts of the maritime Antarctic (Turner et al. 1997, 2005b), and decreases at subantarctic Marion and Kerguelen Islands since the early 1970s (Smith & Steenkamp 1990; Frenot et al. 1997; Smith 2002; Chapuis et al. 2004) and maritime Antarctic Signy Island (Noon et al. 2001). Water availability in terrestrial habitats is governed by direct precipitation and through seasonal snow and glacial melt – the latter is the only source of liquid water on continental Antarctica. Rapid rates of glacial retreat and snow cover across many maritime and subantarctic sites are particularly significant in this context (Convey 2006). Newly exposed ground offers new opportunities for colonisation of both indigenous
and exotic biota without the influence of potential competition from established communities.

**Implications for alien biota**

In general, climate change processes that result in a relaxation of current environmentally imposed constraints are likely to enhance the ability of both natural long-distance colonists and human-assisted aliens to become established, particularly in the subantarctic (Selkirk 1992; Smith 1993; Chown & Language 1994; Kennedy 1995; Bergstrom & Chown 1999). For example, the establishment of the dipteran *Calliphora vicina* at Kerguelen is likely to have been related to the recent warming experienced at this location. This cosmopolitan fly reaches the margin of its physiological tolerance range in the subantarctic. Taking into account the energy requirement in order to complete its life cycle, successful establishment was very unlikely during the 1950s and the 1960s. Since the late 1970s, however, several favourable (warmer) years were experienced, increasing the probability of successful establishment, and correlating with the first record of *C. vicina* on the island in 1978. After initial establishment, the distribution of the fly expanded very rapidly during the early 1980s, as it colonized most of the eastern (warmer) part of the Kerguelen archipelago. The western regions of the archipelago are fractionally colder (< 1°C) and, as yet, *C. vicina* has not been observed there (Frenot et al., unpubl. data).

A second important area in which contemporary climate change is likely to have ecosystem level impacts lies in its consequences for
alien species that are already established and considered as persistent rather than invasive (i.e. the majority of species currently known from the Antarctic regions). Here, there is a clear possibility of a switch from persistent to invasive status. This may occur, for example, through increases in vegetative or sexual reproduction and may then lead to the natural colonization from impacted sites of nearby, currently pristine sites, as is proposed to have happened with alien plant species at the infrequently visited Prince Edward Islands (Gremmen & Smith 1999).

CONCLUSIONS

At present, a large majority of alien terrestrial biota are confined to the subantarctic islands, with much lesser occurrence in maritime Antarctic, and only a single species in continental Antarctic. The full extent of occurrence of alien biota in the Antarctic is currently unknown, as limited or no rigorous survey data or even anecdotal observations exist for many of the smaller invertebrate, lower plant, or microbial groups.

Impacts of alien taxa on indigenous ecosystems range from negligible/transient to significant. Within the Antarctic Treaty area these impacts are currently low in comparison with the dramatic effects resulting from some invasive alien biota on the subantarctic islands.
Most alien species are representatives of widespread families and/or are European in origin. Major correlates of invasion are human visitor numbers/frequency and temperature. The risk of further introductions to the Antarctic region, although lower than in many other parts of the planet, is significant, with potentially disproportionate consequences in the context of impacts on regional and global biodiversity and conservation issues.

Current climatic trends will further enhance the chance of introduced species establishment and, therefore, opportunities for alien invasion, and will act synergistically with increased direct opportunities through human visitation. Those under the most threat are relatively milder areas with increased human visitation and the most dramatic changes in environmental conditions.

Unless stringent measures are taken to reduce propagule load on humans, their food, cargo, and transport vessels, it is reasonable to predict that, as the number of human vectors visiting Antarctic ice free areas increases, so will the introduction and establishment of new alien taxa and, therefore, subsequent modification of ecosystem functioning.

There is a clear and urgent need for the establishment of long-term monitoring programmes to identify and assess future invasions, monitor the status of species already established or assess the effectiveness of any mitigation procedures adopted. A range of further measures are available for consideration, in concert with monitoring, in order to minimise the risk of introductions. Practicable approaches
include: cessation of imports of foreign biological material and soil; cessation of on-station cultivation of biological material; precaution in the import of building materials used to upgrade or expand the stations; stringent measures to ensure rodent free status of ships and aircraft; logistical planning to minimize the risk of intra-regional and local transfer of propagules to pristine locations; control of visitor numbers and access to more sensitive or pristine sites; cleaning/sterilization of high risk transport locations for aliens, such as cargo surfaces, foodstuffs and clothing; establishment of a code of conduct for all visitors in order to assess and to minimize both the risk of introduction of new alien taxa into the Antarctic and subantarctic and the risk of accidental transfer of regionally indigenous taxa between major ice-free localities.

During the next decade, research conducted under the umbrella of the new SCAR Programme Evolution and Biodiversity in Antarctica (EBA) will provide an important tool for further understanding colonization processes and alien species impacts in the Antarctic. Concentrated activities planned under the International Polar Year, in particular the international collaborative programme Aliens in Antarctica, are intended to provide the first continent-wide assessment of anthropogenically-associated propagule pressure on Antarctica, and thereby allow the development of realistic control and mitigation measures based on objectively assessed risks.
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REFERENCES


NON-NATIVE SPECIES IN ANTARCTIC TERRESTRIAL AND FRESHWATER ENVIRONMENTS: PRESENCE, SOURCES, IMPACTS AND PREDICTIONS

PETER CONVEY

ABSTRACT

Uniquely, unlike any other continent or even the subantarctic islands of the Southern Ocean, terrestrial ecosystems of the Antarctic continent have yet to experience significant impacts from the introduction of non-native species. At present, single figure numbers of non-native plants and animals are known to have become established, in all instances over the last few decades, with most such events occurring on the northern Antarctic Peninsula and archipelagos of the Scotia Arc. None of these species have yet become invasive. This paper reviews the current status of non-native species on the Antarctic continent, and considers their likely routes of arrival and the future risks associated with their establishment. Increasing human contact with the continent, through scientific, logistical and tourism-related operations, provides by far the greatest source of transport of alien biota and colonising propagules, far outweighing natural routes of colonisation (although these still operate). Contemporary regional climate change trends will act synergistically to increase the pool of potential colonists with

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appropriate biological attributes, and their chances of successful establishment. There also remain very large gaps in our knowledge of both the indigenous and alien terrestrial biota of Antarctica, particularly, but not restricted to, the field of microbiology. Accepting that human contact with the continent will inevitably continue, any contact carries with it a risk of the introduction of non-native species. By virtue of the relatively limited number of routes and modes of access, and concentration of operations at mostly defined locations, Antarctica provides the only continental-scale opportunity remaining to humans to demonstrate our ability to put in place practicable control and mitigation measures that will slow rates of introduction and establishment.

INTRODUCTION

This paper focuses on the presence and (potential) impacts of non-indigenous organisms on the native biota of the terrestrial and freshwater ecosystems of Antarctica. Antarctica (in this paper being the area south of 60°S latitude) includes two currently recognised terrestrial biogeographical zones, the maritime and continental Antarctic, and their subdivisions (see Smith 1984; Longton 1988, for further description; Peat, Clarke & Convey 2007; Chown & Convey 2007, for recent refinement). The maritime Antarctic includes the western coast of the Antarctic Peninsula to c. 72°S, the South Shetland, South Orkney and South Sandwich Islands and the isolated Bouvetøya (although the latter two lie north of 60°S), and Peter I Øya. This area does not include all, or even a majority of, the geological
region of West Antarctica. The continental Antarctic is much larger, including all of East Antarctica, the Balleny Islands, and the remaining parts of the Antarctic Peninsula and West Antarctica. Terrestrial habitats of the maritime and continental Antarctic are usually small in area and often extremely isolated, including coastal Rocky regions and inland nunataks and mountain ranges. The extensive ice free cold deserts of Victoria Land (Lyons, Howard-Williams & Hawes 1997) provide a unique exception to this generalisation.

The Antarctic terrestrial biota is species poor and also lacks representatives of many higher taxonomic groups (Block 1984; Smith 1984; Convey 2001, in press). Terrestrial faunal communities consist of invertebrates (Diptera – two species only, Acari, Collembola, Nematoda, Rotifera, Tardigrada, Protista), and plant communities largely of cryptogams (mosses, liverworts, lichens), with only two higher plants present. Biodiversity and community complexity at a large scale generally decrease with increasing latitude and environmental severity, although the detailed pattern is considerably more complex (Convey 2001, in press; Clarke 2003; Chown & Convey 2007). In relation to most groups present, fine scale observational survey data are sparse and large lacunae remain in knowledge of even the basic biology and biogeography of much of the Antarctic terrestrial biota. The continental Antarctic includes faunal communities amongst the simplest on the planet (Freckman & Virginia 1997), uniquely in some areas lacking even Nematoda (Convey & McInnes 2005). Ecosystem structure and trophic complexity are very simple. Most invertebrates are thought to be microbivores or detritivores, with predation insignificant (Lister, Block & Usher 1988; Usher, Block &
Jumeau 1989), although there is an element of dogma in this view as few rigorous autecological studies have been attempted (Hogg et al. 2006).

Even in comparison with the level of biological data available for macrofauna and flora, minimal information is currently available for most microbiota. Microbial autotrophs are fundamental to polar terrestrial ecosystem processes (Vincent 1988; Wynn-Williams 1993, 1996a) and, as elsewhere, an understanding of their role in ecosystem function is a vital component in developing understanding of ecosystem level responses to change. Although the use of molecular biological techniques is now leading to an increase in microbial diversity data available from continental and maritime Antarctica (Lawley et al. 2004; Adams et al. 2006; Boenigk et al. 2006; Yergeau et al. 2007), the spatial coverage of such studies remains very limited.

The simplicity of Antarctic terrestrial ecosystems leads to predictions that they will be particularly vulnerable to the various processes involved in environmental change, amongst which are that changes in biogeographical distributions and the colonisation of currently non-indigenous species are expected (Freckman & Virginia 1997; Bergstrom & Chown 1999; Walther et al. 2002; Convey 2003). This simplicity also leads to predictions that Antarctic ecosystems include examples lacking, or poor in, specific biological functional groups that will, therefore, include little of the functional redundancy that is typical in more diverse ecosystems of lower latitudes. In the context of consideration of the possible consequences of colonisation of Antarctica by currently non-indigenous biota, the lack of indigenous
diversity (however defined) opens up the possibility of the occupation of new ecological niches (including currently unrepresented trophic functions and levels), inevitably leading to large changes in the structure and function of trophic webs in ecosystems. When, inevitably, colonisation events occur, responses of the indigenous biota will be constrained by features of their typically “adversity-selected” life history strategies (Convey 1996). While these organisms are well-placed to survive the abiotic environmental extremes of Antarctic terrestrial ecosystems, their competitive abilities are very poorly developed, meaning that species and communities are vulnerable to increased competition and predation from invading taxa (Convey 1996, 2003; Frenot et al. 2005; Convey et al. 2006, 2007). This vulnerability is already well demonstrated in the literature relating to the consequences of the presence of a wide range of non-indigenous species on the various subantarctic islands (Frenot et al. 2005, this volume; Convey et al. 2006, 2007).

NATURAL DISPERSAL TO THE ANTARCTIC CONTINENT

While the Antarctic is to a large extent isolated and protected by oceanic and atmospheric barriers from the natural transfer of biota from lower latitudes, these barriers are not hermetically sealed and it is clear that such transfers take place over evolutionary timescales, both into and out of the region (Clarke, Barnes & Hodgson 2005; Barnes et al. 2006). Although successful establishment events are clearly rare, several potential dispersal routes exist, with reported instances of occurrence (reviewed by Hughes et al. 2006). Air or water currents
have carried biota long distances (Benninghoff & Benninghoff 1985; Marshall 1996; Marshall & Convey 1997; Greenslade, Farrow & Smith 1999; Hughes et al. 2004; Muñoz et al. 2004; Convey 2005; Lewis, Riddle & Smith 2005), as have zoochoric associations with migratory birds and mammals (Schlichting, Speziale & Zink 1978; Bailey & James 1979; Pugh 1997; Barnes et al. 2004), and attachment to natural or anthropogenic debris (hydrochory) (Barnes 2002; Barnes & Fraser 2003). At the South Atlantic Gough Island (a cold temperate oceanic island) and subantarctic Marion Island, it has been possible to assess the relative contributions of natural colonisation processes and anthropogenic introductions over the centuries since each island’s discovery (Gaston et al. 2003; Gremmen & Smith 2004). These authors found that natural processes have been outweighed by anthropogenic by at least two orders of magnitude over this period, although it is not clear that the same expectation can be applied to colonisation of the much more severe Antarctic environment, as the “pool” of available colonists with appropriate pre-adapted biological features is likely to be smaller.

**ANTHROPOGENIC ASSISTANCE**

In the subantarctic, the last two centuries have seen major changes in the structure and functioning of subantarctic terrestrial ecosystems (Frenot et al. 2005, this volume; Convey et al. 2006). These changes have involved the introduction of a wide range of non-indigenous plants and animals, with the majority (other than large grazing and predatory non-rods) generally being introduced
inadvertently. While, even in the subantarctic, knowledge of the presence, distribution and status of non-indigenous species is often far from complete, it is already clear from the studies listed that the subantarctic provides a warning of consequences to be expected in the event of establishment of invasive alien species (Frenot et al. 2005) within the Antarctic continent (maritime and continental Antarctic). At present, very few non-indigenous species are known to have become established in this region, and none of these are classified as invasive (these discussed in detail below). Even in the absence of specific monitoring programmes, however, it is already clear that many analogous transfers of biota do occur, with the major vectors including cargo, vehicles, food, clothing and people themselves (Sjoling & Cowan 2000; Whinam, Chilcott & Bergstrom 2004; Frenot et al. 2005; Lewis, Riddle & Smith 2005; Lewis, Bergstrom & Whinam 2006; Hughes et al. 2006; Hughes 2007). Even where specific control measures and procedures exist, failure of their implementation can lead to significant accidental transfer events (Hughes 2007). Until relatively recently, the majority of human access to and within the Antarctic continent involved lengthy transport by sea or overland/ice, which itself provided an imperfect “colonisation filter” by requiring the presence of a coloniser life stage with extended survival abilities. In recent decades the level of access by air has increased rapidly, reducing transport times from weeks to mere hours, and potentially providing an extremely efficient means of dispersal (Bölter & Stonehouse 2002; Frenot et al. 2005).

As with the subantarctic islands, the early history of human contact with the Antarctic continent generated many examples of the
deliberate import of a range of vertebrates for transport (dogs, ponies), food (pigs, chickens) and recreational and pest control (cats) purposes. In contrast with the subantarctic, these animals could only survive within the confines of established stations or closely associated with expeditions; it is very likely that rodents (rats, mice) will have been taken ashore inadvertently during these periods, and they have likewise failed to become established at any location on the continent. Such deliberate imports are no longer permitted under the Antarctic Treaty System (ATS), and the last dogs were removed from the continent in 1994. The 1960s and 1970s also saw a number of intentional botanical transplant experiments into Antarctic field locations, particularly the maritime Antarctic South Orkney Islands (Edwards et al. 1973; Edwards 1980; Smith 1996), as part of attempts to assess the characteristics prerequisite of potential colonising species. These transplants were sourced from locations typified by cold climates (subantarctic South Georgia, the Falkland Islands, Arctic locations). Again, such transplants are no longer permitted, and a strict permitting system exists under the ATS for controlling the import into Antarctica of non-native biota for scientific purposes, including the specifying of controlled conditions for storage/handling and subsequent destruction.

KNOWN INSTANCES OF INTRODUCTION AND ESTABLISHMENT

It is clear that the number of recorded instances of non-indigenous species becoming established in the maritime and continental Antarctic biogeographical zones is much lower than that for the
subantarctic (Table 1), with a total of up to eight species (five proven) known from the former two zones compared with approximately 200 from the latter. There is no evidence to date of any non-indigenous species becoming invasive in the maritime or continental Antarctic, with all currently classified as persistent aliens (Frenot et al. 2005). In addition to the small number of species that have become established in the Antarctic environment, there are many anecdotal and a few published instances of non-indigenous biota existing synanthropically within human habitation and other station buildings over periods of at least several years (e.g. Greenslade 1987, 2006; Hughes et al. 2005).

The five proven examples are all found in the immediate vicinity of active research stations. Three are grasses of the genus Poa: P. annua near the Polish Arctowski Station, King George Island (Olech 1996); P. pratensis at Cierva Point near the Argentinean Primavera Station, northern Antarctic Peninsula (Smith 1996); and P. trivialis near the Japanese Syowa Station, on the continental coast (Japan 1996). While all are known to have been established for at least several years, there are no detailed studies published of any population or distribution trends, although it is known anecdotally that the extent of the P. annua population at Arctowski Station has expanded in recent years, and there have been some partial attempts at removal, while P. trivialis remains a single plant. Both P. annua and P. pratensis are among non-indigenous species that have become invasive on several subantarctic islands.

The remaining species known to have persistent status are both invertebrates accidentally introduced to the immediate vicinity of the
<table>
<thead>
<tr>
<th>Biological group</th>
<th>Maritime Antarctic</th>
<th>Continental Antarctic</th>
<th>Entire Subantarctic</th>
<th>Subantarctic Islands</th>
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<tr>
<td></td>
<td></td>
<td></td>
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<td>1</td>
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<td>33</td>
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<td>16</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table 1** The occurrence of non-indigenous species across Antarctic biogeographical zones (updated from Frenot et al. (2005)).
British Signy Island Station (South Orkney Islands, maritime Antarctic). The introductions were almost certainly made during the 1960s plant transplant experiments mentioned above (Block, Burn & Richard 1984; Convey & Block 1996; Dozsa-Farkas & Convey 1997), although their presence was not recognised until the early 1980s, long after the originally transplanted plant material had been removed. They include the enchytraeid worm *Christensenidrilus blocki* and the brachypterous chironomid midge *Eretmoptera murphyi*, both otherwise known only from the subantarctic island of South Georgia. The latter species is parthenogenetic, a life history characteristic often associated with the successful colonisation of isolated or environmentally extreme locations (Frenot *et al.* 2005).

Three further records of non-indigenous Collembola have been published from maritime Antarctic sites, but no subsequent studies have taken place to allow any assessment of either their persistence or status. The cosmopolitan springtail *Hypogastrura viatica* has been recorded from the South Shetland Islands (where there are many research stations and much human activity) and Léonie Island in Marguerite Bay (several kilometres from the British Rothera Station on Adelaide Island) (Greenslade 1995). If proven to have become established at either location, this species is a particular concern, as it or its congeners have become aggressive invasive species on some subantarctic islands, including South Georgia and Macquarie Island (Convey *et al.* 1999; Frenot *et al.* 2005; Greenslade 2006). *Folsomia candida* and *Protaphorura* sp. have been reported from Deception Island (South Shetland Islands) (Greenslade & Wise 1984). Here, their
association with human activity is unproven as, although Deception Island has been the site of several research stations, it is also geothermally active, a characteristic known to encourage the natural establishment of lower latitude plant and animal taxa otherwise unable to survive in the Antarctic terrestrial environment (Convey, Greenslade & Pugh 2000; Convey et al. 2000a; Smith 2005). The current status of these two species is unknown.

MICROBIAL GROUPS

The potential significance of microbial introductions to the Antarctic continent has only recently received research attention, and very few detailed studies or data currently exist (Frenot et al. 2005). This dearth of information is compounded by the very real problem of separating a “newly recorded” microbial taxon that has been introduced by anthropogenic means, from one that is present naturally and is either cosmopolitan in distribution or has dispersed to the region by natural means, as many microbes are hypothesised to have virtually unrestricted dispersal capabilities (Finlay 2002). Advances in the availability of molecular phylogenetic tools promise to improve our ability to identify non-indigenous microbes – for instance, while the classically described algal flora is thought to be largely cosmopolitan (Broady 1996), molecular studies of various microbial groups are now showing them to be more distinct, and by implication, indicative of more ancient evolutionarily isolation (Franzmann 1996; Lawley et al. 2004; Boenigk et al. 2006). Molecular biological methods that ease the
detection of specific microbes as “indicators” of human activity are also now available (Baker, Ah Tow & Cowan 2003).

As with larger organisms, the risks of importation of microorganisms into the Antarctic, and their subsequent movement within the continent, are recognized (Smith 1996; Wynn-Williams 1996b; Gavaghan 2002), and some microbial introductions have been reported (Broady & Smith 1994; Wynn-Williams 1996b; Kashyap & Shukla 2001; Minasaki et al. 2001). Such reports, however, also highlight another problem in defining the current state of knowledge, in that there is normally no subsequent attempt to assess whether establishment has occurred, as distinct from simple transfer. Circumstantial evidence of microbial introductions is provided by studies such as those of Kerry (1990), Upton, Pennington & Haston (1997) and Azmi & Seppelt (1998) that compare diversity at human impacted sites (such as the vicinity of research stations) and pristine areas, suggesting that taxa present only at the former are likely to be associated with human activity.

The potential of anthropogenic routes of microbial introduction has received attention in the context of forming a potential source of disease in wildlife (Kerry, Riddle & Clarke 1999), although an indisputable link has yet to be demonstrated. Even in instances where evidence of disease exposure exists (e.g. presence of specific antibodies), alternative routes of exposure should be considered – for instance, most Antarctic birds and mammals encounter humans beyond the Antarctic itself during at least part of the year. While some, particularly skuas and gulls, regularly forage around ports and refuse
sites as well as following ships at sea, before returning to Antarctica to interact with other native biota and to breed.

One of the potentially most pervasive sources of human-associated microbial introduction to the Antarctic continent is found in sewage, generally taken to include human waste and “grey water”. Faecal bacteria have been located in the marine and terrestrial environments and sea ice in the vicinity of sewage outfalls, and can potentially contaminate marine vertebrates (Olsen et al. 1996; Edwards, McFeters & Venkatesan 1998; Smith & McFeters 1999; Hughes 2003a, 2003b). Their presence also raises the possibility of transfer of genetic material to indigenous microbiota (Smith & McFeters 1999), or the introduction of viruses. There would appear to be no practical alternative to sewage discharge from the main research stations, but it should also be recognised that effective mitigation measures that considerably reduce microbial release are often practicable (Hughes & Blenkharn 2003; Hughes 2004).

Human presence is not simply restricted to research stations, as field parties travel extensively, if sporadically, across the continent. While most travel is inevitably over ice and snow, terrestrial habitats (e.g. rock outcrops) have historically formed the focus of many field activities, and these provide simple soil habitats for potential microbial colonists. Few studies of microbial introductions to such sites have been published (e.g. Cameron 1972; Wynn-Williams 1996b; Sjoling & Cowan 2000; Cowan & Ah Tow 2004 2005). Meyer, Morrow & Wyss (1963) and Nedwell, Russell & Cresswell-Maynard (1994) reported the presence of viable bacteria amongst historical expedition remains that
had been in situ for up to 80-90 years. A detailed examination of the microbial community associated with one 30-40 year old field waste dump on Alexander Island (Hughes & Nobbs 2004) likewise reported the presence of a range of culturable microbes, and highlighted the potential of such sites for future environmental pollution and negative consequences for human health and scientific research.

THE RISKS OF INTRA-CONTINENTAL TRANSFER

While a focus on the risks associated with the establishment of species not already native to the Antarctic continent is clearly important, there is a danger that a separate, but still fundamentally important, risk will thereby be overlooked. It is often not appreciated that the Antarctic continent is not a single biogeographical unit and, therefore, that there are clear threats to regional biodiversity from transfers occurring within the continent. In this context, it is important to recognise the strength of the biogeographical boundary across the southern Antarctic Peninsula (the “Gressitt Line” – Chown & Convey 2007), across which a number of major higher taxonomic groups (in particular the Acari, Collembola and Nematoda) share no or virtually no species. Contemporary biogeographical studies are also highlighting that the current view of Antarctic terrestrial biogeography is over-simplified. A continent-wide analysis of biogeographical associations in the moss and lichen flora (Peat, Clarke & Convey 2007) supports refinement of the two-part continental and maritime Antarctic zonation in use until now. Detailed regional studies of nematodes (Maslen & Convey 2006) and tardigrades (Convey &
McInnes 2005) report the existence of considerable levels of previously unknown diversity within specific subregions that do not reconcile comfortably with the accepted clines of decreasing diversity with increasing latitude and environmental severity; elsewhere on the planet these findings would be interpreted as indicative of the existence of long-term refugia or biodiversity hotspots.

Molecular biological studies are also now starting to generate data indicating that at least some elements of the Antarctic terrestrial biota are considerably more ancient or evolutionarily distinct than previously suspected (Allegrucci et al. 2006; Boenigk et al. 2006; Stevens & Hogg 2006). Such studies highlight an often unappreciated element of biodiversity – that of local evolutionary differentiation. The highly fragmented and isolated nature of Antarctic terrestrial ecosystems, combined with evidence of their long-term existence as provided by such studies, provides an ideal template upon which differentiation processes can occur. The biogeographical and genetic distinctness of such ecosystems, however, is clearly much more vulnerable than previously appreciated to the inadvertent transfer of biota within the Antarctic itself. Two examples can be used as illustrative case studies of the risks associated with intra-continental transfer of biota otherwise regarded as native to the Antarctic continent.

First, Convey et al. (2000b) describe the terrestrial ecosystems of isolated nunataks on the northern coast of maritime Antarctic Charcot Island, itself a very isolated island in the eastern Bellingshausen Sea, west of Alexander Island. These nunataks have been visited on only four or five occasions by geologists and biologists operating with the
British Antarctic Survey, with access being via an approximately two hour flight from the British Rothera Station. The biota and diversity of the terrestrial ecosystems at this location are exceptional in a number of respects, but most pertinent here is that they lack any representatives of the Collembola, with the only arthropods present being a diverse Acari community, otherwise typical of the maritime Antarctic. Maslen & Convey (2006) also report the presence of previously unknown Nematoda at this site. At present, no other locations within the maritime Antarctic are known to lack Collembola. This lack of an otherwise ubiquitous biological and functional group provides an almost unique research opportunity, in combination with studies of ‘typical’ maritime Antarctic terrestrial ecosystems, to address fundamental questions in ecological theory relating to species and functional redundancy and the controls of ecosystem structure. It is also clear that any human contact with the ecosystems of Charcot Island, which will inevitably originate from a maritime Antarctic location where Collembola are native, will immediately create a serious risk of the transfer of these arthropods. If such an eventuality occurs, the likelihood of establishment is considerably increased by the fact that the Collembola indigenous to the maritime Antarctic already possess the ecophysiological and life history features required for survival at this location, while rapid detection of transfer is unlikely, and any form of mitigation impracticable.

Second, Convey & McInnes (2005) have described tardigrade dominated terrestrial ecosystems associated with inland nunatak ranges covering a wide area in Ellsworth Land, at 75-77ºS in the southern Antarctic Peninsula. These ecosystems are currently unique
worldwide in lacking any representatives of the Nematoda, a group previously thought to be ubiquitous in terrestrial ecosystems (Freckman & Virginia 1997). The risks faced by these ecosystems are at least twofold. First, as in the example of Charcot Island, they lack representatives of taxonomic and functional groups that are generally common in most other Antarctic terrestrial ecosystems, including those from which the logistical operations required to access Ellsworth Land emanate. Hence the inadvertent transfer of pre-adapted Antarctic biota is a very real possibility. Second, these Ellsworth Land mountain ranges (and also the larger Ellsworth Mountains range, about which virtually no biological information is available) host “forward support” facilities and field camps supporting, primarily, the deep field operations of the British Antarctic Survey (Sky Hi Nunataks) and tourism activities of Antarctic Logistics and Expeditions (Patriot Hills). As well as these primary operators, these locations are visited by the aeroplanes of several other operators, in journeys emanating from diverse locations across the Antarctic continent and southern Antarctic Peninsula, and even from King George Island (South Shetland Islands) and Punta Arenas (Tierra del Fuego), and the frequency and operational footprint of such journeys is increasing. Virtually all of these journeys inevitably cross the biogeographical boundary formed by the Gressitt Line, hence further exacerbating the risk of intra-continental transfer of species native only to one part of the Antarctic continent. While transfer in such instances is only one step in the process ultimately leading to establishment, it should again be emphasised that many of the biota that could potentially be transferred will automatically be pre-adapted to environmental conditions at the new location.
CONCLUSIONS

The Antarctic continent appears currently to be largely unaffected by the introduction of non-indigenous species, with very few known examples of long term establishment, and no species yet becoming invasive. This simple and apparently positive picture should not, however, lead to complacency. The current level of knowledge is based on a very incomplete dataset, with relevant information simply not available for many biological groups (in particular, but not restricted to, microbial groups) and geographical locations, or over the extended timescales required to identify true establishment and population trends. As well as there being a clear and urgent requirement for baseline and continuing biological survey to address this lack of knowledge, there are also no established monitoring studies designed with the intention of identifying new instances of introduction, or targeting non-indigenous species already known to be established in order to provide continuing assessment of their status or any change in the threat they pose.

It is clear that, both for the subantarctic and the continent itself, anthropogenic mechanisms of colonisation already far outweigh natural dispersal and colonisation processes (Pugh 1997; Frenot et al. 2005; Chown & Convey 2007). This effectively negates the dispersal filter that exists through the isolation of Antarctic terrestrial habitats, by removing the need for physiological or life history strategies allowing survival of the stresses inevitably experienced during unassisted transfer from the other southern continents or Southern Ocean islands.
It is well known that many lower latitude microbial, plant and invertebrate species possess features that would allow them to survive in the more extreme conditions of the Antarctic. Antarctica is now faced by twin threats from such species. First, regional climate change trends leading to amelioration of existing climate regimes will lower the ecophysiological barriers involved in “natural” transfer and establishment. Second, continuing and increased human contact with the continent will result in a greater frequency of inadvertent anthropogenic introduction events (Frenot et al. 2005; Convey et al. 2006, in press).

Humans are already having extraordinary impacts on regional and global diversity (Brooks et al. 2002; Thomas et al. 2004; Balmford et al. 2005; Gaston 2005), impacts that are largely yet to be felt by the Antarctic continent. Human contact with Antarctica, both through the research and logistic activities of national Antarctic operators, and the various elements of recreational tourism, is currently increasing rapidly and, realistically, is likely to continue to do so (Frenot et al. 2005; COMNAP 2006; IAATO 2006). While it is clear that any human visit to the continent carries with it a risk of the introduction of new non-indigenous species, in an Antarctic context there are realistic measures available to minimise this risk (e.g. Whinam, Chilcott & Bergstrom 2004; Frenot et al. 2005; Curry et al. 2005; De Poorter et al. 2006). In combination with monitoring programmes that would allow the rapid adoption of mitigation measures, a practical measure of protection can be given to maintain the integrity of Antarctic ecosystems. There is clearly an urgent requirement to better understand the native biodiversity of Antarctic terrestrial ecosystems,
as well as to document the existence and current status of non-indigenous species, and set in place sufficient and robust monitoring and control measures to allow assessment of and response to any change in status and risk to native ecosystems.

The consequences of establishment of non-indigenous species in Antarctica will mirror those already well documented worldwide. These include the loss of biodiversity through the blurring of biogeographic boundaries and loss of genetic identity (Chown & Convey 2007). In the context of Antarctic terrestrial ecosystems, their typically island-like and isolated nature exacerbates this risk, in the process also compromising the value of the continent as a scientific research resource. In comparison with terrestrial ecosystems across the rest of the world, the Antarctic continent is still, arguably, unique. It is the least affected by the introduction of non-indigenous species to date. Through the relatively limited number (in absolute terms) of access routes, vessels and journeys it is the most practicable of continents on which to apply control measures. High standards of environmental stewardship are imposed on visitors to the continent through agreed mechanisms within the ATS and the International Association of Antarctica Tour Operators (IAATO). This combination of factors means that the Antarctic provides one of the last opportunities available to humankind to demonstrate our ability to instigate and apply continent-wide control and conservation measures, while failure to do so will provide an irreversible legacy.
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AVAILABILITY AND APPLICABILITY OF LEGAL TOOLS FOR MANAGING NON-NATIVE SPECIES

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ABSTRACT

It can no longer be assumed that the remoteness and extreme climatic conditions of Antarctica will protect it from the unintentional introduction of non-native species. A changing, more benign climate in certain parts of Antarctica, coupled with increasing visitation means the risks of non-native species being introduced and becoming established are increasing. At present the region remains relatively free from invasions by alien species. The Antarctic Treaty³ Parties therefore have an opportunity to develop and implement preventative measures to ensure the ongoing protection of the Antarctic environment.

In an Antarctic context some progress has been made to address the issue, through the Protocol on Environmental Protection to the Antarctic Treaty 1991.⁴ However, the Protocol deals only with the control of intentional introductions of non-native species and does not

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³ The Antarctic Treaty, opened for signature 1 December 1959, 402 UNTS 71 (entered into force 23 June 1961) (‘Antarctic Treaty’).
necessarily provide an adequate framework for managing the risks of unintentional introductions.

Away from Antarctica, a number of international agreements have addressed the issue of biodiversity conservation and the risks associated with non-native species. While these agreements do not necessarily apply directly to the Antarctic region, certain provisions and approaches will be valuable to the Antarctic Treaty Parties in their development of Antarctic-specific measures.

This paper reviews the legal tools available for regulating and managing the risks associated with non-native species introductions.

INTRODUCTION

With the adoption of the Protocol in 1991, the Antarctic Treaty Parties committed themselves “to the comprehensive protection of the Antarctic environment and dependent and associated ecosystems” and designated Antarctica as “a natural reserve devoted to peace and science”.

The Treaty Parties also agreed that the “protection of the Antarctic environment and dependent and associated ecosystems, and the intrinsic value of Antarctica…shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area.”

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5 Protocol, Article 2
6 Protocol, Article 3
No other region on the planet enjoys a comparable level of international commitment to its protection. But if this commitment to protecting the natural environment in Antarctica is to be more than a paper exercise it requires the Treaty Parties to respond to challenges as they arise and, to the maximum extent possible, anticipate future threats. The Treaty Parties already have a track record of taking such pre-emptive action. The Convention on the Conservation of Antarctic Seals 1972⁷ (CCAS), was negotiated due to concerns over the potential resumption of commercial sealing in Antarctica. The negotiations on living resources and mineral resources that led respectively to the Convention for the Conservation of Antarctic Marine Living Resources 1980⁸ (CCAMLR) and the Convention on the Regulation of Antarctic Mineral Resource Activities 1988⁹ (CRAMRA) stemmed from concern amongst the Treaty Parties that unregulated resource activity could have serious effects on the Antarctic environment as well as lead to tension and conflict that could put the Antarctic Treaty itself at risk.¹⁰

This characteristic of tackling Antarctic environmental issues in a proactive and precautionary way, before they develop into major problems, may now need to be applied to the issue of non-native species. With parts of Antarctica showing a significant warming trend,

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⁷ Convention on the Conservation of Antarctic Seals, opened for signature 1 June 1972, 29 UST441 (entered into force 11 March 1978) (‘CCAS’).
¹⁰ Though CRAMRA is unlikely to enter into force now that the Protocol has introduced an indefinite ban on mineral resource activities.
and thus a less hostile environment, and with ever increasing visitation to Antarctica, the risks associated with unintentional species introductions may well require the Treaty Parties to take preventive action.

To the north of the Antarctic continent invasive alien species have had a major impact on the natural biodiversity of many of the subantarctic islands (Frenot et al. 2005). Rats on South Georgia have had a devastating effect on several ground-nesting birds. There is a long list of non-native vascular plants on many subantarctic Islands. Maritime Antarctica is also not immune from persistent non-native species with two species of grass (*Poa pratensis* and *Poa annua*) present in small areas at Cierva Point on the northern Antarctic Peninsula and King George Island respectively (Smith 1996). More recently, Tavares and De Melo (2004) have reported the first discovery of a non-indigenous marine species in Antarctic waters. Their reanalysis of material collected during a 1986 Antarctic Peninsula research cruise revealed the presence of both a male and female North Atlantic spider crab. Other examples of non-native Antarctic species are provided in other papers in this volume.

In other parts of the world there are numerous examples of the impacts of invasive alien species on local and regional biodiversity and economies and the issue is now the subject of increasing attention at national and international levels.

Against this background, this paper will consider the existing legal controls that are in place within the Antarctic Treaty System (ATS) to
manage non-native species as well as looking at regulatory controls internationally and to consider the utility of these regimes in the Antarctic context.

LEGAL TOOLS WITHIN THE ATS

The Agreed Measures on the Conservation of Antarctic Fauna and Flora 1964

The Antarctic Treaty itself contains little in the way of environmental protection provisions. However, within just three years of its entry into force the Parties had turned their attention to issues related to the management of the Antarctic environment. The first substantive demonstration of this was the adoption of the 1964 Agreed Measures on the Conservation of Antarctic Fauna and Flora. The Agreed Measures addressed the issue of non-indigenous species, parasites and diseases through its Article IX, which provided for:

- a prohibition on the importation to Antarctica of any species of animal or plant not indigenous to the Antarctic Treaty Area except in accordance with a permit;
- a restriction on the types of animals and plants that could be permitted (these were listed in Annex C to the Agreed Measures), and the need for permits to specify strict controls;
- an exemption for the importation of food; and
- an obligation on Governments to ensure that all reasonable precautions be taken against accidental introduction of

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parasites and diseases particularly those precautions set out in Annex D to the Agreed Measures.

Annex C limited the importation of non-indigenous species to Antarctica to dogs, domestic animals and plants, laboratory animals and plants including viruses, bacteria, yeasts and fungi. Annex D required dogs to be inoculated against specified diseases and prohibited the importation to Antarctica of live poultry.

At the time the focus of attention was clearly on terrestrial Antarctica, with no specific mention of controls to prevent introductions to the marine environment. This issue was to an extent addressed in 1980 with the adoption of CCAMLR.

**Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR)**

Whilst CCAMLR was negotiated to address the issue of commercial harvesting of marine species, and more specifically concerns over the commercial harvesting of krill, the convention does recognise the issue of non-native species in its Article II, in which the key principles of conservation are set out. Article II(3)(c) states that one of the conservation principles of CCAMLR is the:
“preservation of changes or minimisation of the risk of changes in the marine ecosystem which are not potentially reversible over two to three decades, taking into account the state of available knowledge of the direct and indirect impact of harvesting, *the effect of introduction of alien species* (emphasis added), the effects of associated activities on the marine ecosystem and of the effects of environmental changes, with the aim of making possible the sustained conservation of Antarctic marine living resources”.

Further, Article IX of the Convention requires the CCAMLR Commission to give effect to Article II by (*inter alia*):

- Facilitating scientific research on the Antarctic marine ecosystem;
- Compiling data on the status and changes in populations of Antarctic marine living resources including factors affecting their distribution, abundance and productivity.

CCAMLR also contains in its Article V(2) an obligation on the Contracting Parties which are not Parties to the Antarctic Treaty to agree that, in their activities in the Antarctic Treaty area:

“…they will observe as and when appropriate the Agreed Measures…and such other measures as have been recommended by the Antarctic Treaty Consultative Parties in fulfilment of their responsibility for the protection of the Antarctic environment from all forms of harmful human interference.”

It would therefore seem that CCAMLR Parties have an obligation to manage their harvesting and associated activities within the
Convention Area, so as to avoid the introduction of non-native species at least if their introduction carries a risk of irreversible changes in the marine environment, and, in that regard, at a minimum, to assess the potential impacts of introduced species in the Convention Area. Whether this obligation has been met by the Parties is hard to judge however, given that, to date, the matter of non-native marine species has not received any significant attention at any of the annual CCAMLR meetings. However, with non-native species introductions being addressed more proactively by the Antarctic Treaty Parties, these provisions of CCAMLR may, in future, take on a more active obligation.

The Protocol

Between 1964 and 1991, other than implementation of Article IX of the Agreed Measures, very little further attention was paid to the issue of non-native species at the political level. In 1991 the Treaty Parties adopted the Protocol, which was intended to provide a comprehensive environmental protection regime for Antarctica. To that extent the Protocol, which entered into force in 1998, brought together and superseded many earlier environmental provisions that had been adopted by the Parties, including the 1964 Agreed Measures.\(^\text{12}\)

Annex II to the Protocol deals specifically with the conservation of Antarctic Fauna and Flora and Article 4 of Annex II deals with the issue of non-native species. To a large extent the authors of the

\(^{12}\) Annex II and Annex V to the Protocol between them superseded the provisions of the 1964 Agreed Measures.
Protocol transcribed the provisions of Article IX of the Agreed Measures into Article 4 of Annex II to the Protocol, which provides for:

- a prohibition on the introduction of non-native animals or plants onto land or ice shelves, or into water in the Antarctic Treaty area except in accordance with a permit;
- a restriction on the types of animals and plants that may be permitted;
- removal or disposal of a permitted species, prior to expiration of the permit, by effective means in order to eliminate risk to native fauna or flora;
- a banning of dogs from 1 April 1994; and
- an exemption for food.

The notable differences between Article IX of the Agreed Measures and Article 4 of Annex II to the Protocol is that the latter includes provisions for the destruction/removal of non-native species that have been permitted, as well as a prohibition on the introduction of dogs, and a requirement to remove all existing dogs in Antarctica by 1 April 1994 (which was achieved).

It is clear that the primary focus of Article 4 of Annex II is the regulation of intentional introductions of non-native species. The exception to this last comment is Article 4(6) of Annex II, which requires precautions to be taken to “prevent the introduction of microorganisms not present in the native fauna and flora”. The reason why this article focuses on microorganisms is not clear, particularly when
so little is known about what species are present in the native fauna and flora.

The need to take broad measures to prevent the unintentional introduction of non-native species is not explicitly stated anywhere in the Protocol. The Protocol does, however, contain provisions that imply the need to take precautions to prevent unintentional introductions. For example, Article 3 of the Protocol states that activities in the Antarctic Treaty area shall be planned and conducted so as to avoid, inter alia:

- detrimental changes in the distribution, abundance and productivity of species and populations of species of fauna and flora;
- further jeopardy to endangered and threatened species and populations of such species; and
- degradation of, or substantial risk to, areas of biological, scientific, historic, aesthetic or wilderness significance.

As the introduction of non-native species poses one of the greatest threats to biodiversity in Antarctica as elsewhere, this provision would seem, at a minimum, to create an obligation on Treaty Parties to give careful consideration to the risk of the introduction of non-native species through their activities and to plan and conduct those activities so as to eliminate or minimise the risk of any such introductions.

At present, the only specific provision that might be considered to be relevant to the prevention of unintentional introductions of non-native
species (and then only in relation to the marine environment) is Annex IV, Article 9, which requires vessels of Treaty Parties operating in the Treaty Area to have:

“…sufficient capacity on board for the retention of all sludge, dirty ballast, tank washing water and other oily residues and mixtures, and have sufficient capacity on board for the retention of garbage, while operating in the Antarctic Treaty area and have concluded arrangements to discharge such oily residues and garbage at a reception facility after leaving that area.”

This provision may assist in minimising the introduction of non-native marine species, e.g. by preventing the disposal of garbage at sea, but this is not its main purpose. Annex IV does not, however, mention non-native marine species per se, and says nothing for example about the issue of hull fouling.

Annex V to the Protocol deals with area protection and management and provides for the designation of terrestrial and marine protected areas. Any area, including any marine area, may be designated as an Antarctic Specially Protected Area (ASPA) or an Antarctic Specially Managed Area (ASMA). An ASPA may be approved to protect outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or ongoing or planned scientific research. An ASMA may be approved to assist in the planning and co-ordination of activities, avoid possible conflicts, improve co-operation between Parties or minimise environmental impacts.
In the case of ASPAs, any such areas should include the need to keep areas inviolate from human interference,\textsuperscript{13} examples of major ecosystems,\textsuperscript{14} areas with important and unusual assemblages of species\textsuperscript{15} and the type locality or only known habitat of any species.\textsuperscript{16}

Whilst Annex V does not specifically refer to the need to protect areas from the introduction of non-native species, Article 5 of the annex provides for management plans for ASPAs to include restrictions on materials and organisms which may be brought into any protected area.

**Discussion**

Taken together, these various provisions of the Protocol, might be considered to provide sufficient means for managing the issue of non-native species in Antarctica. However, those provisions of the Protocol that explicitly address the issue of non-native species, (i.e. those found in Annex II), only appear to address intentional, and therefore by inference, already controlled, introductions. The remaining provisions deal with the issue only implicitly, with few direct obligations placed on Parties to tackle the issue.

The Protocol was specifically designed to allow for modifications and amendments to be made to it. As such, further consideration may need to be given as to whether the existing provisions adequately

\textsuperscript{13} Protocol, Annex V, Article 3(2)(a)  
\textsuperscript{14} Protocol, Annex V, Article 3(2)(b)  
\textsuperscript{15} Protocol, Annex V, Article 3(2)(c)  
\textsuperscript{16} Protocol, Annex V, Article 3(2)(d)
address the issue of unintentional introductions of non-native species to Antarctica, or if more explicit obligations should be included.  

OTHER INTERNATIONAL LEGAL INSTRUMENTS, AGREEMENTS AND INDUSTRY ARRANGEMENTS

Outside of the Antarctic region, there are numerous international treaties, agreements and arrangements that, to varying degrees, address the issue of conservation of biodiversity and control of non-native species. Table 1 (CBD 2001) provides a summary of these international legal agreements. The key treaties that specifically address the issue of non-native species are the Convention on Biological Diversity 1992 (CBD), the United Nations Convention on the Law of the Sea 1982 (UNCLOS) and the International Convention for the Control and Management of Ships Ballast Water & Sediments 2004 (Ballast Water Convention). While none of these contain provisions of specific application to the Antarctic Treaty Area, review of these external legal instruments is a means of assessing current international legal thinking and best practice on the issue.

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17 It is noted that the issue is beginning to receive greater attention within the Antarctic Treaty arena. Several papers on the issue have been tabled at recent meetings of the Committee for Environmental Protection (e.g. ATCM XXIII / WP32 (Australia); ATCM XXVIII / WP28 (Australia); ATCM XXIX / WP5rev.1 (UK); ATCM XXIX / WP13 (New Zealand); ATCM XXIX / WP37 (SCAR); The Committee has also placed the issue as a standing item on its agenda.


International Agreements

The Convention on Biological Diversity 1992 (CBD)

The most comprehensive of the international agreements related to protection of biodiversity is the CBD. The objective of which, found in its Article 1, is “…the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources…”

Under the CBD, governments agree to:

- prepare national strategies and action plans;
- identify genomes, species, and ecosystems crucial for conservation and sustainable use;
- monitor biodiversity and factors that are affecting biological systems;
- establish effectively managed systems of protected areas;
- rehabilitate degraded ecosystems;
- exchange information;
- conduct public information programmes; and
- various other activities for implementing the objectives of the CBD.

On the specific issue of invasive alien species the convention itself is reasonably succinct. Article 8(h) of the CBD calls on Parties to “prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species.”
Despite the legal brevity, the issue of invasive alien species has been the focus of considerable attention by the Conference of the Parties (COP) to the CBD, which has recognized that there is an urgent need to address the impact of invasive alien species. Steps toward eradication, control, and mitigation of impacts combined with legislation and guidelines at national, regional and international levels were addressed during COP 6 (2002), which adopted Decision VI/23, which, *inter alia*:

- recognised that invasive alien species represent one of the primary threats to biodiversity, especially in geographically and evolutionary isolated ecosystems;
- called upon Parties to develop national invasive alien species strategies and action plans;
- urged Parties to co-operate internationally;
- encouraged increased collaboration and co-operation with the Global Invasive Species Programme; and
- adopted fifteen “Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species that Threaten Ecosystems, Habitats or Species”.

In its Decision VII/13 COP 7 (2004) invited Parties to the CBD, as well as national, regional and international organisations to (*inter alia*):

- improve the coordination of regional measures through the development of regional standards, risk analysis and co-operation mechanisms;
incorporate invasive alien species considerations, monitoring, reporting and notification of new threats into regional agreements and other instruments.

Whilst the unique jurisdictional status of Antarctica makes it difficult to directly apply the CBD to the Antarctic Treaty area, the Antarctic Treaty Parties may benefit significantly from close examination of work done under the auspices of the CBD on the issue of invasive alien species (CBD 2001). Indeed this may provide a useful model for the Treaty Parties to consider. The text of the convention itself is relatively brief in relation to invasive alien species, but the CBD Parties have expanded upon those provisions through decisions adopted at COP meetings and a range of practical implementation tools such as guiding principles, guidelines and reporting and information sharing processes.

In 2000, the CBD undertook a comprehensive review of the efficiency and efficacy of existing legal instruments applicable to invasive alien species. This review found that “many international instruments reference the subset of alien species that may have undesired environmental or economic impacts.” But while many instruments reference alien species, “only a few have developed guidance for effective implementation.” The review found that there are “gaps, overlaps and inconsistencies…at all levels.” So while lessons may be learned from these international legal instruments and agreements, Antarctic Treaty Parties should take note of areas where there are opportunities for improvements.
The aim of UNCLOS as stated in its Preamble is to:

“[p]rovide a legal order for the seas and oceans which will facilitate international communication, and will promote the peaceful uses of the seas and oceans, the equitable and efficient utilisation of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment”.

UNCLOS specifically addresses the protection and preservation of the marine environment in its Part XII. The general obligation for the protection of the marine environment is outlined in Article 192 which provides that “[s]tates have the obligation to protect and preserve the marine environment.” Further, Article 196 of UNCLOS requires Parties:

“to take all measures necessary to prevent, reduce and control the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto.”

Whilst the unresolved nature of the Antarctic territorial claims situation complicates the relevance of this provision in respect of coastal state duties, it creates a clear and relevant obligation for all flag states whose vessels operate in the Southern Ocean. It may also provide an impetus to address the issue in more specific terms in the context of the Southern Ocean marine environment.
It is also worth recording that a number of regional seas agreements (such as those pertaining to the Caribbean, the Southeast Pacific and the Mediterranean) contain provisions to minimise or prohibit introductions of alien species, though nothing is yet in place for the Southern Ocean.

**The International Convention for Control and Management of Ship’s Ballast Water & Sediments 2004 (Ballast Water Convention)**

The International Maritime Organization (IMO) has begun to address the issue of marine transport of alien species. The Ballast Water Convention is not yet in force, but aims to:

“…prevent, minimise and ultimately eliminate the risks to the environment, human health, property and resources arising from transfer of harmful aquatic organisms and pathogens through the control and management of ships’ ballast water and sediments”.

Once in force, this convention will apply equally to vessels of states parties operating in the Southern Ocean. It is worth recalling that IMO has in the past agreed “special area” provisions for Antarctica (under MARPOL 73/78). Consideration might therefore be given to seeking IMO’s approval to similar provisions under the Ballast Water Convention that may, for example, introduce a prohibition on ballast water exchange in the Antarctic Treaty area, significantly strengthening the provisions of Annex IV to the Protocol discussed above.
It is also noted that there are currently no international agreements in place to deal with the issue of hull fouling despite the high risk that this carries in relation to transport of alien species. It might also be argued that the International Convention on the Control of Harmful Anti-fouling Systems on Ships (IMO 2005) may be inadvertently increasing the risks associated with hull fouling.

**Industries and sectors**

**Aviation**

The International Civil Aviation Organisation (ICAO) has recently recognised aviation as a significant pathway for dissemination of alien species. ICAO’s Resolution 35-19 (2004) urged its member states to support efforts to reduce the risk of introducing, through civil air transport, potentially invasive alien species to areas outside their natural range. ICAO has also addressed the issue of aircraft disinsection to help minimise the transportation of insects, particularly those carrying diseases (e.g. mosquitoes and malaria).\(^{21}\)

The extent to which aircraft pose a risk of introducing non-native species into the Antarctic region needs to be assessed. Aircraft are used to support the logistics and field operations of most of the National Antarctic Programmes. These aircraft carry passengers and cargo inter-continentally as well as intra-continentally. Helicopters also operate from ships to areas of land in the Antarctic and subantarctic.

\(^{21}\) See for example: ICAO ASSEMBLY – 36\(^{\text{th}}\) Session. Executive Committee - AGENDA ITEM 18.
**Tourism**

Under the CBD, the Parties have developed international guidelines for activities related to sustainable tourism development in vulnerable terrestrial, marine and coastal ecosystems and habitats of major importance for biological diversity and protected areas, including fragile riparian and mountain ecosystems. The CBD Guidelines on Biodiversity and Tourism Development recognise that impacts of tourism in relation to the environment and biological diversity “may include increased risk of introduction of alien species”, and note that “impact management for tourism development and activities can include the adoption and effective implementation of policies, good practices and lessons learned that cover, *inter alia*, preventing the introduction of alien species as a result of the construction, landscaping and operating of tourism activities, including, for example, from shipping associated with tourism” (CBD 2004).

In an Antarctic context the Treaty Parties have adopted Tourism Guidelines (Recommendation XVIII-1) that oblige tourists not to “bring non-native plants or animals into the Antarctic such as live poultry, pet dogs and cats or house plants”. However, as with the Protocol itself, little is currently in place to control unintentional introductions through tourism, and the industry remains largely self-regulating with respect to its operations.
Science

The majority of infrastructure, operations and logistics in the Antarctic are used to support scientific research activities. While the overall number of scientists and support staff is lower than the overall total number of tourists that visit the Antarctic each year, the number of person hours associated with supporting scientific research in the Antarctic far outweighs the number of person hours of tourists on the Antarctic continent. As awareness of the issue increases, a number of National Antarctic Programmes are now beginning to investigate the risks of the introduction of non-native species associated with their activities.

External to the Antarctic, an Ad Hoc Technical Expert Group (AHTEG) on invasive alien species produced a report which was an exhaustive analysis of gaps and inconsistencies in the international regulatory framework in relation to invasive alien species (UNEP 2005). This report recognised that a pathway for unintentional introductions of non-native species was scientific research. This clearly is a key issue to consider in the context of Antarctica.

Other International Guidelines

In addition to those noted above, there are other more generic guidelines and codes of conduct that have been prepared. Of these it is perhaps worth noting in particular the IUCN’s Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion (IUCN
These guidelines recommend that, at the international level, governments should:

- Implement the provisions of international treaties (notably the CBD);
- Implement decisions taken by Parties to specific global and regional conventions;
- Consider the need for further agreements on a bilateral or multilateral basis to control introductions of alien species;
- Consider the desirability of co-operative action, including information sharing and response actions, to prevent movement of alien species across borders; and
- Generally develop international co-operation to prevent and combat damage caused by alien invasive species.

IUCN's Environmental Law Centre has also developed a Guide to Designing Legal and Institutional Frameworks on Alien Invasive Species (Shine, Williams & Gundling 2000).

In the marine context the International Council for the Exploration of the Sea (ICES) has begun to address the issue of alien marine species through its Working Group on Ballast and other Shipping Vectors which has developed a Code of Practice on the Introductions and Transfers of Marine Organisms (ICES 2004). This too may have practical application in an Antarctic context.
National Legislation

A number of countries have developed national legislation to manage and control the introduction of invasive alien species within national borders. New Zealand’s Biosecurity Act 1993 (as amended) invests powers in key officials and bodies at the national and local level; places controls on the importation of goods arriving by air and sea; provides for the development of national and regional pest management strategies; as well as setting out enforcement provisions, offences and penalties. New Zealand is also one of the first countries to develop a national Biosecurity Strategy (NZ Biosecurity Council 2003). Hereto, lessons and experiences learnt at the national level may be called upon in the development of provisions applicable to Antarctica.

CONCLUSIONS

The Antarctic Treaty Parties recognised the risk and the potential consequences of the introduction of non-native species into Antarctica as early as 1964, and formally addressed the issue with the adoption of the Agreed Measures in that year. But the focus at the time was the control of intentional introductions. Apart from the issuing of permits for the purpose of controlling intentional introductions little was done under the Agreed Measures to address the wider issue.

The provisions on non-native species included in the Protocol of 1991 are similar to those of the Agreed Measures 1964 and, in practice, little
attention has so far been given to the risks and potential significance of unintentional introductions.

In other parts of the world the damage caused by the introduction (intentional and unintentional) of non-native species has become increasingly apparent. As a consequence a number of international agreements have recognised the issue and attempted to address it to a greater or lesser extent. The steps taken range from statements of high-level, legally binding obligation, through more detailed standards and guidelines, to recommended strategies and the sharing of best practice. For the most part, however, the issue is being dealt with in a highly sectoral way and gaps appear to remain (for example the issue of hull fouling).

A number of countries, including New Zealand, have adopted strategies, backed by legislation, to control and manage the introduction of non-native species into areas under national sovereignty or jurisdiction. These strategies include information campaigns, the introduction of new technology in such areas as the testing of ballast water, improved record keeping, the systematic collection of baseline data and improved monitoring and surveillance systems.

It has become clear that the relative remoteness of Antarctica and the harshness of its climate cannot be relied upon to protect it from the threat of the introduction of non-native species and especially unintentional introductions. It seems highly desirable that, consistent with their history of tackling issues proactively before they become
major problems, the Antarctic Treaty Parties look to take further preventive action.

In considering such further preventive action at this point the ATS has some clear advantages. First, it can draw upon a range of international and national experience with different models in different sectors. Second, because it has appropriate existing decision making structures and a history of international cooperation it has an opportunity to develop a comprehensive regime to cover all key pathways, species and environments (marine, terrestrial and freshwater).

It is too early to offer prescriptions about the process that might be followed, the phases of that process or the elements that should be included in such a regime, but a few broad points may be in order.

In terms of process, it is obvious that substantial work is involved in assembling, analysing, and assessing in an Antarctic context, the rules and practices that have been developed elsewhere. Within the ATS the CEP might be best placed to lead this, but it will be important also to find appropriate ways of involving CCAMLR. It will be equally important to enlist the assistance and cooperation of other international agencies and organisations, such as the IMO for example with respect to ballast water exchange in the Treaty area.

An early phase of the process should include promotion of awareness of the issue and encouragement of the sharing of best practice. This should not be confined to the Treaty Parties themselves but should
include others with a direct interest such as IUCN and relevant tourism organisations. This initial phase may give rise to immediate improvements in management perhaps based on interim practice guidelines developed through the CEP.

The essential elements of the regime will become clearer through the process itself, though a significant element is likely to include an ongoing commitment to education, awareness raising, and continuous improvement. Constant vigilance will be a critical component if any regime is to remain effective. It will never be sufficient to put in place a set of specific rules relating to standards of behaviour and assume their implementation will ensure the issue has been dealt with successfully.

Education and continuous improvement in practice and procedure will be important components of a successful regime, so too will be a commitment to the collection of appropriate baseline data at key sites and monitoring against that data.

This is not to suggest that education, an exhortation to continuous improvement and some effective monitoring is all that is needed. They will be an important step in the prevention of introductions of non-native species and they have the advantage that their commencement is not dependent on the conclusion of a legal instrument. But in the longer run, there should be a commitment to them that forms part of a set of legally binding obligations that may include substantive rules as well as processes for updating those rules in a timely manner to take
account of developments both in Antarctica and in other parts of the world.

The establishment of commitments in legally binding form would be an important manifestation of the commitment of the Treaty Parties to being proactive on the issue, to setting standards for themselves of an appropriately precautionary kind and to taking collective steps to secure compliance by the wider international community. It would also reflect the fact that, when it comes to the damage that can be caused by the introduction of non-native species, prevention is much easier than cure and nowhere is that more likely to be the case than Antarctica.

The form or forms these legally binding measures should take is a matter to be worked out in due course but, as noted above, it will be important to ensure that they apply to all environments.

REFERENCES


<table>
<thead>
<tr>
<th>Instrument</th>
<th>Status</th>
<th>Relevant Provisions/Resolutions</th>
<th>Species / Ecosystems Covered</th>
<th>Vectors / Pathways Covered</th>
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<tr>
<td>1. Convention on Biological Diversity (Nairobi, 1992)</td>
<td>Binding (1993) (1993) (Parties - 179) Non-binding guidance (2000) Date of adoption 29.01.2000</td>
<td>To prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species Art. 8(h). The safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the and sustainable use of biological diversity (Art. 1)</td>
<td>All</td>
<td>All (no specific provisions)</td>
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<td>United Nations Convention on the Law of the Sea (Montego Bay, 1982)</td>
<td>Binding (1994) (Parties - 135)</td>
<td>To prevent, reduce and control pollution of the marine environment resulting… the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes. (Art. 196)</td>
<td>Marine environment</td>
<td>No Specific Provision</td>
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<td>Convention on Wetlands of Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, 1971)</td>
<td>Binding (1975) (Parties - 123)</td>
<td>COP7/Resolution VII.14 “Invasive Species and Wetlands” (No specific provisions in the Convention text)</td>
<td>Wetlands, and wetland species</td>
<td>No Specific Provision</td>
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<td>4. Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979) <a href="http://www.wcmc.org.uk/cms/">http://www.wcmc.org.uk/cms/</a></td>
<td>01.11.1983 (Parties - 70)</td>
<td>To prevent, reduce or control factors that are endangering or are likely to further endanger Appendix 1 species, including strictly controlling the introduction of, or controlling or eliminating, already introduced exotic species. Art. III (4) (c)</td>
<td>All species and their habitats</td>
<td>No Specific Provision</td>
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<td>5. Convention on the Law of the Non-Navigational Uses of International Watercourses (New York, 1997) <a href="http://www.un.org">http://www.un.org</a></td>
<td>Not in force</td>
<td>To prevent the introduction of species, alien or new, into an international watercourse, which may have effects detrimental to the ecosystem of the watercourse resulting in significant harm to other watercourse States. (Art. 22)</td>
<td>International watercourse marine and freshwaters</td>
<td>no specific provisions</td>
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<td>Standards recognized by WTO</td>
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| 8. The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (Marrakech, 1995) http://www.wto.org/english/tratop_e/sps_e/spsagr.htm | 01.01.1995 (Parties - 132) | Provides a uniform framework governing the adoption of sanitary and phytosanitary measures applied to protect human, animal or plant life or health. | Pests and diseases affecting human, plant and animal health | Trade in goods and products |
| **9. International Health a, 1982, adopted by the 22nd World Health Assembly amended by world Health Assembly in 1973, and the 34th World Health Assembly in 1981)** [http://www.who.int](http://www.who.int) | **Under revision (expected completion: 2002)** | **Purpose is to ensure the maximum security against the international spread of diseases. Goals are to: (1) detect, reduce or eliminate sources from which infection spreads; (2) improve sanitation in and around ports and airports, and (3) prevent dissemination of vectors.** | **Diseases affecting human health. Specifically cholera, plague and yellow fever** | **International traffic** |


<p>| <strong>11. Code of Practice on Transfers of Marine Organisms (ICES/EIFAC 1994)</strong> | <strong>Non-binding</strong> | <strong>Recommends practices and procedures to diminish risks of detrimental effects from marine organism introduction and transfer, including those genetically modified. Also applicable to freshwater organisms. Requires ICES members to submit a prospectus to regulators, including a detailed analysis of potential environmental impacts to the aquatic ecosystem.</strong> | <strong>All aquatic ecosystems</strong> | <strong>Direct introductions including for fisheries and aquaculture</strong> |</p>
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<th>12. Code of Conduct for Responsible Fisheries (FAO, 1995) <a href="http://www.fao.org/fi/agreement/codecond/ficonde.asp">http://www.fao.org/fi/agreement/codecond/ficonde.asp</a></th>
<th>Non-binding</th>
<th>Sets out principles and international standards for responsible fishing practices, including aquaculture, including: Pre-introduction discussion with neighboring states when non-indigenous stocks are to be introduced into transboundary aquatic ecosystems.; Harmful effects of non-indigenous and genetically altered stocks to be minimized.</th>
<th>Aquatic ecosystems</th>
<th>Direct introductions including for fisheries and aquaculture</th>
</tr>
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<td></td>
<td>14. The Biological and Toxin Weapons Convention (signed in 1972, and entered into force in 1975) <a href="http://projects.sipri.se/cbw/docs/bw-btwc-mainpage.html">http://projects.sipri.se/cbw/docs/bw-btwc-mainpage.html</a></td>
<td>Binding</td>
<td>To prohibit the development, production and stockpiling of biological and toxin weapons, and destroy them for the protection of populations and the environment.</td>
<td>Microbial and other biological agents used as weapons</td>
<td>Various</td>
</tr>
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**Table 1** Major global instruments related to invasive alien species.  
ANTARCTIC QUARANTINE MANAGEMENT: AUSTRALIA’S FRAMEWORK AND PRACTICE

SANDRA POTTER1 AND TOM MAGGS2

ABSTRACT

The Protocol on Environmental Protection to the Antarctic Treaty (Protocol) requires that parties to the Antarctic Treaty do not introduce animals or plants to the Antarctic Treaty area other than for specified purposes. The manner by which this requirement is practically achieved has yet to be collectively agreed. So, to date, parties have individually developed and applied measures that they consider will provide the Antarctic with an appropriate level of protection. The Australian Antarctic Division has developed a quarantine management system for Australia’s Antarctic Program. This paper describes the principles underpinning those quarantine practices currently in place.

INTRODUCTION

Australia is one of the original signatories to the Antarctic Treaty and is an active Consultative State member of the Antarctic Treaty System (ATS). The Australian Antarctic Division (AAD) is the agency of the

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2 Australian Antarctic Division.
Department of the Environment and Water Resources that is responsible for advancing Australia’s Antarctic interests. This includes, *inter alia*, coordinating and managing Australian Antarctic Program logistics.

The AAD recognises that the movement of aircraft, ships, personnel and cargo in support of activities in the Antarctic, subantarctic and Southern Ocean creates a risk of transferring species, wildlife disease, and material of quarantine concern. The AAD is therefore committed to administering and conducting its activities in a way that will prevent or minimise such risks, consistent with the principles of the Protocol including its annexes, in particular, on the protection of fauna and flora, and waste management.

In the 1990s the AAD’s quarantine management efforts were limited to the pre-shipment inspection of fresh produce, cleaning of footwear and outer clothing prior to landings at subantarctic islands, restricting the use of poultry products in the Antarctic and subantarctic, and restricting the supply of specific vegetables to the subantarctic islands.

Practices have since been revised and broadened to cover a wider range of potential pathways for introductions (see Potter 2006). The AAD’s cargo packing operations have been relocated to a dedicated ship-side facility certified as a Quarantine Approved Premise by the Australian Quarantine and Inspection Service (AQIS). Cargo undergoes routine cleanliness checks and all AAD-chartered ships, aircraft and small watercraft undergo pre-departure inspections. Aircraft are disinfected, polar clothing issued to program personnel
has been modified (e.g. to minimise the use of Velcro which can harbour seeds) and expedition personnel are comprehensively briefed on quarantine issues. These strengthened measures have been developed in response to a concerning increase in the number of reports of invertebrates and organic matter amidst food and other cargo sent to Australia’s Antarctic and subantarctic stations, and with reference to research and the quarantine procedures in place for other sites of high conservation value.

The documentation of policy praxis in relation to natural areas and non-indigenous species is desirable as it has the potential to expose assumptions, facilitate the assessment of the adequacy of management actions, provide for organisational continuity when managers change, and facilitate review processes as new knowledge surfaces, or conditions and values change (Schwartz & Randall 1995).

While the principles underpinning the AAD's quarantine management system may have long been “understood” by AAD managers, they have only recently been documented. These principles are identified and discussed below.
QUARANTINE MANAGEMENT PRINCIPLES

Quarantine management for Australia’s Antarctic Program should reflect excellence and leadership in the development and implementation of policy and procedures.

This overarching principle reflects the AAD’s Environmental Policy, aspirations to the adoption of best practice environmental management, and the Australian Government’s Antarctic policy objectives of protecting the environment of, and influencing developments in, a region geographically proximate to Australia (AAD undated; AAD 2005).

Public education and the training of program personnel should be integral components of protection measures.

Training and effective self-regulation are considered keys to achieving environmental protection outcomes in the Antarctic. The attention given by individuals to cleaning and checking their personal effects and other gear is therefore of paramount importance in minimising accidental introductions through human activities; significant propagule loads have been reported on the clothing and footwear of expeditioners prior to mandatory pre-landing cleaning sessions (see Whinam, Chilcott & Bergstrom 2005).

Information about quarantine issues and the need to only pack and wear gear that is free of soil, seeds and other material of quarantine concern is delivered in a number of ways. Prior to travelling, program
participants receive documents explaining their environmental, including quarantine, obligations. They also participate in pre-departure and or shipboard training that involves a mix of formal lectures and hands-on gear checking and cleaning. The theoretical content of this training responds to the types of perceptions identified in a survey by Renkin (1996) – that “nothing would survive down here anyway” and that “measures are really only warranted for the Sub-Antarctic.”

Quarantine-aware program personnel are also well-placed to observe and report on the efficacy of quarantine processes more broadly. The reporting of incursions has been facilitated by the development of a simple-to-use, web-based, incident notification system. Since the system’s inception in 2003, some 30 separate post-departure quarantine incursion reports have been logged by station personnel. Most reports have been findings of invertebrates in food – both dry stores and fresh produce.

**The technical expertise of individuals and organisations with relevant quarantine experience or roles should be sourced and utilised.**

While Australian Antarctic Territory is excluded from Australia’s national quarantine arrangements and instruments including the Quarantine Act 1908, Quarantine Proclamation 1998 and Quarantine Regulations 2000, the AAD recognises that national and domestic quarantine services offer a wealth of knowledge and experience that may be tapped into to enhance the biosecurity of Antarctic operations.
Protocols and procedures successfully adapted for Antarctic operations include those related to aircraft and cargo fumigation, mail screening, food export inspections, port surveillance, container inspection, the use of quarantine detector dogs, and, most recently, the development of quality assurance programs for contractors.

National quarantine goals and policies may be inappropriate though, for direct translation. For example, the objective of Australian biosecurity is the prevention or control of the entry, establishment or spread of pests and diseases that could cause significant damage to human beings, animals, plants, other aspects of the environment, or economic activities, whereas, in addition to biodiversity conservation, Antarctic quarantine measures also need to factor the Protocol’s specific recognition of the intrinsic value of Antarctica and its value as an area for the conduct of scientific research.

**Protection measures for the Antarctic and subantarctic should be employed regardless of whether a species or disease has been determined unable to establish or cause environmental harm.**

This precautionary approach recognises that making quantitative predictions about the ability of species to establish is very difficult – a position widely acknowledged in the literature. It also recognises the advantages of taking practical measures to prevent an introduction over costly and difficult eradication or control responses. Responding to, say, a human-introduced disease outbreak or marine pest invasion, or even a small fly introduced and confined to a station’s infrastructure, can be especially challenging in Antarctica (see e.g. Smith 2005).
High standards of quarantine management should be delivered while maintaining operational efficiency in the logistical support of activities; quarantine protection measures should be commensurate with the magnitude and scale of operations.

The costs of establishing and maintaining scientific stations in Antarctica are high, making the prudent use of resources an especially important planning consideration. Quarantine processes that, for example, entail significant expenditure for potentially minimal returns (as may be the case for the lay-up of ships in fresh water as a hull fouling mitigation strategy), or could result in significant re-supply delays (as may be the case for the pre-loading fumigation of all south-bound cargo), or could compromise the safety of program personnel, are unlikely to be acceptable.

Quarantine protection measures should be focussed on preventative action and reflect a multiple-barrier approach.

A consistent theme in both the conservation biology and environmental management literature is the desirability of avoiding the need for resource-intensive, post-invasion control or eradication activities (e.g. Ruiz & Carlton 2003; SSC 2000; Wittenberg & Cock 2001). A focus on pre-border or “off shore” quarantine measures as a first line of defence, is consistent with prevention. To this end, the AAD has adopted the point of departure for the Antarctic as the preferred opportunity for the implementation of quarantine measures.

The need for a staged or multiple barrier approach – argued by Nairn et al. (1996) and otherwise referred to as the continuum of quarantine
– is also recognised. Using the import of fresh food into Antarctica as an example: the tender documentation provided to the AAD’s provedores, and in turn by the provedores to their suppliers, stipulates that fruit and vegetables are to be delivered free of invertebrates, soil and other biota; a third party inspection of the produce occurs before it is packed; ozone-generating units are deployed in the refrigerated containers transporting the produce to Antarctica; and station chefs are required to report on the quality of goods received. Finally, any scraps and spoiled fruit and vegetables are incinerated and the ash returned to Australia.

Organisational system failures may occur as a result of communication issues, insufficient incentives to complete tasks, unanticipated time pressures resulting in trade-offs, resource constraints, differing attitudes to risk, and the capabilities and personalities of individuals involved in quarantine processes (e.g. in attentiveness to details, delivering training programs, or comfort levels in policing practices). Where human behaviours are not taken into account, risks may be greater than otherwise calculated (Freudenburg 1988). The logic applied here in response is that the more quarantine checks and balances that there are in place, the greater is the likely level of success.
The use of methyl bromide and other quarantine treatments associated with adverse environmental impacts and human health should be minimised.\(^3\)

The Montreal Protocol on Substances that Deplete the Ozone Layer 1987 targets methyl bromide for phase-out. While some of its uses for quarantine and pre-shipment purposes are currently exempt, an AAD aim is to avoid its use altogether or, at the very least, ensure that the minimum effective application rates are adopted.

Marine paints used to retard hull fouling are another treatment associated with adverse environmental impacts. The leaching of tributyltin from these, for example, has had extensive impacts on aquatic organisms (ANZECC 2000) and is now banned under the International Convention on the Control of Harmful Anti-fouling Systems on Ships 2001.

This principle recognises that in selecting quarantine treatments there is a need to reconcile the benefits the treatment offers with the potential adverse impacts associated with the treatments. A similar approach is required under the Protocol for the clean up of past waste disposal sites in Antarctica.

\(^3\) Note: regulations on methyl bromide usage have changed since the workshop in April 2005 and since the submission of this paper for publication.
AAD’s quarantine management procedures and performance should be monitored, evaluated and improved upon as a component of AAD’s Environmental Management System.

Central to conservation practice and the pro-active management of areas of high conservation value is the evaluation of management effectiveness, and the application of the results of evaluations (CBD 2004).

This “continuous improvement principle” acknowledges the need to review protection measures regularly as new threats and pathways for introductions are identified, as quarantine management technologies are advanced, as risks analyses are completed, and as incident trends suggest that existing procedures are insufficient. It also recognises that environmental management systems, and by implication quarantine management systems, are more likely to be effective when they are main-streamed into an organisations’ core business rather than treated as an additional overlay or burden on operations. The AAD has had an ISO 14001-certified environmental management system in place since 2002.

The environmental impact assessment process associated with any intentional imports of biota to the Antarctic and subantarctic region for research purposes should involve a wide consultation process.

The AAD administers Australia’s legislation implementing the Protocol, namely the Antarctic Treaty (Environment Protection) Act 1980. Some
70 environmental impact assessments are assessed by the AAD annually.

As well as being “the regulator”, the AAD is also often “the proponent”. Details of activities for which the environmental impacts are expected to exceed the descriptor of “less than minor or transitory” are therefore published on the AAD’s website and in the Australian Government Gazette. A 30-day period is typically allowed for public comment.

**Research projects having a high potential to facilitate the introduction and spread of biota should be rejected if the risks cannot be adequately mitigated.**

Concern that the activities of scientists may result in accidental species transfer to remote and pristine environments is expressed in the United Nations Environment Program’s Report of the Ad Hoc Technical Expert Group on gaps and inconsistencies in the international regulatory framework in relation to invasive alien species (UNEP 2005). The report identifies scientific research as a potentially significant pathway for introductions, stating: “Researchers may pose a particular risk to biodiversity because they have access to sites of high conservation value that may be closed to the general public, and may carry equipment or organisms to those sites” (UNEP 2005).

Also, researchers may seek to deliberately import species. While applications to permit the taking of non-indigenous species into the Antarctic are not anticipated, intentional imports to the Antarctic and subantarctic for research purposes are not unknown (see e.g.
Edwards 1980; Holdgate 1964). The assessment of requests will need to consider the potential impacts of the import alongside the likely contributions of the research. “The responsibility to understand and study protected and environmentally sensitive areas must not take precedence over our primary obligation: to protect and care for them” (ASTEC 1998).

**Introductions effected through Australian Antarctic Program activities should be eradicated or controlled; eradication should be undertaken where there is significant prospect for success.**

Eradication is usually seen as preferable to control, and may be feasible if a problem is detected sufficiently early. In other circumstances, eradication may not be achievable for technical reasons. This is likely to be the case for the marine environment where few successful eradication efforts have been recorded, and where there is a high potential for non-target species to be impacted by some eradication methods (Peebles 2004).

The AAD is attempting to eradicate a small “mushroom gnat”, *Lycoriella ingenua*, introduced to Casey Station via produce in about 1998. No other Australian introductions are known to have established.
Unauthorised deliberate introductions, and negligence resulting in significant accidental introductions, should be investigated and appropriate action taken.

An AAD environmental policy commitment is that AAD will “comply with all applicable environmental laws and agreements, and require compliance with them by participants in activities supported by the AAD, by other Australian visitors to the Antarctic, and by our contractors and suppliers” (AAD 2005).

The level of stakeholder confidence in the effectiveness of quarantine procedures should be established.

Community interest in the Antarctic region and its protection is high. The report of Professor M. Nairn’s review of Australian quarantine practices makes pertinent comment for Antarctic quarantine, saying, “The formulation of quarantine policies and programs must be a consultative process involving the Australian community. Quarantine policies and programs should not be developed in isolation. In formulating these policies and programs, government officials must understand and consider the concerns and interests of the community” (Nairn et al. 1996).
CONCLUSIONS

There is now agreement within the ATS that the introduction of non-indigenous species to the Antarctic is a significant issue warranting pro-active management. Numerous CEP meeting Working Papers and Information Papers have highlighted disease and non-indigenous species risks (e.g. Australia 1999, Australia 2001a, Japan 1996, IUCN 2005), called for parties to review their operations to ensure non-native species are not introduced (e.g. Australia 1995, Australia 2005, IUCN 1998), and have identified or promoted possible responses (e.g. Australia 1999, Australia 2001b, Australia 2004, IAATO 2005).

The discussion here of the principles and considerations behind Australia’s approach to Antarctic quarantine management may be of interest to other national programs in the refinement of their practices.

REFERENCES


ABSTRACT

The Antarctic region comprises habitats and ecosystems that are clearly unique and characterised by extremes. It is difficult to imagine terrestrial species that could invade such environments, however, while the extremes of climate may currently protect this area, such conditions may not always remain so. With climate change now well recognised, there is a need to pre-empt any foreign species incursion that has the potential to do irreparable harm to the delicate ecosystems in the region. Pest risk assessment methods have an important place in this process. One of the most important components of risk assessment is to determine whether a species is able to establish a viable population in the region. Obviously, abiotic factors, especially climatic variables are the most influential variables determining successful establishment of terrestrial species. If an appropriate risk assessment indicates that it is unlikely a species can establish a viable population under either present or future conditions, that means attention can shift to other species so effort can be prioritised.

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Well used, as well as innovative, predictive methods that have been applied in more temperate regions can be adapted for pest risk assessment for the Antarctic region. A range of methods that have been applied to both terrestrial and marine species and ecosystems are described and examples are given to illustrate their potential use to protect this important area from devastating impacts of alien invasive species.

INTRODUCTION

Assessment of the risk of invasion of alien species into the Antarctic or subantarctic region requires all the tools and methods used to assess the risk of invasive species elsewhere in the world. The Antarctic region comprises habitats and ecosystems that are clearly unique and while most techniques for pest risk assessment discussed here have been applied to species in mainly terrestrial temperate environments, such methods can also be used to assess potential invasions into marine ecosystems and more extreme terrestrial conditions. Some of the examples discussed here have been applied to insects and weeds but can equally be applied to other taxonomic groups such as other invertebrate species, plants, fungi and also bacteria. The methods offer more predictive approaches to pest risk assessment and so provide the opportunity to be pro-active rather than reactive to the threat of non-native species incursion into these ecologically sensitive areas.

Before describing the tools in detail the process of pest risk assessment requires definition and explanation. The definition used here is based on
the framework that is followed by biosecurity agencies in New Zealand (Biosecurity New Zealand 2006) and is based on guidelines provided by the World Organisation for Animal Health, Organisation Internationale Epizooties (OIE), and the Commission for Phytosanitary Measures (CPM) under the International Plant Protection Convention (IPPC). Specifically, pest risk assessment is the second stage of a more encompassing Pest Risk Analysis (PRA) that involves three main steps:

1. Initiation of a full pest risk analysis and identification of a pathway;
2. Pest risk assessment;
3. Risk management.

Within the PRA, the pest risk assessment process also comprises the following sections each of which comprises many steps:

1. Categorization of individual pest species;
2. Evaluation of probability of pest entry, establishment and spread;
3. Evaluation of economic and biological consequences.

Clearly, formal pest risk assessments are very detailed investigations and each aspect requires careful consideration and high-quality data. The methods and techniques discussed here are concerned mainly with tools that can be used to help evaluate the probability of species establishment and spread. Indeed, the complexity of the task is well illustrated by the evaluations required to assess the risk of species entry establishment and spread illustrated in detail in Figure 1.
Mostly, the PRA is a reactive procedure often carried out in response to the interception of an unwanted species in a new area or the importation of a new commodity. A predictive or pre-emptive approach that identifies a new threat so that measures to prevent its establishment can be implemented before it is detected or becomes an unmanageable new incursion, is much more desirable.

PREDICTING INVASIVE SPECIES ESTABLISHMENT

Nearly 190 years of exploration, have given terrestrial alien species many opportunities to establish in the Antarctic region. For most species, as hitchhikers on the equipment and produce transported by numerous expeditions, the extreme conditions are highly unlikely to provide the food or climate to which they are adapted. Naturally, most species have failed to establish. The most immediate concern, however, is the prospect that the harsh Antarctic environment may change to become more amenable to more species, increasing the probability of establishment of foreign invaders. Moreover, the growth of tourism brings more shipping into the region increasing the risk of marine organisms arriving that are capable of devastating impact on the Antarctic marine ecosystem. Obviously, it is important to identify the species that may pose a threat well before they emerge. Identification and prioritisation of potential invaders promotes proactive measures such that pathways are identified and arrival prevented. To prioritise threats, good data are clearly required but are often lacking or insufficient when information about a particular species is scarce. In such cases a pest risk assessment is often based on expert opinion
Traditional Pest Risk Assessment

- Categorisation of the species
- *Assessment of its probability of introduction, establishment and spread*
- Assessment of potential economic/environmental consequences

Figure 1 Breakdown of the steps for the evaluation of the risk of pest entry, establishment and spread (FAO 2001).
Figure 2 Early tools for matching climates using subantarctic island examples. A) Monthly rainfall and temperature profiles for Campbell Island; B) Climatographs comparing different localities.
only, but even with the barest details, there are tools that can be used to inform that opinion.

**Climate Matching, Ecoclimatic Assessment and Ecological Niche Modelling**

**Graphical approaches**

Identification of potential invasive species can be aided by consideration of known invaders elsewhere in the world, particularly if they come from climates or environmental conditions that are analogous to regions in which we are interested in investigating (Peacock & Worner 2006). This means a useful initial step in a PRA is to compare the climate or environmental conditions in the region of interest with similar regions in other parts of the world, to identify potential locations from which an invasive species might originate. This preliminary analysis is based on the assumption that species in analogous conditions are already pre-adapted to conditions in the new location.

There are several ways to do such an analysis. The earliest techniques applied to the terrestrial environment were most often graphical models called climatographs. There are basically two types: One, mean monthly temperatures are plotted against mean monthly humidity or rainfall totals (Figure 2A); and, two, mean monthly temperatures and rainfall profiles from different localities are depicted on the same graph such that they can be compared in shape and height (Figure 2B). Different climates will produce climatographs of different shapes such that combination of levels of climatic factors at localities where the target species currently
occurs can be compared with climatic features where the species might pose a threat (Worner 1994).

These graphical tools have been used mainly by biological control scientists to determine if biological control introductions are likely to establish in the area of introduction. While a simple visual comparison of climatographs for different localities indicates climate similarity between regions, more recently, quantitative similarity indices are more often used to derive a quantifiable index of climate comparability using approaches such as that outlined by Sutherst et al. (1999) or by application of other well known similarity indices, for example, the Euclidian distance (Krebs 2001). Similarity indices have the advantage that a number of environmental variables can be combined to produce a single metric.

Figure 2B compares the climate for Reykjavik, Iceland, with three islands of the subantarctic region and Casey Station on the coast of the Antarctic continent. Of the three islands, Campbell represents a cold temperate location, Macquarie is classified as a true subantarctic location, and Deception is classified as a maritime location. On the climatograph, areas of difference and overlap are easily identified. For example, it can be seen that Deception Island and Macquarie Island have different temperatures but have very similar rainfall at similar times of the year.

While only two–dimensional representations of the data are possible, additional information can be used to produce eco-climatographs for particular species. For example, Howe & Burgess (1953) created an
eco-climatograph by superimposing a climatograph as shown in Figure 2B, over graphs depicting the relationship of survival and development of the Australian spider beetle, *Ptinus ocellus*, to temperature and relative humidity determined in lab studies allowing more detailed interpretation of why some locations in the world were unsuitable for *Ptinus* development (Worner 1994).

Such graphical methods are, however, not often used today. Even though they are valuable tools for quick assessments of climate or environmental comparability to inform the risk assessment process, it appears these approaches undeservedly fell from favour, overshadowed by the perceived potential for improved prediction provided by more sophisticated statistical analyses and computer models (Worner 1994). Computer models, such as the well used CLIMEX system, provide a Match Climate Function (Sutherst et al. 1999) that automatically calculates climate similarity for a large range of global climates. Peacock & Worner (2006) found the climate matching function in the computer system CLIMEX very useful to identify analogous climates for New Zealand. This approach can easily be improved by using the latest version of CLIMEX and its climate matching function that allows sequential comparison of the climates of regions with the rest of the world to provide a composite result set. CLIMEX can also be used to explore the effects of climate change both on the climate match function and species response to climatic conditions. Unfortunately, the CLIMEX weather database does not include information for any of the subantarctic islands of the Antarctic, but this information can be easily added to the system for future analyses.
Statistical approaches

The climatographs discussed can only represent at most three environmental variables simultaneously. There are a number of straightforward statistical approaches. For example, a multivariate statistical technique such as discriminant analysis can be useful for identifying the environmental limits of species distributions. Given good data, discriminant analysis will identify environmental variables that can discriminate between the presence or absence, of a species in its known distribution. That information can then be used to predict species presence or absence in a new region where it is not normally found and given the appropriate data could be used to determine whether parts of the Antarctic region were suitable for the establishment of species of interest.

For example, Peacock & Worner (2006) used discriminant analysis to identify which climate variables best discriminated between two groups of insect pest species. One group had established in New Zealand and the other group had not. All species in both groups are often intercepted at the border and were assumed to have had considerable opportunity to establish. The discriminant analysis classified the presence/absence sites and Peacock & Worner (2006) found seasonal air temperature, particularly in summer, was found to best discriminate the absence of species that are not established in New Zealand. No individual climate variable, however, could be identified as clearly influential classifying the insect species already established in New Zealand.
In addition, other statistical analyses that could be used to predict species establishment in the Antarctic include ordination techniques such as principal component analysis (PCA). PCA can simplify the interpretation of complex environmental data sets comprised of variables that may be highly correlated. PCA is a data reduction method that can identify smaller and more important combinations of variables that best explain the distributional patterns or variance within data (Manly 1986). For example, the results of a PCA analysis (Peacock & Worner 2005) for the two groups of species described previously are shown in Figures 3 and 4.

A marked difference between the combined global distributions of the two study groups of insect pests is apparent. For the group that has not established in New Zealand the majority of the species tend to occupy the warm/dry and wet/warm sites whereas the distribution of the other group of New Zealand established insect species extends into regions that are dry/cold and wet/cold areas. Peacock & Worner (2005) went further and used scores from the PCA analysis and the results of discriminant analysis to construct binary regression models to predict establishment of all the study species in areas where they are not presently found. These models were also compared with artificial neural network models that are completely new approaches for predicting the distribution of species based on artificial intelligence.

**Computer modelling**

Other detailed ecoclimatic assessment or ecological niche modelling approaches are available, but require more complex computer
modelling. More complex ecoclimatic assessment is provided in CLIMEX (Sutherst & Maywald 1985). Other examples of similar programs more commonly known as ecological niche models are, CLIMATE (Kriticos & Randall 2001), STASH (Sykes 2001), BIOCLIM (Neave & Norton 1998), GARP (Peterson & Vieglas 2001), DISTRIB (Iverson et al. 1999) and many others that are either regression or process based (see Elith et al. 2006; Heikkinen et al. 2006). Of all of these modelling approaches perhaps CLIMEX and GARP are the most well known and have been widely used, but now compete with a wide variety of machine or statistical learning methods (Heikkinen et al. 2006).

CLIMEX uses maximum and minimum temperatures, relative humidity, precipitation and the response of the organism to moisture, temperature and daylight, combined into one, or two, meaningful indices, to indicate the potential for population growth of a species in a particular area. The two indices are the Growth Index (GI) and the Eco-climatic Index (EI). Examples are shown in the following sections. Worner (2002) suggested that a frustration associated with such computer based models is that the climate database is small. The most recent version of CLIMEX has much more detailed gridded climate (New et al. 2002), but unfortunately still does not include climate details of the subantarctic or Antarctic regions. If such detail for the Antarctic were added, CLIMEX is well placed to investigate the effects of climate change on species distributions and could therefore quickly indicate expected conditions in the region.
Insect pests established in New Zealand

Insect pests not yet established in New Zealand

Figure 3 Principal component scores of the combined global distributions of each insect pest (n=21) that are not established in New Zealand and those that have already established in New Zealand (n=15) (Peacock & Worner 2005).
Figure 4 Principal component score plot of the New Zealand climate sites (n=310) (Peacock & Worner 2005).
When one has good abiotic and biotic information on a species then more detailed mechanistic models can be used to predict their distribution and establishment in regions where they are not presently found. For example Pitt et al. (2006) investigated the probability of establishment of gypsy moth in New Zealand based on a detailed phenology model originally developed by Régnière et al. (2002). Pitt et al. (2006) also used the model to predict changes in the distribution of the insect under climate change. Such models only need appropriate climate data and developmental data for the organism concerned to provide useful predictions.

**Ecological Informatics and Computational Intelligence**

While risk assessments of individual species are clearly important there are many hundreds of known global invasive species and just as many unknown species that could become troublesome in the vulnerable ecosystems in the Southern Ocean especially in a changing climate. The question is which species are more likely to pose the greatest threat to a region and thereby deserve a closer analysis of risk? Prioritising species will direct pre-emptive research and help allocate resources. Such prediction may seem impossible but ecological informatics and computational intelligence can help. Computational intelligence is the term applied to computer programs that are able to learn, adapt or evolve. Such programs include artificial neural networks that are particularly good for analysing complex and noisy ecological data.
As an example, Worner & Gevrey (2006) constructed a database on insect pest distribution records from data recorded in the Commonwealth Agricultural Bureaux International (CABI) Crop Compendium (CABI 2003) that includes global distributional information for approximately 10,000 recognised species of insects, diseases and weeds. Their database comprised exclusively the species distributions for 3088 insect pests, recorded over 459 geographic regions throughout the world. Only 800 species of the original 3088, however, were considered to have complete distribution data. With the species grouping or assemblage for each region represented as a column of ones and zeroes indicating species presence or absence, respectively, Worner & Gevrey (2006) were able to group geographic regions that have similar pest species assemblages onto a two-dimensional map based on a slightly different approach to the more traditional method of carrying out a cluster analysis based on some sort of similarity metric.

This approach was to use an artificial neural network called a Self Organising Map (SOM) to detect patterns in the database. Artificial neural networks are computer algorithms designed to mimic the animal brain where the connections between neurons or processing elements become reinforced, or made stronger, the more the model matches the real world. SOMs are excellent pattern detectors, and, over many iterations, the SOM computational algorithms group similar assemblages together and can project these onto a two-dimensional map represented by cells. Because each assemblage represents a geographic region, the regions sharing similar species assemblages are grouped together. For example, New Zealand is grouped with
parts of Australia and many European and Mediterranean countries. That is not unexpected when the origin of most of New Zealand’s crop and garden plants are considered. The result is high-dimensional data is reduced, for easy visualisation, that can often reveal previously hidden predictive information.

Underlying the SOM and associated with each cell, is a “weight” that indicates the strength of association of each species with the assemblage associated with each cell. The weight or strength of the association falls between 0 and 1, with values close to 1 indicating a very strong association with the corresponding assemblage. This means that it is possible to measure how strongly each species is associated with New Zealand’s cell and clearly those species that are most strongly associated with New Zealand’s pest assemblage but are not yet established, deserve closer study. So how can this approach help with predicting species invasion into the Antarctic region?

*Applying the computational intelligence approach to the Antarctic and subantarctic regions*

While the SOM approach provided a useful map to predict association of a species with the New Zealand species assemblage, can such an analysis help predict potential invasive species in the Antarctic region? A recent example of using a SOM analysis in the marine ecosystem to determine analogous sites with respect to environmental variables is given by Leal (2007). Leal collated data comprising 34 environmental variables for 357 ports generated within the International Maritime Organisation (IMO) project, GloBallast. Leal then used a SOM analysis
to group ports that were similar with respect to these environmental variables. Clearly if ports that have been invaded by a new species are grouped with others in the data set then that could indicate those ports that are likely to provide suitable habitat for the invader and the approach could be used to identify marine sites in the Antarctic region that might be susceptible to a new invader given that the necessary data exists.

Using, for example, the oat aphid, *Rophalsiphum padi* as a starting point, the SOM analysis on global insect pest species described previously provides additional information about the strength of association of individual species with the species grouping or assemblages in each region as well as species co-occurrence. Strong associations between species on a global scale and in certain regions could indicate the co-occurrence of suitable environmental conditions as well as indicate the next or most likely invaders. For example, the six phytophagous (plant feeding) insect pest species that co-occur most often globally with the oat aphid are listed in Table 1.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
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<tbody>
<tr>
<td><em>Agrotis ipsilon</em></td>
<td>Black cutworm</td>
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<tr>
<td><em>Plutella xylostella</em></td>
<td>Diamond-backed moth</td>
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<tr>
<td><em>Delia platura</em></td>
<td>Onion or seed corn maggot</td>
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<tr>
<td><em>Acyrthosiphon pisum</em></td>
<td>Pea aphid</td>
</tr>
<tr>
<td><em>Aphis gossypii</em></td>
<td>Melon aphid</td>
</tr>
<tr>
<td><em>Myzus persicae</em></td>
<td>Green peach aphid</td>
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</tbody>
</table>

**Table 1** The six species of phytophagous insect pests that co-occur most often with the oat aphid, *Rophalsiphum padi*. 
So, do these other species co-occur with the oat aphid anywhere in the Antarctic or subantarctic region? Unfortunately, not many invertebrate species lists for the subantarctic islands appear published. The South African National Antarctic Programme (SANAP) website records the naturalized alien insect species of Marion Island (SANAP 2007). The known phytophagous pest species in this list are shown in Table 2.

<table>
<thead>
<tr>
<th>Moths</th>
<th>Diamond-backed moth (<em>Plutella xylostella</em>)</th>
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<tbody>
<tr>
<td></td>
<td>Noctuid moth (<em>Agrotis ipsilon</em>)</td>
</tr>
<tr>
<td>Aphids</td>
<td>Potato aphid (<em>Macrosiphum euphobiae</em>)</td>
</tr>
<tr>
<td></td>
<td>Aphid (<em>Myzus ascalonicus</em>)</td>
</tr>
<tr>
<td></td>
<td>Oat aphid (<em>Rhopalosiphum padi</em>)</td>
</tr>
</tbody>
</table>

**Table 2** Naturalised aliens of Marion Island.

Two co-occurring species indicated by the SOM analysis, also appear in Table 2, the Diamond-backed moth, *Plutella xylostella* and the Noctuid moth, *Agrotis ipsilon*. If other species that co-occur with the Oat aphid are considered (Table 1), *Delia platura* and the aphid, *Myzus persicae* have a wide global distribution (CABI 2003). However, it is interesting that *Delia platura* is recorded from high latitudes in Greenland and Iceland but *Myzus persicae* is not. Does that mean that *Delia platura* is more of a threat than *Myzus persicae* to the subantarctic islands? Clearly, the biology of the species under consideration needs to be taken into account, and in particular, each
species life history parameters. If the secondary hosts of the aphid species are considered, the species that are established in subantarctic regions commonly have grasses as intermediate/over-wintering hosts, whereas those that are not established (on Marion Island at least), for example, *Myzus persicae* has Prunus species as over-wintering hosts. Clearly such species are not present in these high latitudes.

**CONCLUSIONS**

While the methods and tools considered here have been applied to pest risk assessment of mainly terrestrial species and in particular, insects, it should be clear from the examples that given appropriate data they can be usefully applied to most other taxa that have potential to invade terrestrial Antarctic ecosystems. With very little modification, many of the techniques, and in particular the multivariate analyses and computational intelligence approaches can be applied to the marine environment. Because species invasions attract a great deal of research interest worldwide there is constant development and comparison of new types of models that predict species distributions. For example, Elith *et al.* (2006) compare novel methods along with well-established modelling approaches and their ability to predict species distributions from occurrences. They found in general that the novel approaches performed better. That does not mean, however, that well established methods should be ignored. Often they provide predictions that affirm a newer approach or provide some information that adds additional knowledge to the process of pest risk assessment.
Already there is evidence of ecological impacts of recent climate change (Walther et al. 2002) and the recent warming trend (0.5°C) is the likely explanation for the increase in numbers of individuals and populations of terrestrial plants in the Antarctic since the mid-1960s (Smith 1994, cited in McCarty 2001). Model projections over the next 50 or so years suggests a maximum 3°C increase in temperature and much emphasis has been placed on the effect on the existing flora and fauna in the region. Clearly though, among the threats to the Antarctic are species that may change the unique nature of that continent and that could also threaten its marine life.

Prediction and prevention are the most sensible ways to avoid environmental catastrophe caused by the incursion of an aggressive invasive species into such delicate ecosystems. Prevention needs education, information, good operational procedures and monitoring to establish baseline data and to gauge what is happening in similar climates and eco-regions. Prediction requires large amounts of good data, comparative methods, rigorous validation and sensitivity analyses and continued development of new predictive tools, particularly those that can deal with uncertainty and the fuzzy nature of the data and decisions that need to be made.
REFERENCES


## APPENDIX 1
### LIST OF ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADD</td>
<td>Australian Antarctic Division</td>
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<tr>
<td>AFZ</td>
<td>Australian Fishing Zone</td>
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<td>AHTEG</td>
<td>Ad Hoc Technical Expert Group</td>
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<td>AQIS</td>
<td>Australian Quarantine Inspection Service</td>
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<td>ASOC</td>
<td>Antarctic and Southern Ocean Coalition</td>
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<td>ASMA</td>
<td>Antarctic Specially Managed Area</td>
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<td>ASPA</td>
<td>Antarctic Specially Protected Area</td>
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<td>AT</td>
<td>Antarctic Treaty</td>
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<td>ATCM</td>
<td>Antarctic Treaty Consultative Meeting</td>
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<td>ATS</td>
<td>Antarctic Treaty System</td>
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<td>BAS</td>
<td>British Antarctic Survey</td>
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<tr>
<td>BIOROSS</td>
<td>Biodiversity of the Ross Sea</td>
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<tr>
<td>CABI</td>
<td>Commonwealth Agricultural Bureaux International</td>
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<tr>
<td>CBD</td>
<td>Convention on Biological Diversity</td>
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<td>CCAMLR</td>
<td>Convention for the Conservation of Antarctic Marine Living Resources</td>
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<tr>
<td>CEP</td>
<td>Committee for Environmental Protection</td>
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<tr>
<td>CHM</td>
<td>Common Heritage of Mankind</td>
</tr>
<tr>
<td>COMNAP</td>
<td>Council of Managers of National Antarctic Programmes</td>
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<tr>
<td>COP</td>
<td>Conference of the Parties</td>
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<tr>
<td>CPM</td>
<td>Commission for Phytosanitary Measures</td>
</tr>
<tr>
<td>CRAMRA</td>
<td>Convention for the Regulation of Antarctic Mineral Resource Activity</td>
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<tr>
<td>EBA</td>
<td>Evolution and Biodiversity in Antarctica</td>
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<td>EEZ</td>
<td>Exclusive Economic Zone</td>
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<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
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<tr>
<td>FAO</td>
<td>Food and Agricultural Organisation</td>
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<td>IAATO</td>
<td>International Association of Antarctica Tour Operators</td>
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<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
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<tr>
<td>ICES</td>
<td>International Council for the Exploration of the Sea</td>
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<td>ICSU</td>
<td>International Council for Science</td>
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<td>IGY</td>
<td>International Geophysical Year</td>
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<td>IMO</td>
<td>International Maritime Organisation</td>
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<tr>
<td>IP</td>
<td>Information Paper</td>
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<td>IPOA</td>
<td>International Plan of Action</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>IPPC</td>
<td>International Plant Protection Convention</td>
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<td>IPR</td>
<td>Intellectual Property Rights</td>
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<td>ISA</td>
<td>International Seabed Authority</td>
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<td>IUCN</td>
<td>International Union for the Conservation of Nature</td>
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<td>IUU</td>
<td>Illegal, Unreported and Unregulated</td>
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<tr>
<td>IWC</td>
<td>International Whaling Convention</td>
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<td>LGP</td>
<td>Latitudinal Gradients Project</td>
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<td>MFAT</td>
<td>Ministry of Foreign Affairs and Trade</td>
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<tr>
<td>NGO</td>
<td>Non-Governmental Organisation</td>
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<tr>
<td>OIE</td>
<td>Organisation Internationale Epizooties</td>
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<tr>
<td>PCA</td>
<td>Principle Component Analysis</td>
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<td>PRA</td>
<td>Pest Risk Analysis</td>
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<tr>
<td>RiSCC</td>
<td>Regional Sensitivity to Climate Change in Antarctica</td>
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<tr>
<td>SCAR</td>
<td>Scientific Committee for Antarctic Research</td>
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<tr>
<td>SOFSP</td>
<td>Southern Ocean Fisheries Survey Programme</td>
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<tr>
<td>SOM</td>
<td>Self Organising Map</td>
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<tr>
<td>TISGC</td>
<td>Treaty Initiative to Share the Genetic Global Commons</td>
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<tr>
<td>TRIPS</td>
<td>Trade Related Aspects of Intellectual Property</td>
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<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
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<tr>
<td>UNGA</td>
<td>United Nations General Assembly</td>
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<td>WP</td>
<td>Working Paper</td>
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<td>WTO</td>
<td>World Tourism Organisation</td>
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APPENDIX 2
TEXT OF THE ANTARCTIC TREATY 1959

The Governments of Argentina, Australia, Belgium, Chile, the French Republic, Japan, New Zealand, Norway, the Union of South Africa, the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland, and the United States of America,

*Recognizing* that it is in the interest of all mankind that Antarctica shall continue for ever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord;

*Acknowledging* the substantial contributions to scientific knowledge resulting from international cooperation in scientific investigation in Antarctica;

*Convinced* that the establishment of a firm foundation for the continuation and development of such cooperation on the basis of freedom of scientific investigation in Antarctica as applied during the International Geophysical Year accords with the interests of science and the progress of all mankind;

*Convinced* also that a treaty ensuring the use of Antarctica for peaceful purposes only and the continuance of international harmony in Antarctica will further the purposes and principles embodied in the Charter of the United Nations;

Have agreed as follows:

**Article I**

1. Antarctica shall be used for peaceful purposes only. There shall be prohibited, *inter alia*, any measure of a military nature, such as the establishment of military bases and fortifications, the carrying out of military manoeuvres, as well as the testing of any type of weapon.

2. The present Treaty shall not prevent the use of military personnel or equipment for scientific research or for any other peaceful purpose.
**Article II**

Freedom of scientific investigation in Antarctica and cooperation toward that end, as applied during the International Geophysical Year, shall continue, subject to the provisions of the present Treaty.

**Article III**

In order to promote international cooperation in scientific investigation in Antarctica, as provided for in Article II of the present Treaty, the Contracting Parties agree that, to the greatest extent feasible and practicable:

1. information regarding plans for scientific programs in Antarctica shall be exchanged to permit maximum economy of and efficiency of operations;

2. scientific personnel shall be exchanged in Antarctica between expeditions and stations;

3. scientific observations and results from Antarctica shall be exchanged and made freely available.

**Article IV**

1. Nothing contained in the present Treaty shall be interpreted as:

   a. a renunciation by any Contracting Party of previously asserted rights of or claims to territorial sovereignty in Antarctica;

   b. a renunciation or diminution by any Contracting Party of any basis of claim to territorial sovereignty in Antarctica which it may have whether as a result of its activities or those of its nationals in Antarctica, or otherwise;

   c. prejudicing the position of any Contracting Party as regards its recognition or non-recognition of any other State's rights of or claim or basis of claim to territorial sovereignty in Antarctica.
2. No acts or activities taking place while the present Treaty is in force shall constitute a basis for asserting, supporting or denying a claim to territorial sovereignty in Antarctica or create any rights of sovereignty in Antarctica.

3. No new claim, or enlargement of an existing claim, to territorial sovereignty in Antarctica shall be asserted while the present Treaty is in force.

**Article V**

1. Any nuclear explosions in Antarctica and the disposal there of radioactive waste material shall be prohibited.

2. In the event of the conclusion of international agreements concerning the use of nuclear energy, including nuclear explosions and the disposal of radioactive waste material, to which all of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX are parties, the rules established under such agreements shall apply in Antarctica.

**Article VI**

The provisions of the present Treaty shall apply to the area south of 60deg. South Latitude, including all ice shelves, but nothing in the present Treaty shall prejudice or in any way affect the rights, or the exercise of the rights, of any State under international law with regard to the high seas within that area.

**Article VII**

1. In order to promote the objectives and ensure the observance of the provisions of the present Treaty, each Contracting Party whose representatives are entitled to participate in the meetings referred to in Article IX of the Treaty shall have the right to designate observers to carry out any inspection provided for by the present Article. Observers shall be nationals of the Contracting Parties which designate them. The names of observers shall be communicated to every other Contracting Party having the right to
designate observers, and like notice shall be given of the termination of their appointment.

2. Each observer designated in accordance with the provisions of paragraph 1 of this Article shall have complete freedom of access at any time to any or all areas of Antarctica.

3. All areas of Antarctica, including all stations, installations and equipment within those areas, and all ships and aircraft at points of discharging or embarking cargoes or personnel in Antarctica, shall be open at all times to inspection by any observers designated in accordance with paragraph 1 of this Article.

4. Aerial observation may be carried out at any time over any or all areas of Antarctica by any of the Contracting Parties having the right to designate observers.

5. Each Contracting Party shall, at the time when the present Treaty enters into force for it, inform the other Contracting Parties, and thereafter shall give them notice in advance, of

   a. all expeditions to and within Antarctica, on the part of its ships or nationals, and all expeditions to Antarctica organized in or proceeding from its territory;

   b. all stations in Antarctica occupied by its nationals; and

   c. any military personnel or equipment intended to be introduced by it into Antarctica subject to the conditions prescribed in paragraph 2 of Article I of the present Treaty.

Article VIII

1. In order to facilitate the exercise of their functions under the present Treaty, and without prejudice to the respective positions of the Contracting Parties relating to jurisdiction over all other persons in Antarctica, observers designated under paragraph 1 of Article VII and scientific personnel exchanged under sub-paragraph 1(b) of Article III of the Treaty, and members of the staffs accompanying any such persons, shall be subject only to the jurisdiction of the Contracting Party of which they are nationals in respect of all acts
or omissions occurring while they are in Antarctica for the purpose of exercising their functions.

2. Without prejudice to the provisions of paragraph 1 of this Article, and pending the adoption of measures in pursuance of subparagraph 1(e) of Article IX, the Contracting Parties concerned in any case of dispute with regard to the exercise of jurisdiction in Antarctica shall immediately consult together with a view to reaching a mutually acceptable solution.

**Article IX**

1. Representatives of the Contracting Parties named in the preamble to the present Treaty shall meet at the City of Canberra within two months after the date of entry into force of the Treaty, and thereafter at suitable intervals and places, for the purpose of exchanging information, consulting together on matters of common interest pertaining to Antarctica, and formulating and considering, and recommending to their Governments, measures in furtherance of the principles and objectives of the Treaty, including measures regarding:

   a. use of Antarctica for peaceful purposes only;

   b. facilitation of scientific research in Antarctica;

   c. facilitation of international scientific cooperation in Antarctica;

   d. facilitation of the exercise of the rights of inspection provided for in Article VII of the Treaty;

   e. questions relating to the exercise of jurisdiction in Antarctica;

   f. preservation and conservation of living resources in Antarctica.

2. Each Contracting Party which has become a party to the present Treaty by accession under Article XIII shall be entitled to appoint representatives to participate in the meetings referred to in paragraph 1 of the present Article, during such times as that Contracting Party demonstrates its interest in Antarctica by conducting substantial research activity there, such as the
establishment of a scientific station or the despatch of a scientific expedition.

3. Reports from the observers referred to in Article VII of the present Treaty shall be transmitted to the representatives of the Contracting Parties participating in the meetings referred to in paragraph 1 of the present Article.

4. The measures referred to in paragraph 1 of this Article shall become effective when approved by all the Contracting Parties whose representatives were entitled to participate in the meetings held to consider those measures.

5. Any or all of the rights established in the present Treaty may be exercised as from the date of entry into force of the Treaty whether or not any measures facilitating the exercise of such rights have been proposed, considered or approved as provided in this Article.

Article X

Each of the Contracting Parties undertakes to exert appropriate efforts, consistent with the Charter of the United Nations, to the end that no one engages in any activity in Antarctica contrary to the principles or purposes of the present Treaty.

Article XI

1. If any dispute arises between two or more of the Contracting Parties concerning the interpretation or application of the present Treaty, those Contracting Parties shall consult among themselves with a view to having the dispute resolved by negotiation, inquiry, mediation, conciliation, arbitration, judicial settlement or other peaceful means of their own choice.

2. Any dispute of this character not so resolved shall, with the consent, in each case, of all parties to the dispute, be referred to the International Court of Justice for settlement; but failure to reach agreement on reference to the International Court shall not absolve parties to the dispute from the responsibility of continuing to seek to resolve it by any of the various peaceful means referred to in paragraph 1 of this Article.
Article XII

1a. The present Treaty may be modified or amended at any time by unanimous agreement of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX. Any such modification or amendment shall enter into force when the depositary Government has received notice from all such Contracting Parties that they have ratified it.

1b. Such modification or amendment shall thereafter enter into force as to any other Contracting Party when notice of ratification by it has been received by the depositary Government. Any such Contracting Party from which no notice of ratification is received within a period of two years from the date of entry into force of the modification or amendment in accordance with the provision of subparagraph 1(a) of this Article shall be deemed to have withdrawn from the present Treaty on the date of the expiration of such period.

2a. If after the expiration of thirty years from the date of entry into force of the present Treaty, any of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX so requests by a communication addressed to the depositary Government, a Conference of all the Contracting Parties shall be held as soon as practicable to review the operation of the Treaty.

2b. Any modification or amendment to the present Treaty which is approved at such a Conference by a majority of the Contracting Parties there represented, including a majority of those whose representatives are entitled to participate in the meetings provided for under Article IX, shall be communicated by the depositary Government to all Contracting Parties immediately after the termination of the Conference and shall enter into force in accordance with the provisions of paragraph 1 of the present Article.

2c. If any such modification or amendment has not entered into force in accordance with the provisions of subparagraph 1(a) of this Article within a period of two years after the date of its communication to
all the Contracting Parties, any Contracting Party may at any time after the expiration of that period give notice to the depositary Government of its withdrawal from the present Treaty; and such withdrawal shall take effect two years after the receipt of the notice by the depositary Government.

**Article XIII**

1. The present Treaty shall be subject to ratification by the signatory States. It shall be open for accession by any State which is a Member of the United Nations, or by any other State which may be invited to accede to the Treaty with the consent of all the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX of the Treaty.

2. Ratification of or accession to the present Treaty shall be effected by each State in accordance with its constitutional processes.

3. Instruments of ratification and instruments of accession shall be deposited with the Government of the United States of America, hereby designated as the depositary Government.

4. The depositary Government shall inform all signatory and acceding States of the date of each deposit of an instrument of ratification or accession, and the date of entry into force of the Treaty and of any modification or amendment thereto.

5. Upon the deposit of instruments of ratification by all the signatory States, the present Treaty shall enter into force for those States and for States which have deposited instruments of accession. Thereafter the Treaty shall enter into force for any acceding State upon the deposit of its instruments of accession.

6. The present Treaty shall be registered by the depositary Government pursuant to Article 102 of the Charter of the United Nations.
Article XIV

The present Treaty, done in the English, French, Russian and Spanish languages, each version being equally authentic, shall be deposited in the archives of the Government of the United States of America, which shall transmit duly certified copies thereof to the Governments of the signatory and acceding States.
APPENDIX 3
THE PROTOCOL ON ENVIRONMENTAL PROTECTION TO THE ANTARCTIC TREATY 1991

Preamble

The States Parties to this Protocol to the Antarctic Treaty, hereinafter referred to as the Parties,

Convinced of the need to enhance the protection of the Antarctic environment and dependent and associated ecosystems;

Convinced of the need to strengthen the Antarctic Treaty system so as to ensure that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord;

Bearing in mind the special legal and political status of Antarctica and the special responsibility of the Antarctic Treaty Consultative Parties to ensure that all activities in Antarctica are consistent with the purposes and principals of the Antarctic Treaty;

Recalling the designation of Antarctica as a Special Conservation Area and other measures adopted under the Antarctic Treaty system to protect the Antarctic environment and dependent and associated ecosystems;

Acknowledging further the unique opportunities Antarctica offers for scientific monitoring of and research on processes of global as well as regional importance;

Reaffirming the conservation principles of the Convention on the Conservation of Antarctic Marine Living Resources;

Convinced that the development of a Comprehensive regime for the protection of the Antarctic environment and dependent and associated ecosystems is in the interest of mankind as a whole;
Desiring to supplement the Antarctic Treaty to this end;

Have agreed as follows:

Article 1

Definitions

For the purposes of this Protocol:

1. "The Antarctic Treaty" means the Antarctic Treaty done at Washington on 1 December 1959;

2. "Antarctic Treaty area" means the area to which the provisions of the Antarctic Treaty apply in accordance with Article VI of that Treaty;

3. "Antarctic Treaty Consultative Meetings" means the meetings referred to in Article IX of the Antarctic Treaty;

4. "Antarctic Treaty Consultative Parties" means the Contracting Parties to the Antarctic Treaty entitled to appoint representatives to participate in the meetings referred to in Article IX of that Treaty;

5. "Antarctic Treaty system" means 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;

6. "Arbitral Tribunal" means the arbitral Tribunal established in accordance with the Schedule to this Protocol, which forms an integral part thereof;

7. "Committee" means the Committee for Environmental Protection established in accordance with Article 11.
Article 2

Objective and Designation

The Parties commit themselves to the comprehensive protection of the Antarctic environment and dependent and associated ecosystems and hereby designate Antarctica as a natural reserve, devoted to peace and science.

Article 3

Environmental Principles

1. 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.

2. To this end:
   a. activities in the Antarctic Treaty area shall be planned and conducted so as to limit adverse impacts on the Antarctic environment and dependent and associated ecosystems;
   b. activities in the Antarctic Treaty area shall be planned and conducted so as to avoid:
      i. adverse effects on climate or weather patterns;
      ii. significant adverse effects on air or water quality;
      iii. significant changes in the atmospheric, terrestrial (including aquatic), glacial or marine environments;
      iv. detrimental changes in the distribution, abundance or productivity of species of populations of species of fauna and flora;
v. further jeopardy to endangered or threatened species or populations of such species; or

vi. degradation of, or substantial risk to, areas of biological, scientific, historic, aesthetic or wilderness significance;

c. activities in the Antarctic Treaty area shall be planned and conducted on the basis of information sufficient to allow prior assessments of, and informed judgments about, their possible impacts on the Antarctic environment and dependent and associated ecosystems and on the value of Antarctica for the conduct of scientific research; such judgments shall take account of:

i. the scope of the activity, including its area, duration and intensity;

ii. the cumulative impacts of the activity, both by itself and in combination with other activities in the Antarctic Treaty area;

iii. whether the activity will detrimentally affect any other activity in the Antarctic Treaty area;

iv. whether technology and procedures are available to provide for environmentally safe operations;

v. whether there exists the capacity to monitor key environmental parameters and ecosystem components so as to identify and provide early warning of any adverse effects of the activity and to provide for such modification of operating procedures as may be necessary in the light of the results of monitoring or increased knowledge of the Antarctic environment and dependent and associated ecosystems; and

vi. whether there exists the capacity to respond promptly and effectively to accidents, particularly those with potential environmental effects;
d. regular and effective monitoring shall take place to all assessment of the impacts of ongoing activities, including the verification of predicted impacts;

e. regular and effective monitoring shall take place to facilitate early detection of the possible unforeseen effects of activities carried on both within and outside the Antarctic Treaty area on the Antarctic environment and dependent and associated ecosystems.

3. Activities shall be planned and conducted in the Antarctic Treaty area so as to accord priority to scientific research and to preserve the value of Antarctica as an area for the conduct of such research, including research essential to understanding the global environment.

4. Activities undertaken in the Antarctic Treaty area pursuant to scientific research programs, tourism and all other governmental and non-governmental activities in the Antarctic Treaty area for which advance notice is required in accordance with Article VII (5) of the Antarctic Treaty, including associated logistic activities, shall:

   a. take place in a manner consistent with the principles in this Article; and

   b. be modified, suspended or cancelled if they result in or threaten to result in impacts upon the Antarctic environment or dependent or associated ecosystems inconsistent with those principles.

Article 4

Relationship with other Components of the Antarctic Treaty System

1. This Protocol shall supplement the Antarctic Treaty and shall neither modify nor amend that Treaty.

2. Nothing in this Protocol shall derogate from the rights and obligations of the Parties to this Protocol under the other
international instruments in force within the Antarctic Treaty system.

Article 5

Consistency with other Components of the Antarctic Treaty System

The Parties shall consult and cooperate with the Contracting Parties to the other international instruments in force within the Antarctic Treaty system and their respective institutions with a view to ensuring the achievement of the objectives and principles of this Protocol and avoiding any interference with the achievement of the objectives and principles of those instruments or any inconsistency between the implementation of those instruments and of this Protocol.

Article 6

Cooperation

1. The Parties shall cooperate in the planning and conduct of activities in the Antarctic Treaty area. To this end, each Party shall endeavour to:

   a. promote cooperative programs of scientific, technical and educational value, concerning the protection of the Antarctic environment and dependent and associated ecosystems;

   b. provide appropriate assistance to other Parties in the preparation of environmental impact assessments;

   c. provide to other Parties upon request information relevant to any potential environmental risk and assistance to minimise the effects of accidents which may damage the Antarctic environment or dependent and associated ecosystems;

   d. consult with other Parties with regard to the choice of sites for prospective station sand other facilities so as to avoid the cumulative impacts caused by their excessive concentration in any location;
e. where appropriate, undertake joint expeditions and share the use of stations and other facilities; and

f. carry out such steps as may be agreed upon at Antarctic Treaty Consultative Meetings.

2. Each Party undertakes, to the extent possible, to share information that may be helpful to other Parties in planning and conducting their activities in the Antarctic Treaty area, with a view to the protection of the Antarctic environment and dependent and associated ecosystems.

3. The Parties shall co-operate with those Parties which may exercise jurisdiction in areas adjacent to the Antarctic Treaty area with a view to ensuring that activities in the Antarctic Treaty area do not have adverse environmental impacts on those areas.

Article 7

**Prohibition of Mineral Resource Activities**

Any activity relating to mineral resources, other than scientific research, shall be prohibited.

Article 8

**Environmental Impact and Assessment**

1. Proposed activities referred to in paragraph 2 below shall be subject to the procedures set out in Annex I for prior assessment of the impacts of those activities on the Antarctic environment or on dependent or associated ecosystems according to whether those activities are identified as having:

   a. less than a minor or transitory impact;

   b. a minor or transitory impact; or

   c. more than a minor or transitory impact.

2. Each Party shall ensure that the assessment procedures set out in Annex I are applied in the planning processes leading to decisions
about any activities undertaken in the Antarctic Treaty area pursuant to scientific research programs, tourism and all other governmental and non-governmental activities in the Antarctic Treaty area for which advance notice is required under Article VII (5) of the Antarctic Treaty, including associated logistic support activities.

3. The assessment procedures set out in Annex I shall apply to any change in an activity whether the change arises from an increase or decrease in the intensity of an existing activity, from the addition of an activity, the decommissioning of a facility, or otherwise.

4. Where activities are planned jointly by more than one Party, the Parties involved shall nominate one of their number to coordinate the implementation of the environmental impact assessment procedures set out in Annex I.

Article 9

Annexes

1. The Annexes to this Protocol shall form an integral part thereof.

2. Annexes, additional to Annexes I-IV, may be adopted and become effective in accordance with Article IX of the Antarctic Treaty.

3. Amendments and modifications to Annexes may be adopted and become effective in accordance with Article IX of the Antarctic Treaty, provided that any Annex may itself make provision for amendments and modifications to become effective on an accelerated basis.

4. Annexes and any amendments and modifications thereto which have become effective in accordance with paragraphs 2 and 3 above shall, unless an Annex itself provides otherwise in respect of the entry into effect of any amendment or modification thereto, become effective for a Contracting Party to the Antarctic Treaty which is not an Antarctic Treaty Consultative Party, or which was not an Antarctic Treaty Consultative Party at the time of the adoption, when notice of approval of that Contracting Party has been received by the Depositary.
5. Annexes shall, except to the extent that an Annex provides otherwise, be subject to the procedures for dispute settlement set out in Articles 18 to 20.

**Article 10**

*Antarctic Treaty Consultative Meetings*

1. Antarctic Treaty Consultative Meetings shall, drawing upon the best scientific and technical advice available:
   a. define, in accordance with the provisions of this Protocol, the general policy for the comprehensive protection of the Antarctic environment and dependent and associated ecosystems; and
   b. adopt measures under Article IX of the Antarctic Treaty for the implementation of this Protocol.

2. Antarctic Treaty Consultative Meetings shall review the work of the Committee and shall draw fully upon its advice and recommendations in carrying out the tasks referred to in paragraph 1 above, as well as upon the advice of the Scientific Committee on Antarctic Research.

**Article 11**

*Committee for Environmental Protection*

1. There is hereby established the Committee for Environmental Protection.

2. Each Party shall be entitled to be a member of the Committee and to appoint a representative who may be accompanied by experts and advisers.

3. Observer status in the Committee shall be open to any Contracting Party to the Antarctic Treaty which is not a Party to this Protocol.

4. The Committee shall invite the President of the Scientific Committee on Antarctic Research and the Chairman of the Scientific Committee for the Conservation of Antarctic Marine Living Resources to participate as observers at its sessions. The
Committee may also, with the approval of the Antarctic Treaty Consultative Meeting, invite such other relevant scientific, environmental and technical organisations which can contribute to its work to participate as observers at its sessions.

5. The Committee shall present a report on each of its sessions to the Antarctic Treaty Consultative Meeting. The report shall cover all matters considered at the session and shall reflect the views expressed. The report shall be circulated to the Parties and to observers attending the session, and shall thereupon be made publicly available.

6. The Committee shall adopt its rules of procedure which shall be subject to approval by the Antarctic Treaty Consultative Meeting.

**Article 12**

*Functions of the Committee*

1. The functions of the Committee shall be to provide advice and formulate recommendations to the Parties in connection with the implementation of this Protocol, including the operation of its Annexes, for consideration at Antarctic Treaty Consultative Meetings, and to perform such other functions as may be referred to it by the Antarctic Treaty Consultative Meetings. In particular, it shall provide advice on:

   a. the effectiveness of measures taken pursuant to this Protocol;

   b. the need to update, strengthen or otherwise improve such measures;

   c. the need for additional measures, including the need for additional Annexes, where appropriate;

   d. the application and implementation of the environmental impact assessment procedures set out in Article 8 and Annex I;

   e. means of minimising or mitigating environmental impacts of activities in the Antarctic Treaty area;
f. procedures for situations requiring urgent action, including response action in environmental emergencies;

g. the operation and further elaboration of the Antarctic Protected Area system;

h. inspection procedures, including formats for inspection reports and checklists for the conduct of inspections;

i. the collection, archiving, exchange and evaluation of information related to environmental protection;

j. the state of the Antarctic environment; and

k. the need for scientific research, including environmental monitoring, related to the implementation of this Protocol.

2. In carrying out its functions, the Committee shall, as appropriate, consult with the Scientific Committee on Antarctic Research, the Scientific Committee for the Conservation of Antarctic Marine Living Resources and other relevant scientific, environmental and technical organisations.

Article 13

Compliance with this Protocol

1. Each Party shall take appropriate measures within its competence, including the adoption of laws and regulations, administrative actions and enforcement measures, to ensure compliance with this Protocol.

2. Each Party shall exert appropriate efforts, consistent with the Charter of the United Nations, to the end that no one engages in any activity contrary to this Protocol.

3. Each Party shall notify all other Parties of the measures it takes pursuant to paragraphs 1 and 2 above.
4. Each Party shall draw the attention of all other Parties to any activity which in its opinion affects the implementation of the objectives and principles of this Protocol.

5. The Antarctic Treaty Consultative Meetings shall draw the attention of any State which is not a Party to this Protocol to any activity undertaken by that State, its agencies, instrumentalities, natural or juridical persons, ships, aircraft or other means of transport which affects the implementation of the objectives and principles of this Protocol.

Article 14

Inspection

1. In order to promote the protection of the Antarctic environment and dependent and associated ecosystems, and to ensure compliance with this Protocol, the Antarctic Treaty Consultative Parties shall arrange, individually or collectively, for inspections by observers to be made in accordance with Article VII of the Antarctic Treaty.

2. Observers are:

   a. observers designated by any Antarctic Treaty Consultative Party who shall be nationals of that Party; and

   b. any observers designated at Antarctic Treaty Consultative Meetings to carry out inspections under procedures to be established by an Antarctic Treaty Consultative Meeting.

3. Parties shall co-operate fully with observers undertaking inspections, and shall ensure that during inspections, observers are given access to all parts of stations, installations, equipment, ships and aircraft open to inspection under Article VII (3) of the Antarctic Treaty, as well as to all records maintained thereon which are called for pursuant to this Protocol.

4. Reports of inspections shall be sent to the Parties whose stations, installations, equipment, ships or aircraft are covered by the reports. After those Parties have been given the opportunity to comment, the reports and any comments thereon shall be
circulated to all the Parties and to the Committee, considered at Antarctic Treaty Consultative Meeting, and thereafter made publicly available.

Article 15

Emergency Response Action

1. In order to respond to environmental emergencies in Antarctic Treaty area, each Party agrees to:

   a. provide for prompt and effective response action to such emergencies which might arise in the performance of scientific research programs, tourism and all other governmental and non-governmental activities in the Antarctic Treaty area for which advance notice is required under Article VII (5) of the Antarctic Treaty, including associated logistic support activities; and

   b. establish contingency plans for response to incidents with potential adverse effects on the Antarctic environment or dependent and associated ecosystems.

2. To this end, the Parties shall:

   a. co-operate in the formulation and implementation of such contingency plans; and

   b. establish procedures for immediate notification of, and co-operative response to, environmental emergencies.

3. In the implementation of this Article, the Parties shall draw upon the advice of the appropriate international organisations.

Article 16

Liability

Consistent with the objectives of this Protocol for the comprehensive protection of the Antarctic environment and dependent and associated ecosystems, the Parties undertake to elaborate rules and procedures
relating to liability for damage arising from activities taking place in the Antarctic Treaty area and covered by this Protocol. Those rules and procedures shall be included in one or more Annexes to be adopted in accordance with Article 9 (2).

**Article 17**

**Annual Report by Parties**

1. Each Party shall report annually on the steps taken to implement this Protocol. Such reports shall include notifications made in accordance with Article 13 (3), contingency plans established in accordance with Article 15 and any other notifications and information called for pursuant to this Protocol for which there is no other provision concerning the circulation and exchange of information.

2. Reports made in accordance with paragraph 1 above shall be circulated to all Parties and to the Committee, considered at the next Antarctic Treaty Consultative Meeting, and made publicly available.

**Article 18**

**Dispute Settlement**

If a dispute arises concerning the interpretation or application of this Protocol, the parties to the dispute shall, at the request of any one of them, consult among themselves as soon as possible with a view to having the dispute resolved by negotiation, inquiry, mediation, conciliation, arbitration, judicial settlement or other means of which the parties to the dispute agree.

**Article 19**

**Choice of Dispute Settlement Procedure**

1. Each Party, when signing, ratifying, accepting, approving or acceding to this Protocol, or at any time thereafter, may choose, by written declaration, one or both of the following means for the settlement of disputes concerning the interpretation or application
of Articles 7, 8 and 15 and, except to the extent that an Annex provides otherwise, the provisions of any Annex and, insofar as it relates to these Articles and provisions, Article 13:

a. the International Court of Justice;

b. the Arbitral Tribunal.

2. A declaration made under paragraph 1 above shall not affect the operation of Article 18 and Article 20 (2).

3. A Party which has not made a declaration under paragraph 1 above or in respect of which a declaration is no longer in force shall be deemed to have accepted the competence of the Arbitral Tribunal.

4. If the parties to a dispute have accepted the same means for the settlement of a dispute, the dispute may be submitted only to that procedure, unless the parties otherwise agree.

5. If the parties to a dispute have not accepted the same means for the settlement of a dispute, or if they have both accepted both means, the dispute may be submitted only to the Arbitral Tribunal, unless the parties otherwise agree.

6. A declaration made under paragraph 1 above shall remain in force until it expires in accordance with its terms or until three months after written notice of revocation has been deposited with the Depositary.

7. A new declaration, a notice of revocation or the expiry of a declaration shall not in any way affect proceedings pending before the International Court of Justice or the Arbitral Tribunal, unless the parties to the dispute otherwise agree.

8. Declarations and notices referred to in this Article shall be deposited with the Depositary who shall transmit copies thereof to all Parties.
Article 20

Dispute Settling Procedure

1. If the parties to a dispute concerning the interpretation or application of Articles 7, 8 or 15 or, except to the extent that an Annex provides otherwise, the provisions of any Annex or, insofar as it relates to these Articles and provisions, Article 13, have not agreed on a means for resolving it within 12 months of the request for consultation pursuant to Article 18, the dispute shall be referred, at the request of any party to the dispute, for settlement in accordance with the procedure determined by Article 19 (4) and (5).

2. The Arbitral Tribunal shall not be competent to decide or rule upon any matter within the scope of Article IV of the Antarctic Treaty. In addition, nothing in this Protocol shall be interpreted as conferring competence or jurisdiction on the International Court of Justice or any other tribunal established for the purpose of settling disputes between Parties to decide or otherwise rule upon any matter within the scope of Article IV of the Antarctic Treaty.

Article 21

Signature

This Protocol shall be open for signature at Madrid on the 4th of October 1991 and thereafter at Washington until the 3rd of October 1992 by any State which is a Contracting Party to the Antarctic Treaty.

Article 22

Ratification, Acceptance, Approval or Accession

1. This Protocol is subject to ratification, acceptance or approval by signatory States.

2. After the 3rd of October 1992 this Protocol shall be open for accession by any State which is a Contracting Party to the Antarctic Treaty.
3. Instruments of ratification, acceptance, approval or accession shall be deposited with the Government of the United States of America, hereby designated as the Depository.

4. After the date on which this Protocol has entered into force, the Antarctic Treaty Consultative Parties shall not act upon a notification regarding the entitlement of a Contracting Party to the Antarctic Treaty to appoint representatives to participate in Antarctic Treaty Consultative Meetings in accordance with Article IX (2) of the Antarctic Treaty unless that Contracting Party has first ratified, accepted, approved or acceded to this Protocol.

Article 23

Entry into Force

1. This Protocol shall enter into force on the thirtieth day following the date of deposit of instruments of ratification, acceptance, approval or accession by all States which are Antarctic Treaty Consultative Parties at the date on which this Protocol is adopted.

2. For each Contracting Party to the Antarctic Treaty which, subsequent to the date of entry into force of this Protocol, deposits an instrument of ratification, acceptance, approval or accession, this Protocol shall enter into force on the thirtieth day following such deposit.

Article 24

Reservations

Reservations to this Protocol shall not be permitted.

Article 25

Modification or Amendment

1. Without prejudice to the provisions of Article 9, this Protocol may be modified or amended at any time in accordance with the procedures set forth in Article XII (1) (a) and (b) of the Antarctic Treaty.
2. If, after the expiration of 50 years from the date of entry into force of this Protocol, any of the Antarctic Treaty Consultative Parties so requests by a communication addressed to the Depositary, a conference shall be held as soon as practicable to review the operation of this Protocol.

3. A modification or amendment proposed at any Review Conference called pursuant to paragraph 2 above shall be adopted by a majority of the Parties, including three-quarters of the States which are Antarctic Treaty Consultative Parties at the time of adoption of this Protocol.

4. A modification or amendment adopted pursuant to paragraph 3 above shall enter into force upon ratification, acceptance, approval or accession by three-quarters of the Antarctic Treaty Consultative Parties, including ratification, acceptance, approval or accession by all States which are Antarctic Treaty Consultative Parties at the time of adoption of this Protocol.

5a. With respect to Article 7 the prohibition on Antarctic mineral resource activities contained therein shall continue unless there is in force a binding legal regime on Antarctic mineral resource activities that includes an agreed means for determining whether, and if so, under which conditions, any such activities would be acceptable. This regime shall fully safeguard the interests of all States referred to in Article IV of the Antarctic Treaty and apply the principles thereof. Therefore, if a modification or amendment to Article 7 is proposed at a Review Conference referred to in paragraph 2 above, it shall include such a binding legal regime.

5b. If any such modification or amendment has not entered into force within 3 years of the date of its adoption, any Party may at any time thereafter notify to the Depositary of its withdrawal from the Protocol, and such withdrawal shall take effect 2 years after receipt of the notification by the Depositary.
Article 26

Notifications by the Depositary

The Depositary shall notify all Contracting Parties to the Antarctic Treaty of the following:

a. signatures of this Protocol and the deposit of instruments of ratification, acceptance, approval or accession;

b. the date of entry into force of this Protocol and any additional Annex thereto;

c. the date of entry into force of any amendment or modification to this Protocol;

d. the deposit of declarations and notices pursuant to Article 19; and

e. any notification received pursuant to Article 25 (5) (b).

Article 27

Authentic Texts and Registration with the United Nations

1. This Protocol, done in the English, French, Russian and Spanish languages, each version being equally authentic, shall be deposited in the archives of the Government of the United States of America, which shall transmit duly certified copies thereof to all Contracting Parties to the Antarctic Treaty.

2. This Protocol shall be registered by the Depositary pursuant to Article 102 of the Charter of the United Nations.
ANNEX I
ENVIRONMENTAL IMPACT ASSESSMENT

Article 1

Preliminary stage

1. The environmental impacts of proposed activities referred to in Article 8 of the Protocol shall, before their commencement, be considered in accordance with appropriate national procedures.

2. If an activity is determined as having less than a minor or transitory impact, the activity may proceed forthwith.

Article 2

Initial environmental evaluation

1. Unless it has been determined that an activity will have less than a minor or transitory impact, or unless a Comprehensive Environmental Evaluation is being prepared in accordance with Article 3, an Initial Environmental Evaluation shall be prepared. It shall contain sufficient detail to assess whether a proposed activity may have more than a minor or transitory impact and shall include:

   a. a description of the proposed activity, including its purpose, location, duration, and intensity; and

   b. consideration of alternatives to the proposed activity and any impacts that the activity may have, including consideration of cumulative impacts in the light of existing and known planned activities.

2. If an Initial Environmental Evaluation indicates that a proposed activity is likely to have no more than a minor or transitory impact, the activity may proceed, provided that appropriate procedures, which may include monitoring, are put in place to assess and verify the impact of the activity.
Article 3

Comprehensive environmental evaluation

1. If an Initial Environmental Evaluation indicates or if it is otherwise determined that a proposed activity is likely to have more than a minor or transitory impact, a Comprehensive Environmental Evaluation shall be prepared.

2. A Comprehensive Environmental Evaluation shall include:

   a. a description of the proposed activity including its purpose, location, duration and intensity, and possible alternatives to the activity, including the alternative of not proceeding, and the consequences of those alternatives;

   b. a description of the initial environmental reference state with which predicted changes are to be compared and a prediction of the future environmental reference state in the absence of the proposed activity;

   c. a description of the methods and data used to forecast the impacts of the proposed activity;

   d. estimation of the nature, extent, duration, and intensity of the likely direct impacts of the proposed activity;

   e. consideration of possible indirect or second order impacts of the proposed activity;

   f. consideration of cumulative impacts of the proposed activity in the light of existing activities and other known planned activities;

   g. identification of measures, including monitoring programmes, that could be taken to minimise or mitigate impacts of the proposed activity and to detect unforeseen impacts and that could provide early warning of any adverse effects of the activity as well as to deal promptly and effectively with accidents;

   h. identification of unavoidable impacts of the proposed activity;
i. consideration of the effects of the proposed activity on the conduct of scientific research and on other existing uses and values;

j. an identification of gaps in knowledge and uncertainties encountered in compiling the information required under this paragraph;

k. a non-technical summary of the information provided under this paragraph; and

l. the name and address of the person or organization which prepared the Comprehensive Environmental Evaluation and the address to which comments thereon should be directed.

3. The draft Comprehensive Environmental Evaluation shall be made publicly available and shall be circulated to all Parties, which shall also make it publicly available, for comment. A period of 90 days shall be allowed for the receipt of comments.

4. The draft Comprehensive Environmental Evaluation shall be forwarded to the Committee at the same time as it is circulated to the Parties, and at least 120 days before the next Antarctic Treaty Consultative Meeting, for consideration as appropriate.

5. No final decision shall be taken to proceed with the proposed activity in the Antarctic Treaty area unless there has been an opportunity for consideration of the draft Comprehensive Environmental Evaluation by the Antarctic Treaty Consultative Meeting on the advice of the Committee, provided that no decision to proceed with a proposed activity shall be delayed through the operation of this paragraph for longer than 15 months from the date of circulation of the draft Comprehensive Environmental Evaluation.

6. A final Comprehensive Environmental Evaluation shall address and shall include or summarise comments received on the draft Comprehensive Environmental Evaluation. The final Comprehensive Environmental Evaluation, notice of any decisions relating thereto, and any evaluation of the significance of the predicted impacts in relation to the advantages of the proposed activity, shall be circulated to all Parties, which shall also make
them publicly available, at least 60 days before the commencement of the proposed activity in the Antarctic Treaty area.

**Article 4**

*Decisions to be based on comprehensive environmental evaluations*

Any decision on whether a proposed activity, to which Article 3 applies, should proceed, and, if so, whether in its original or in a modified form, shall be based on the Comprehensive Environmental Evaluation as well as other relevant considerations.

**Article 5**

*Monitoring*

1. Procedures shall be put in place, including appropriate monitoring of key environmental indicators, to assess and verify the impact of any activity that proceeds following the completion of a Comprehensive Environmental Evaluation.

2. The procedures referred to in paragraph 1 above and in Article 2(2) shall be designed to provide a regular and verifiable record of the impacts of the activity in order, inter alia, to:
   a. enable assessments to be made of the extent to which such impacts are consistent with the Protocol; and
   b. provide information useful for minimising or mitigating impacts, and, where appropriate, information on the need for suspension, cancellation or modification of the activity.

**Article 6**

*Circulation of information*

1. The following information shall be circulated to the Parties, forwarded to the Committee and made publicly available:
   a. a description of the procedures referred to in Article 1;
b. an annual list of any Initial Environmental Evaluations prepared in accordance with Article 2 and any decisions taken in consequence thereof;

c. significant information obtained, and any action taken in consequence thereof, from procedures put in place in accordance with Articles 2(2) and 5; and

d. information referred to in Article 3(6).

2. Any Initial Environmental Evaluation prepared in accordance with Article 2 shall be made available on request.

Article 7

Cases of emergency

1. This Annex shall not apply in cases of emergency relating to the safety of human life or of ships, aircraft or equipment and facilities of high value, or the protection of the environment, which require an activity to be undertaken without completion of the procedures set out in this Annex.

2. Notice of activities undertaken in cases of emergency, which would otherwise have required preparation of a Comprehensive Environmental Evaluation, shall be circulated immediately to all Parties and to the Committee and a full explanation of the activities carried out shall be provided within 90 days of those activities.

Article 8

Amendment or modification

1. This Annex may be amended or modified by a measure adopted in accordance with Article IX(1) of the Antarctic Treaty. Unless the measure specifies otherwise, the amendment or modification shall be deemed to have been approved, and shall become effective, one year after the close of the Antarctic Treaty Consultative Meeting at which it was adopted, unless one or more of the Antarctic Treaty Consultative Parties notifies the Depositary, within
that period, that it wishes an extension of that period or that it is unable to approve the measure.

2. Any amendment or modification of this Annex which becomes effective in accordance with paragraph 1 above shall thereafter become effective as to any other Party when notice of approval by it has been received by the Depositary.

ANNEX II
CONSERVATION OF ANTARCTIC FAUNA AND FLORA

Article 1

Definitions

For the purposes of this Annex:

1. "native mammal" means any member of any species belonging to the Class Mammalia, indigenous to the Antarctic Treaty area or occurring there seasonally through natural migrations;

2. "native bird" means any member, at any stage of its life cycle (including eggs), of any species of the Class Aves indigenous to the Antarctic Treaty area or occurring there seasonally through natural migrations;

3. "native plant" means any terrestrial or freshwater vegetation, including bryophytes, lichens, fungi and algae, at any stage of its life cycle (including seeds, and other propagules), indigenous to the Antarctic Treaty area;

4. "native invertebrate" means any terrestrial or freshwater invertebrate, at any stage of its life cycle, indigenous to the Antarctic Treaty area;

5. "appropriate authority" means any person or agency authorized by a Party to issue permits under this Annex;

6. "permit" means a formal permission in writing issued by an appropriate authority;
7. "take" or "taking" means to kill, injure, capture, handle or molest, a native mammal or bird, or to remove or damage such quantities of native plants that their local distribution or abundance would be significantly affected;

8. "harmful interference" means:
   a. flying or landing helicopters or other aircraft in a manner that disturbs concentrations of birds and seals;
   b. using vehicles or vessels, including hovercraft and small boats, in a manner that disturbs concentrations of birds and seals;
   c. using explosives or firearms in a manner that disturbs concentrations of birds and seals;
   d. willfully disturbing breeding or moulting birds or concentrations of birds and seals by persons on foot;
   e. significantly damaging concentrations of native terrestrial plants by landing aircraft, driving vehicles, or walking on them, or by other means; and
   f. any activity that results in the significant adverse modification of habitats of any species or population of native mammal, bird, plant or invertebrate.


Article 2

Cases of emergency

1. This Annex shall not apply in cases of emergency relating to the safety of human life or of ships, aircraft, or equipment and facilities of high value, or the protection of the environment.

2. Notice of activities undertaken in cases of emergency shall be circulated immediately to all Parties and to the Committee.
Article 3

Protection of native fauna and flora

1. Taking or harmful interference shall be prohibited, except in accordance with a permit.

2. Such permits shall specify the authorized activity, including when, where and by whom it is to be conducted and shall be issued only in the following circumstances:

   a. to provide specimens for scientific study or scientific information;

   b. to provide specimens for museums, herbaria, zoological and botanical gardens, or other educational or cultural institutions or uses; and

   c. to provide for unavoidable consequences of scientific activities not otherwise authorized under sub-paragraphs (a) or (b) above, or of the construction and operation of scientific support facilities.

3. The issue of such permits shall be limited so as to ensure that:

   a. no more native mammals, birds, or plants are taken than are strictly necessary to meet the purposes set forth in paragraph 2 above;

   b. only small numbers of native mammals or birds are killed and in no case more native mammals or birds are killed from local populations than can, in combination with other permitted takings, normally be replaced by natural reproduction in the following season; and

   c. 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.

4. Any species of native mammals, birds and plants listed in Appendix A to this Annex shall be designated "Specially Protected Species", and shall be accorded special protection by the Parties.
5. A permit shall not be issued to take a Specially Protected Species unless the taking:

   a. is for a compelling scientific purpose;

   b. will not jeopardize the survival or recovery of that species or local population; and

   c. uses non-lethal techniques where appropriate.

6. All taking of native mammals and birds shall be done in the manner that involves the least degree of pain and suffering practicable.

**Article 4**

**Introduction of non-native species, parasites and diseases**

1. No species of animal or plant not native to the Antarctic Treaty area shall be introduced onto land or ice shelves, or into water in the Antarctic Treaty area except in accordance with a permit.

2. Dogs shall not be introduced onto land or ice shelves and dogs currently in those areas shall be removed by 1 April 1994.

3. Permits under paragraph 1 above shall be issued to allow the importation only of the animals and plants listed in Appendix B to this Annex and shall specify the species, numbers and, if appropriate, age and sex and precautions to be taken to prevent escape or contact with native fauna and flora.

4. Any plant or animal for which a permit has been issued in accordance with paragraphs 1 and 3 above, shall, prior to expiration of the permit, be removed from the Antarctic Treaty area or be disposed of by incineration or equally effective means that eliminates risk to native fauna or flora. The permit shall specify this obligation. Any other plant or animal introduced into the Antarctic Treaty area not native to that area, including any progeny, shall be removed or disposed of, by incineration or by equally effective means, so as to be rendered sterile, unless it is determined that they pose no risk to native flora or fauna.
5. Nothing in this Article shall apply to the importation of food into the Antarctic Treaty area provided that no live animals are imported for this purpose and all plants and animal parts and products are kept under carefully controlled conditions and disposed of in accordance with Annex III to the Protocol and Appendix C to this Annex.

6. Each Party shall require that precautions, including those listed in Appendix C to this Annex, be taken to prevent the introduction of micro-organisms (e.g., viruses, bacteria, parasites, yeasts, fungi) not present in the native fauna and flora.

**Article 5**

**Information**

Each Party shall prepare and make available information setting forth, in particular, prohibited activities and providing lists of Specially Protected Species and relevant Protected Areas to all those persons present in or intending to enter the Antarctic Treaty area with a view to ensuring that such persons understand and observe the provisions of this Annex.

**Article 6**

**Exchange of information**

1. The Parties shall make arrangements for:
   a. collecting and exchanging records (including records of permits) and statistics concerning the numbers or quantities of each species of native mammal, bird or plant taken annually in the Antarctic Treaty area;

   b. obtaining and exchanging information as to the status of native mammals, birds, plants, and invertebrates in the Antarctic Treaty area, and the extent to which any species or population needs protection;

   c. establishing a common form in which this information shall be submitted by Parties in accordance with paragraph 2 below.
2. Each Party shall inform the other Parties as well as the Committee before the end of November of each year of any step taken pursuant to paragraph 1 above and of the number and nature of permits issued under this Annex in the preceding period of 1 July to 30 June.

Article 7

*Relationship with other agreements outside the Antarctic Treaty system*

Nothing in this Annex shall derogate from the rights and obligations of Parties under the International Convention for the Regulation of Whaling.

Article 8

*Review*

The Parties shall keep under continuing review measures for the conservation of Antarctic fauna and flora, taking into account any recommendations from the Committee.

Article 9

*Amendment or modification*

1. This Annex may be amended or modified by a measure adopted in accordance with Article IX(1) of the Antarctic Treaty. Unless the measure specifies otherwise, the amendment or modification shall be deemed to have been approved, and shall become effective, one year after the close of the Antarctic Treaty Consultative Meeting at which it was adopted, unless one or more of the Antarctic Treaty Consultative Parties notifies the Depositary, within that time period, that it wishes an extension of that period or that it is unable to approve the measure.
2. Any amendment or modification of this Annex which becomes effective in accordance with paragraph 1 above shall thereafter become effective as to any other Party when notice of approval by it has been received by the Depositary.

APPENDICES TO THE ANNEX

Appendix A: Specially Protected Species

All species of the genus Arctocephalus, Fur Seals.

Ommatophoca rossii, Ross Seal.

Appendix B: Importation of Animals and Plants

The following animals and plants may be imported into the Antarctic Treaty area in accordance with permits issued under Article 4 of this Annex:

1. domestic plants; and

2. laboratory animals and plants including viruses, bacteria, yeasts and fungi.

Appendix C: Precautions to Prevent Introduction of Micro-organisms

1. Poultry. No live poultry or other living birds shall be brought into the Antarctic Treaty area. Before dressed poultry is packaged for shipment to the Antarctic Treaty area, it shall be inspected for evidence of disease, such as Newcastle's Disease, tuberculosis, and yeast infection. Any poultry or parts not consumed shall be removed from the Antarctic Treaty area or disposed of by incineration or equivalent means that eliminates risks to native flora and fauna.

2. The importation of non-sterile soil shall be avoided to the maximum extent practicable.
ANNEX III
WASTE DISPOSAL AND WASTE MANAGEMENT

Article 1

General obligations

1. This Annex shall apply to activities undertaken in the Antarctic Treaty area pursuant to scientific research programmes, tourism and all other governmental and non-governmental activities in the Antarctic Treaty area for which advance notice is required under Article VII(5) of the Antarctic Treaty, including associated logistic support activities.

2. The amount of wastes produced or disposed of in the Antarctic Treaty area shall be reduced as far as practicable so as to minimise impact on the Antarctic environment and to minimise interference with the natural values of Antarctica, with scientific research and with other uses of Antarctica which are consistent with the Antarctic Treaty.

3. Waste storage, disposal and removal from the Antarctic Treaty area, as well as recycling and source reduction, shall be essential considerations in the planning and conduct of activities in the Antarctic Treaty area.

4. Wastes removed from the Antarctic Treaty area shall, to the maximum extent practicable, be returned to the country from which the activities generating the waste were organized or to any other country in which arrangements have been made for the disposal of such wastes in accordance with relevant international agreements.

5. Past and present waste disposal sites on land and abandoned work sites of Antarctic activities shall be cleaned up by the generator of such wastes and the user of such sites. This obligation shall not be interpreted as requiring:
   a. the removal of any structure designated as a historic site or monument; or
b. the removal of any structure or waste material in circumstances where the removal by any practical option would result in greater adverse environmental impact than leaving the structure or waste material in its existing location.

**Article 2**

**Waste disposal by removal from the Antarctic Treaty area**

1. The following wastes, if generated after entry into force of this Annex, shall be removed from the Antarctic Treaty area by the generator of such wastes:

   a. radio-active materials;

   b. electrical batteries;

   c. fuel, both liquid and solid;

   d. wastes containing harmful levels of heavy metals or acutely toxic or harmful persistent compounds;

   e. poly-vinyl chloride (PVC), polyurethane foam, polystyrene foam, rubber and lubricating oils, treated timbers and other products which contain additives that could produce harmful emissions if incinerated;

   f. all other plastic wastes, except low density polyethylene containers (such as bags for storing wastes), provided that such containers shall be incinerated in accordance with Article 3(1);

   g. fuel drums; and

   h. other solid, non-combustible wastes;

provided that the obligation to remove drums and solid non-combustible wastes contained in subparagraphs (g) and (h) above shall not apply in circumstances where the removal of such wastes by any practical option would result in greater adverse environmental impact than leaving them in their existing locations.
2. Liquid wastes which are not covered by paragraph 1 above and sewage and domestic liquid wastes, shall, to the maximum extent practicable, be removed from the Antarctic Treaty area by the generator of such wastes.

3. The following wastes shall be removed from the Antarctic Treaty area by the generator of such wastes, unless incinerated, autoclaved or otherwise treated to be made sterile:
   
   a. residues of carcasses of imported animals;
   
   b. laboratory culture of micro-organisms and plant pathogens; and
   
   c. introduced avian products.

**Article 3**

**Waste disposal by incineration**

1. Subject to paragraph 2 below, combustible wastes, other than those referred to in Article 2(1), which are not removed from the Antarctic Treaty area shall be burnt in incinerators which to the maximum extent practicable reduce harmful emissions. Any emission standards and equipment guidelines which may be recommended by, inter alia, the Committee and the Scientific Committee on Antarctic Research shall be taken into account. The solid residue of such incineration shall be removed from the Antarctic Treaty area.

2. All open burning of wastes shall be phased out as soon as practicable, but no later than the end of the 1998/1999 season. Pending the completion of such phase-out, when it is necessary to dispose of wastes by open burning, allowance shall be made for the wind direction and speed and the type of wastes to be burnt to limit particulate deposition and to avoid such deposition over areas of special biological, scientific, historic, aesthetic or wilderness significance including, in particular, areas accorded protection under the Antarctic Treaty.
Article 4

Other waste disposal on land

1. Wastes not removed or disposed of in accordance with Articles 2 and 3 shall not be disposed of onto ice-free areas or into fresh water systems.

2. Sewage, domestic liquid wastes and other liquid wastes not removed from the Antarctic Treaty area in accordance with Article 2, shall, to the maximum extent practicable, not be disposed of onto sea ice, ice shelves or the grounded ice-sheet, provided that such wastes which are generated by stations located inland on ice shelves or on the grounded ice-sheet may be disposed of in deep ice pits where such disposal is the only practicable option. Such pits shall not be located on known ice-flow lines which terminate at ice-free areas or in areas of high ablation.

3. Wastes generated at field camps shall, to the maximum extent practicable, be removed by the generator of such wastes to supporting stations or ships for disposal in accordance with this Annex.

Article 5

Disposal of waste in the sea

1. Sewage and domestic liquid wastes may be discharged directly into the sea, taking into account the assimilative capacity of the receiving marine environment and provided that:

   a. such discharge is located, wherever practicable, where conditions exist for initial dilution and rapid dispersal; and

   b. large quantities of such wastes (generated in a station where the average weekly occupancy over the austral summer is
approximately 30 individuals or more) shall be treated at least by maceration.

2. The by-product of sewage treatment by the Rotary Biological Contactor process or similar processes may be disposed of into the sea provided that such disposal does not adversely affect the local environment, and provided also that any such disposal at sea shall be in accordance with Annex IV to the Protocol.

Article 6

Storage of waste

All wastes to be removed from the Antarctic Treaty area, or otherwise disposed of, shall be stored in such a way as to prevent their dispersal into the environment.

Article 7

Prohibited products

No polychlorinated biphenyls (PCBs), non-sterile soil, polystyrene beads, chips or similar forms of packaging, or pesticides (other than those required for scientific, medical or hygiene purposes) shall be introduced onto land or ice shelves or into water in the Antarctic Treaty area.

Article 8

Waste management planning

1. Each Party which itself conducts activities in the Antarctic Treaty area shall, in respect of those activities, establish a waste disposal classification system as a basis for recording wastes and to facilitate studies aimed at evaluating the environmental impacts of scientific activity and associated logistic support. To that end, wastes produced shall be classified as:

   a. sewage and domestic liquid wastes (Group 1);
b. other liquid wastes and chemicals, including fuels and lubricants (Group 2);

c. solids to be combusted (Group 3);

d. other solid wastes (Group 4); and

e. radioactive material (Group 5).

2. In order to reduce further the impact of waste on the Antarctic environment, each such Party shall prepare and annually review and update its waste management plans (including waste reduction, storage and disposal), specifying for each fixed site, for field camps generally, and for each ship (other than small boats that are part of the operations of fixed sites or of ships and taking into account existing management plans for ships):

   a. programmes for cleaning up existing waste disposal sites and abandoned work sites;

   b. current and planned waste management arrangements, including final disposal;

   c. current and planned arrangements for analysing the environmental effects of waste and waste management; and

   d. other efforts to minimise any environmental effects of wastes and waste management.

3. Each such Party shall, as far as is practicable, also prepare an inventory of locations of past activities (such as traverses, fuel depots, field bases, crashed aircraft) before the information is lost, so that such locations can be taken into account in planning future scientific programmes (such as snow chemistry, pollutants in lichens or ice core drilling).

**Article 9**

*Circulation and review of waste management plans*

1. The waste management plans prepared in accordance with Article 8, reports on their implementation, and the inventories referred to in
Article 8(3), shall be included in the annual exchanges of information in accordance with Articles III and VII of the Antarctic Treaty and related Recommendations under Article IX of the Antarctic Treaty.

2. Each Party shall send copies of its waste management plans, and reports on their implementation and review, to the Committee.

3. The Committee may review waste management plans and reports thereon and may offer comments, including suggestions for minimising impacts and modifications and improvement to the plans, for the consideration of the Parties.

4. The Parties may exchange information and provide advice on, inter alia, available low waste technologies, reconversion of existing installations, special requirements for effluents, and appropriate disposal and discharge methods.

Article 10

Management practices

Each Party shall:

1. designate a waste management official to develop and monitor waste management plans; in the field, this responsibility shall be delegated to an appropriate person at each site;

2. ensure that members of its expeditions receive training designed to limit the impact of its operations on the Antarctic environment and to inform them of requirements of this Annex; and

3. discourage the use of poly-vinyl chloride (PVC) products and ensure that its expeditions to the Antarctic Treaty area are advised of any PVC products they may introduce into that area in order that these products may be removed subsequently in accordance with this Annex.
Article 11

Review

This Annex shall be subject to regular review in order to ensure that it is updated to reflect improvement in waste disposal technology and procedures and to ensure thereby maximum protection of the Antarctic environment.

Article 12

Cases of emergency

1. This Annex shall not apply in cases of emergency relating to the safety of human life or of ships, aircraft or equipment and facilities of high value or the protection of the environment.

2. Notice of activities undertaken in cases of emergency shall be circulated immediately to all Parties and to the Committee.

Article 13

Amendment or modification

1. This Annex may be amended or modified by a measure adopted in accordance with Article IX(1) of the Antarctic Treaty. Unless the measure specifies otherwise, the amendment or modification shall be deemed to have been approved, and shall become effective, one year after the close of the Antarctic Treaty Consultative Meeting at which it was adopted, unless one or more of the Antarctic Treaty Consultative Parties notifies the Depositary, within that time period, that it wishes an extension of that period or that it is unable to approve the measure.

2. Any amendment or modification of this Annex which becomes effective in accordance with paragraph 1 above shall thereafter become effective as to any other Party when notice of approval by it has been received by the Depositary.
ANNEX IV
PREVENTION OF MARINE POLLUTION

Article 1

Definitions

For the purposes of this Annex:
1. "discharge" means any release howsoever caused from a ship and include any escape, disposal, spilling, leaking, pumping, emitting or emptying;

2. "garbage" means all kinds of victual, domestic and operational waste excluding fresh fish and parts thereof, generated during the normal operation of the ship, except those substances which are covered by Articles 3 and 4;


4. "noxious liquid substance" means any noxious liquid substance as defined in Annex II of MARPOL 73/78;

5. "oil" means petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined oil products (other than petrochemicals which are subject to the provisions of Article 4);

6. "oily mixture" means a mixture with any oil content; and

7. "ship" means a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms.
Article 2

Application

This Annex applies, with respect to each Party, to ships entitled to fly its flag and to any other ship engaged in or supporting its Antarctic operations, while operating in the Antarctic Treaty area.

Article 3

Discharge of oil

1. Any discharge into the sea of oil or oily mixture shall be prohibited, except in cases permitted under Annex I of MARPOL 73/78. While operating in the Antarctic Treaty area, ships shall retain on board all sludge, dirty ballast, tank washing waters and other oily residues and mixtures which may not be discharged into the sea. Ships shall discharge these residues only outside the Antarctic Treaty area, at reception facilities or as otherwise permitted under Annex I of MARPOL 73/78.

2. This Article shall not apply to:

   a. the discharge into the sea of oil or oily mixture resulting from damage to a ship or its equipment:

      i. provided that all reasonable precautions have been taken after the occurrence of the damage or discovery of the discharge for the purpose of preventing or minimising the discharge; and

      ii. except if the owner or the Master acted either with intent to cause damage, or recklessly and with the knowledge that damage would probably result; or

   b. the discharge into the sea of substances containing oil which are being used for the purpose of combating specific pollution incidents in order to minimise the damage from pollution.
Article 4

**Discharge of noxious liquid substances**

The discharge into the sea of any noxious liquid substance, and any other chemical or other substances, in quantities or concentrations that are harmful to the marine environment, shall be prohibited.

Article 5

**Disposal of garbage**

1. The disposal into the sea of all plastics, including but not limited to synthetic ropes, synthetic fishing nets, and plastic garbage bags, shall be prohibited.

2. The disposal into the sea of all other garbage, including paper products, rags, glass, metal, bottles, crockery, incineration ash, dunnage, lining and packing materials, shall be prohibited.

3. The disposal into the sea of food wastes may be permitted when they have been passed through a comminuter or grinder, provided that such disposal shall, except in cases permitted under Annex V of MARPOL 73/78, be made as far as practicable from land and ice shelves but in any case not less than 12 nautical miles from the nearest land or ice shelf. Such comminuted or ground food wastes shall be capable of passing through a screen with openings no greater than 25 millimetres.

4. When a substance or material covered by this article is mixed with other such substance or material for discharge or disposal, having different disposal or discharge requirements, the most stringent disposal or discharge requirements shall apply.

5. The provisions of paragraphs 1 and 2 above shall not apply to:

   a. the escape of garbage resulting from damage to a ship or its equipment provided all reasonable precautions have been taken, before and after the occurrence of the damage, for the purpose of preventing or minimising the escape; or
b. the accidental loss of synthetic fishing nets, provided all reasonable precautions have been taken to prevent such loss.

6. The Parties shall, where appropriate, require the use of garbage record books.

**Article 6**

**Discharge of sewage**

1. Except where it would unduly impair Antarctic operations:
   
a. each Party shall eliminate all discharge into the sea of untreated sewage ("sewage" being defined in Annex IV of MARPOL 73/78) within 12 nautical miles of land or ice shelves;

   b. beyond such distance, sewage stored in a holding tank shall not be discharged instantaneously but at a moderate rate and, where practicable, while the ship is en route at a speed of no less than 4 knots.

   This paragraph does not apply to ships certified to carry not more than 10 persons.

2. The Parties shall, where appropriate, require the use of sewage record books.

**Article 7**

**Cases of emergency**

1. Articles 3, 4, 5 and 6 of this Annex shall not apply in cases of emergency relating to the safety of a ship and those on board or saving life at sea.

2. Notice of activities undertaken in cases of emergency shall be circulated immediately to all Parties and to the Committee.

**Article 8**

**Effect on dependent and associated ecosystems**
In implementing the provisions of this Annex, due consideration shall be given to the need to avoid detrimental effects on dependent and associated ecosystems, outside the Antarctic Treaty area.

**Article 9**

**Ship retention capacity and reception facilities**

1. Each Party shall undertake to ensure that all ships entitled to fly its flag and any other ship engaged in or supporting its Antarctic operations, before entering the Antarctic Treaty area, are fitted with a tank or tanks of sufficient capacity on board for the retention of all sludge, dirty ballast, tank washing water and other oily residues and mixtures, and have sufficient capacity on board for the retention of garbage, while operating in the Antarctic Treaty area and have concluded arrangements to discharge such oily residues and garbage at a reception facility after leaving that area. Ships shall also have sufficient capacity on board for the retention of noxious liquid substances.

2. Each Party at whose ports ships depart en route to or arrive from the Antarctic Treaty area undertakes to ensure that as soon as practicable adequate facilities are provided for the reception of all sludge, dirty ballast, tank washing water, other oily residues and mixtures, and garbage from ships, without causing undue delay, and according to the needs of the ships using them.

3. Parties operating ships which depart to or arrive from the Antarctic Treaty area at ports of other Parties shall consult with those Parties with a view to ensuring that the establishment of port reception facilities does not place an inequitable burden on Parties adjacent to the Antarctic Treaty area.

**Article 10**

**Design, construction, manning and equipment of ships**
In the design, construction, manning and equipment of ships engaged in or supporting Antarctic operations, each Party shall take into account the objectives of this Annex.

**Article 11**

**Sovereign immunity**

1. This Annex shall not apply to any warship, naval auxiliary or other ship owned or operated by a State and used, for the time being, only on government non-commercial service. However, each Party shall ensure by the adoption of appropriate measures not impairing the operations or operational capabilities of such ships owned or operated by it, that such ships act in a manner consistent, so far as is reasonable and practicable, with this Annex.

2. In applying paragraph 1 above, each Party shall take into account the importance of protecting the Antarctic environment.

3. Each Party shall inform the other Parties of how it implements this provision.

4. The dispute settlement procedure set out in Articles 18 to 20 of the Protocol shall not apply to this Article.

**Article 12**

**Preventive measures and emergency preparedness and response**

1. In order to respond more effectively to marine pollution emergencies or the threat thereof in the Antarctic Treaty area, the Parties, in accordance with Article 15 of the Protocol, shall develop contingency plans for marine pollution response in the Antarctic Treaty area, including contingency plans for ships (other than small boats that are part of the operations of fixed sites or of ships) operating in the Antarctic Treaty area, particularly ships carrying oil as cargo, and for oil spills, originating from coastal installations, which enter into the marine environment. To this end they shall:

   a. co-operate in the formulation and implementation of such plans; and
b. draw on the advice of the Committee, the International Maritime Organization and other international organizations.

2. The Parties shall also establish procedures for cooperative response to pollution emergencies and shall take appropriate response actions in accordance with such procedures.

Article 13

Review

The Parties shall keep under continuous review the provisions of this Annex and other measures to prevent, reduce and respond to pollution of the Antarctic marine environment, including any amendments and new regulations adopted under MARPOL 73/78, with a view to achieving the objectives of this Annex.

Article 14

Relationship with MARPOL 73/78

With respect to those Parties which are also Parties to MARPOL 73/78, nothing in this Annex shall derogate from the specific rights and obligations thereunder.

Article 15

Amendment or modification

1. This Annex may be amended or modified by a measure adopted in accordance with Article IX(1) of the Antarctic Treaty. Unless the measure specifies otherwise, the amendment or modification shall be deemed to have been approved, and shall become effective, one year after the close of the Antarctic Treaty Consultative Meeting at which it was adopted, unless one or more of the Antarctic Treaty Consultative Parties notifies the Depositary, within that time period, that it wishes an extension of that period or that it is unable to approve the measure.
2. Any amendment or modification of this Annex which becomes effective in accordance with paragraph 1 above shall thereafter become effective as to any other Party when notice of approval by it has been received by the Depositary.

ANNEX V
TO THE PROTOCOL ON ENVIRONMENTAL PROTECTION TO THE ANTARCTIC TREATY – AREA PROTECTION AND MANAGEMENT

Article 1

Definitions

For the purposes of this Annex:

1. "appropriate authority" means any person or agency authorised by a Party to issue permits under this Annex;

2. "permit" means a formal permission in writing issued by an appropriate authority;

3. "Management Plan" means a plan to manage the activities and protect the special value or values in an Antarctic Specially Protected Area or an Antarctic Specially Managed Area.

Article 2

Objectives

For the purposes set out in this Annex, any area, including any marine area, may be designated as an Antarctic Specially Protected Area or an Antarctic Specially Managed Area. Activities in those Areas shall be prohibited, restricted or managed in accordance with Management Plans adopted under the provisions of this Annex.

Article 3

Antarctic Specially Protected Areas
1. Any area, including any marine area, may be designated as an Antarctic Specially Protected Area to protect outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or ongoing or planned scientific research.

2. Parties shall seek to identify, within a systematic environmental-geographical framework, and to include in the series of Antarctic Specially Protected Areas:

   a. areas kept inviolate from human interference so that future comparisons may be possible with localities that have been affected by human activities;

   b. representative examples of major terrestrial, including glacial and aquatic, ecosystems and marine ecosystems;

   c. areas with important or unusual assemblages of species, including major colonies of breeding native birds or mammals;

   d. the type locality or only known habitat of any species;

   e. areas of particular interest to on-going or planned scientific research;

   f. examples of outstanding geological, glaciological or geomorphological features;

   g. areas of outstanding aesthetic and wilderness value;

   h. sites or monuments or recognised historic value; and

   i. such other areas as may be appropriate to protect the values set out in paragraph 1 above.

3. Specially Protected Areas and Sites of Special Scientific Interest designated as such by past Antarctic Treaty Consultative Meetings are hereby designated as Antarctic Specially Protected Areas and shall be renamed and renumbered accordingly.

4. Entry into an Antarctic Specially Protected Area shall be prohibited except in accordance with a permit issued under Article 7.
Article 4

Antarctic Specially Managed Areas

1. Any area, including any marine area, where activities are being conducted or may in the future be conducted, may be designated as an Antarctic Specially Managed Area to assist in the planning and co-ordination of activities, avoid possible conflicts, improve co-operation between Parties or minimise environmental impacts.

2. Antarctic Specially Managed Areas may include:

   a. areas where activities pose risks of mutual interference or cumulative environmental impacts; and

   b. sites or monuments of recognised historic value.

3. Entry into an Antarctic Specially Managed Area shall not require a permit.

4. Notwithstanding paragraph 3 above, an Antarctic Specially Managed Area may contain one or more Antarctic Specially Protected Areas, entry into which shall be prohibited except in accordance with a permit issued under Article 7.

Article 5

Management Plans

1. Any Party, the Committee, the Scientific Committee for Antarctic Research or the Commission for the Conservation of Antarctic Marine Living Resources may propose an area for designation as an Antarctic Specially Protected Area or an Antarctic Specially Managed Area by submitting a proposed Management Plan to the Antarctic Treaty Consultative Meeting.

2. The area proposed for designation shall be of sufficient size to protect the values for which the special protection or management is required.

3. Proposed Management Plans shall include, as appropriate:
a. a description of the value or values for which special protection or management is required;

b. a statement of the aims and objectives of the Management Plan for the protection or management of those values;

c. management activities which are to be undertaken to protect the values for which special protection or management is required;

d. a period of designation, if any;

e. a description of the area, including:
   i. the geographical co-ordinates, boundary markers and natural features that delineate the area;
   ii. access to the area by land, sea or air including marine approaches and anchorages, pedestrian and vehicular routes within the area, and aircraft routes and landing areas;
   iii. the location of structures, including scientific stations, research or refuge facilities, both within the area and near to it; and
   iv. the location in or near the area of other Antarctic Specially Protected Areas or Antarctic Specially Managed Areas designated under this Annex, or other protected areas designated in accordance with measures adopted under other components of the Antarctic Treaty System;

f. the identification of zones within the area, in which activities are to be prohibited, restricted or managed for the purpose of achieving the aims and objectives referred to in subparagraph b. above;

g. maps and photographs that show clearly the boundary of the area in relation to surrounding features and key features within the area;

h. supporting documentation;
i. in respect of an area proposed for designation as an Antarctic Specially Protected Area, a clear description of the conditions under which permits may be granted by the appropriate authority regarding:

i. access to and movement within or over the area;

ii. activities which are or may be conducted within the area, including restrictions on time and place;

iii. the installation, modification, or removal of structures;

iv. the location of field camps;

v. restrictions on materials and organisms which may be brought into the area;

vi. the taking of or harmful interference with native flora and fauna;

vii. the collection or removal of anything not brought into the area by the permit holder;

viii. the disposal of waste;

ix. measures that may be necessary to ensure that the aims and objectives of the Management Plan can continue to be met; and

x. requirements for reports to be made to the appropriate authority regarding visits to the area;

j. in respect of an area proposed for designation as an Antarctic Specially Managed Area, a code of conduct regarding:

i. access to and movement within or over the area;

ii. activities which are or may be conducted within the area, including restrictions on time and place;

iii. the installation, modification, or removal of structures;
iv. the location of field camps;

v. the taking of or harmful interference with native flora and fauna;

vi. the collection or removal of anything not brought into the area by the visitor;

vii. the disposal of waste; and

viii. any requirements for reports to be made to the appropriate authority regarding visits to the area; and

k. provisions relating to the circumstances in which Parties should seek to exchange information in advance of activities which they propose to conduct.

**Article 6**

**Designation Procedures**

1. Proposed Management Plans shall be forwarded to the Committee, the Scientific Committee on Antarctic Research and, as appropriate, to the Commission for the Conservation of Antarctic Marine Living Resources. In formulating its advice to the Antarctic Treaty Consultative Meeting, the Committee shall take into account any comments provided by the Scientific Committee on Antarctic Research and, as appropriate, by the Commission for the Conservation of Antarctic Marine Living Resources. Thereafter, Management Plans may be approved by the Antarctic Treaty Consultative Parties by a measure adopted at an Antarctic Treaty Consultative Meeting in accordance with Article IX(1) of the Antarctic Treaty. Unless the measure specifies otherwise, the Plan shall be deemed to have been approved 90 days after the close of the Antarctic Treaty Consultative Meeting at which it was adopted, unless one or more of the Consultative Parties notifies the Depositary, within that time period, that it wishes an extension of that period or is unable to approve the measure.
2. Having regard to the provisions of Articles 4 and 5 of the Protocol, no marine area shall be designated as an Antarctic Specially Protected Area or an Antarctic Specially Managed Area without the prior approval of the Commission for the Conservation of Antarctic Marine Living Resources.

3. Designation of an Antarctic Specially Protected Area or an Antarctic Specially Managed Area shall be for an indefinite period unless the Management Plan provides otherwise. A review of a Management Plan shall be initiated at least every five years. The Plan shall be updated as necessary.

4. Management Plans may be amended or revoked in accordance with paragraph 1 above.

Upon approval Management Plans shall be circulated promptly by the Depositary to all Parties. The Depositary shall maintain a record of all currently approved Management Plans.

Article 7

Permits

1. Each Party shall appoint an appropriate authority to issue permits to enter and engage in activities within an Antarctic Specially Protected Area in accordance with the requirements of the Management Plan relating to that Area. The permit shall be accompanied by the relevant sections of the Management Plan and shall specify the extent and location of the Area, the authorised activities and when, where and by whom the activities are authorised and any other conditions imposed by the Management Plan.

2. In the case of a Specially Protected Area designated as such by past Antarctic Treaty Consultative Meeting which does not have a Management Plan, the appropriate authority may issue a permit for a compelling scientific purpose which cannot be served elsewhere and which will not jeopardise the natural ecological system in that Area.
3. Each Party shall require a permit-holder to carry a copy of the permit while in the Antarctic Specially Protected Area concerned.

**Article 8**

**Historic Sites and Monuments**

1. Sites or monuments of recognised historic value which have been designated as Antarctic Specially Protected Areas or Antarctic Specially Managed Areas, or which are located within such Areas, shall be listed as Historic Sites and Monuments.

2. Any Party may propose a site or monument of recognised historic value which has not been designated as an Antarctic Specially Protected Area or an Antarctic Specially Managed Area, or which is not located within such an Area, for listing as a Historic Site or Monument. The proposal for listing may be approved by the Antarctic Treaty Consultative Parties by a measure adopted at an Antarctic Treaty Consultative Meeting in accordance with Article IX(1) of the Antarctic Treaty. Unless the measure specifies otherwise, the proposal shall be deemed to have been approved 90 days after the close of the Antarctic Treaty Consultative Meeting at which it was adopted, unless one or more of the Consultative Parties notifies the Depositary, within that time period, that it wishes an extension of that period or is unable to approve the measure.

3. Existing Historic Sites and Monuments which have been listed as such by previous Antarctic Treaty Consultative Meetings shall be included in the list of Historic Sites and Monuments under this Article.

4. Listed Historic Sites and Monuments shall not be damaged, removed or destroyed.

5. The list of Historic Sites and Monuments may be amended in accordance with paragraph 2 above. The Depositary shall maintain a list of current Historic Sites and Monuments.
Article 9

*Information and Publicity*

1. With a view to ensuring that all persons visiting or proposing to visit Antarctica understand and observe the provisions of this Annex, each Party shall make available information setting forth, in particular:

   a. the location of Antarctic Specially Protected Areas and Antarctic Specially Managed Areas;

   b. listing and maps of those Areas;

   c. the Management Plans, including listings of prohibitions relevant to each Area;

   d. the location of Historic Sites and Monuments and any relevant prohibition or restriction.

2. Each Party shall ensure that the location and, if possible, the limits of Antarctic Specially Protected Areas, Antarctic Specially Managed Areas and Historic Sites and Monuments are shown on its topographic maps, hydrographic charts and in other relevant publications.

Parties shall co-operate to ensure that, where appropriate, the boundaries of Antarctic Specially Protected Areas, Antarctic Specially Managed Areas and Historic Sites and Monuments are suitably marked on the site.

Article 10

*Exchange of Information*

1. The Parties shall make arrangements for:

   a. collecting and exchanging records, including records of permits and reports of visits, including inspection visits, to Antarctic Specially Protected Areas and reports of inspection visits to Antarctic Specially Managed Areas;
b. obtaining and exchanging information on any significant change or damage to any Antarctic Specially Managed Area, Antarctic Specially Protected Area or Historic Site or Monument; and

c. establishing common forms in which records and information shall be submitted by Parties in accordance with paragraph 2 below.

2. Each Party shall inform the other Parties and the Committee before the end of November of each year of the number and nature of permits issued under this Annex in the preceding period of 1st July to 30th June.

3. Each Party conducting, funding or authorising research or other activities in Antarctic Specially Protected Areas or Antarctic Specially Managed Areas shall maintain a record of such activities and in the annual exchange of information in accordance with the Antarctic Treaty shall provide summary descriptions of the activities conducted by persons subject to its jurisdiction in such areas in the preceding year.

4. Each Party shall inform the other Parties and the Committee before the end of November each year of measures it has taken to implement this Annex, including any site inspections and any steps it has taken to address instances of activities in contravention of the provisions of the approved Management Plan for an Antarctic Specially Protected Area or Antarctic Specially Managed Area.

Article 11

Cases of Emergency

1. The restrictions laid down and authorised by this Annex shall not apply in cases of emergency involving safety of human life or of ships, aircraft, or equipment and facilities of high value or the protection of the environment.

2. Notice of activities undertaken in cases of emergency shall be circulated immediately to all Parties and to the Committee.
Article 12

Amendment or Modification

1. This Annex may be amended or modified by a measure adopted in accordance with Article IX(1) of the Antarctic Treaty. Unless the measure specifies otherwise, the amendment or modification shall be deemed to have been approved, and shall become effective, one year after the close of the Antarctic Treaty Consultative Meeting at which it was adopted, unless one or more of the Antarctic Treaty Consultative Parties notifies the Depositary, within that time period, that it wishes an extension of that period or that it is unable to approve the measure.

2. Any amendment or modification of this Annex which becomes effective in accordance with paragraph 1 above shall thereafter become effective as to any other Party when notice of approval by it has been received by the Depositary.
# APPENDIX 4
## LIST OF WORKSHOP PARTICIPANTS

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
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