Antarctic Biosecurity
Syndicate Project, GCAS 8

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Contents:

Abstract

The protection of Antarctic ecosystems from alien and invasive species is one of the key aims of the Environmental Protocol (1991) to the Antarctic Treaty System. Despite the patchy nature of different domestic policy implementations and management strategies regarding this issue, recent research has shown that the threats of biological invasions in Antarctica are real. Introductions of nonnative and invasive species in the Subantarctic Islands provide a useful analogue for discussing the potential risks in the Antarctic Peninsula and continent. The increase in human activities and their subsequent logistics support provides increasing opportunities for alien species to hitch-hike to the Antarctic, and for the dispersal of indigenous species around the continent. Moreover, rapid environmental changes the Antarctic Peninsula in particular may provide nonnative species with the environment they are looking for and contributes to the complexity and uncertainties involved. Regardless of the overall lack of knowledge and ill-defined scope of this problem, precautionary measures need to be taken urgently.

Introduction

Protecting the Antarctic environment from nonnative pests and diseases has long been of concern, with the first rules governing introduction of species negotiated as early as 1964.

Despite clear agreement on the desirability of excluding nonnative pests and diseases, the introduction of procedures to implement these agreements has been patchy. Currently, many countries simply advise travellers of the requirement not to bring in biological material, rather than undertaking quarantine or inspections.

In this paper, we discuss Antarctic Biosecurity - the procedures that countries do (or might) put in place to implement international agreements on introduction of nonnative species.

The first section of this paper reviews the status of Antarctic law regarding nonnative species, current biosecurity policies for Antarctica and how other jurisdictions address similar concerns. Section two follows with an analysis of what makes a successful invasive species, and the particular species threats facing Antarctica. Next, section three looks at transport pathways in detail, as the carriers of all potential nonnative species introductions. Finally, section four explores biosecurity management in practice through consideration of three case studies, before we present our conclusions and recommendations.

We have chosen to limit the scope of this paper in several regards.

Firstly, while there are clearly potential issues relating to the transport of Antarctic species northward, in this paper we have chosen to consider only protection of the Antarctic environment from nonnative species.

Secondly, overall, the geographic extent covers the Antarctic continent and surrounding marine environment. The exception to this is Section 2, on Antarctic species. In this section, we have also chosen to cover Subantarctic islands, partly because of the greater availability of data but mostly because, with a changing climate, these islands could give a useful indication of future issues the continent may face.

Finally, we do not address the philosophical debate classifying whether species change that follows from anthropogenic climate change as natural change or as the introduction of species, and whether management of such species is appropriate. In our view, the immediate priorities for Antarctic Biosecurity are to put in place better border controls and management practices now to deal with existing threats, and questions around whether these controls need to be further enhanced to take into account the future impacts of climate change can be considered as the next step.

Section 1. Law and Policy relating to Antarctic Biosecurity

1.1 Why do we care about introduction of nonnative species?

Every country has its invasive species horror story. In New Zealand, introduced possums have decimated native forests and birdlife[1]. In Australia, cane toads are spreading quickly, poisoning native wildlife in their wake[2]. In the United States zebra mussels are clogging waterways[3]. In addition, in South America, North American beavers are flooding forest areas in Tierra del Fuego (Di Paola and Kravetz, 2003).

We now know that introduction of nonnative species can have unforeseeable consequences, but this has not always been a concern. For example, footage of the establishment of Scott Base in 1959 shows the New Zealand party planting out grasses behind the base to see if they would grow (NZFU, 1958).

Attention to biosecurity is a recent phenomenon, growing over the last few decades. A series of international agreements has reflected this attitude change, culminating in the 1992 Convention on Biological Diversity, and in the Antarctic context, the 1991 Environmental Protocol to the Antarctic Treaty.

1.2 Consideration of Nonnative Species in the Antarctic Treaty System

The process for considering how to deal with nonnative species in Antarctica began with the 1959 Antarctic Treaty. Under Article IX of the Treaty, parties agreed to meet further to consider, among other things, the “preservation and conservation of living resources in Antarctica”.

These discussions eventually led to the 1964 ‘Agreed Measures for the Conservation of Antarctic Fauna and Flora’, which agreed that permits would be required for introduction of non-indigenous animals or plants (with an exception for food), and that governments would ensure that all reasonable precautions were taken to prevent the accidental introduction of parasites and diseases into the Treaty Area. [see Appendix 1 for text]. These measures did not enter into force until 1982.

In the marine environment, it was agreed under the 1982 Convention on the Conservation of Antarctic Marine Living Resources [Art II (3) (c)] that introduction of alien species be considered in conservation management decisions. [see Appendix 1 for text].

The 1991 Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol) strengthened earlier provisions considerably. The Protocol has as its environmental principles that (Article 3)

> 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

[1] http://www.doc.govt.nz/Conservation/002~Animal-Pests/Possums/index.asp
[2] http://www.deh.gov.au/biodiversity/invasive/publications/cane-toad/index.html
[3] http://www.invasivespeciesinfo.gov/profiles/zebramussel.shtml

To this end, Annex II, Article 4 of the Protocol regulates the introduction of nonnative species, parasites and diseases. Appendix 1 contains the full text, however key extensions to the previous provisions are that:

- Nonnative plants or animals present under a permit must now be removed or incinerated at the end of the permit
- Any other nonnative plant or animal introduced to the Treaty Area must be removed or disposed of, unless it is determined that they pose no risk to native flora or fauna.
- Each party shall require that precautions be taken to prevent the introduction of microorganisms not present in the native flora and fauna.

Finally, outside the Antarctic Treaty System, the United Nations Convention on the Law of the Sea (UNCLOS), and the Convention on Biological Diversity (CBD) each contain provisions prohibiting introduction of nonnative species. [see Appendix 1 for text].

1.3 A possible goal for Antarctic Biosecurity policy?

In considering establishment of a system of biosecurity controls for Antarctica, it is helpful to consider what the specific goals of the system should be. Many countries have biosecurity rules that are targeted, at least in part, at protecting economic interests. For example, the New Zealand Biosecurity Strategy defines Biosecurity as "the exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health".[4]

How might this be modified in the Antarctic context? Firstly, the Madrid Protocol does not contemplate *management* of a nonnative species - *removal* of nonnative species is mandated. Secondly, the Antarctic values to be protected are spelled out in Article III of the Protocol. Accordingly, we would propose that, in order to satisfy the agreed provisions of the Madrid Protocol, an Antarctic Biosecurity system would need to provide for:

> the exclusion or eradication of risks posed by pests and diseases to 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.

Clearly, this is a stricter requirement than that of the New Zealand domestic system. A key difference to note is that the level of protection required to preserve scientific research values and wilderness values may be far higher than the test New Zealand uses domestically. For example, translocation of species from site to site in Antarctica could seriously damage conduct of scientific research, even without significant damage to the ecosystems or the introduction of species that are nonnative to the area.

1.4 What biosecurity policies have other jurisdictions implemented?

As island nations characterised by unique ecosystems that have evolved in isolation, New Zealand and Australia might be two useful analogues for Antarctic biosecurity needs.

Both countries have specialist agencies to manage biosecurity[5]. Both set very strict border controls on travellers, cargo and vessels with the aim of preventing introduction of nonnative

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[4] http://www.biosecurity.govt.nz/bio-strategy/strategy-index.htm
[5] Biosecurity New Zealand http://www.biosecurity.govt.nz/, and Biosecurity Australia http://www.affa.gov.au/biosecurityaustralia

species. Quarantine and fumigation requirements apply to cargo, as well as the more recent introduction of ballast water discharge rules help manage marine biosecurity risks[6].

Finally, each conducts surveillance for incursions around known risk areas (particularly airports and ports), and has protocols in place for making decisions on eradication or management if a nonnative is detected. This part of the system is critical – despite strict border controls, accidental species introduction has proved unavoidable.

1.5 Current Antarctic Biosecurity Policies

As with all agreed measures under the Antarctic Treaty System, implementation of agreements is the responsibility of the individual governments that are parties to the Treaty. Here we explore how two countries, New Zealand and Australia, currently have different standards of biosecurity measures. Other groups, such as Tourism Operators have introduced their own procedures, which will be discussed in section 3 and 4 of this paper.

New Zealand

New Zealand's revised Statement of Strategic Interest on Antarctica (2002)[7] commits to:

> Conserving, protecting and understanding the biodiversity of Antarctica and the Southern Ocean, in particular the biodiversity of the Ross Sea region, including promotion, protection and management of representative special areas, and enhancing biosecurity.

The first part of this paragraph has undergone some progress relating to understanding biodiversity of Antarctica and the Ross Sea region. The Ross Sea region is explicitly part of the New Zealand Biodiversity Strategy (2003)[8], which states that

> New Zealand also has an active role in biodiversity conservation in our neighbouring marine areas and the Southern Ocean, and in Antarctica (focused on the stewardship of ecosystems within the Ross Dependency).

Funding for the BioRoss programme of marine ecosystem research in the Ross Sea is now available through the Biodiversity Strategy[9].

However, progress on the final clause, *enhancing biosecurity*, has not been as good. New Zealand's strict domestic biosecurity laws do not apply to flights or vessels leaving New Zealand for Antarctica. New Zealand law does not require any inspection of passenger luggage, or quarantine or fumigation of cargo for Antarctica-bound travel[10]. In terms of passenger luggage, travellers are advised of the requirement not to bring biological material into Antarctica, and told that is their responsibility to check clothing and gear.

For operations on the ice, parties are required to self-assess likely impacts through a Preliminary Environmental Evaluation (PEE), as part of the permitting process[11]. In this, they specify what precautions they propose to take to prevent the introduction of species, transfer of soil, and to comply with the poultry diseases prevention policy (which focuses on the protection of penguins). Although Antarctica New Zealand does not undertake enforcement of

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[6] http://www.fish.govt.nz/sustainability/biosecurity/ballastwater.html
[7] http://www.mfat.govt.nz/foreign/antarctica/relationship/nzstrat.html
[8] http://www.biodiversity.govt.nz/
[9] http://www.biodiversity.govt.nz/seas/biodiversity/programmes/bioross.html
[10] http://www.antarcticanz.govt.nz/article/3947.html#2667
[11] http://www.antarcticanz.govt.nz/article/3949.html#2665

biosecurity policies through border controls, they do audit some parties to check compliance with the practices outlined in their permits. Antarctica New Zealand argues that group leaders have a strong incentive to comply with permit conditions, as failure to do so could damage their ability to make future research visits to the ice (Gilbert, 2005).

Australia

In 2003, Australia launched its new Antarctic biosecurity policy "Take it new, or keep it clean"[12]. The initiative aims to ensure effective quarantine practices by all visitors, expeditioners and tourists, to Australia's Subantarctic islands and Antarctic stations.

Studies on transport of seeds on clothing, and discovery of soil, insects and plant material in cargo have motivated new, stricter cargo handling practices. Quarantine officials and sniffer dogs check all vessels and cargo before departure and regular fumigation of the cargo facility is undertaken. Cargo handlers inspect all fresh fruit and vegetables before packing. Travellers receive specific instruction on examining and cleaning clothing and equipment.

In addition, some issued clothing and equipment is modified to reduce risks, for example the replacement of Velcro, identified as a major transporter of seeds, with other types of fasteners.

1.6 Current moves within the Antarctic Treaty System toward improving Biosecurity policies

The last few years have seen the issue of biosecurity appear on the radar screen of the Antarctic Treaty Consultative Meetings (ATCMs), and the Scientific Committee on Antarctic Research (SCAR) who advise them.

A 1998 Australian workshop on protecting wildlife from introduced diseases launched discussions (AUS, 1999). Although the broader issue on nonnative species was raised by the IUCN (The World Conservation Union) at the time (IUCN, 1998), the focus of Antarctic Treaty System discussions until 2004 remained the prevention of disease introduction.

A turning point was the reporting of research by Yves Frenot, Steve Chown and collaborators (Frenot *et al*., 2005) to the 2004 SCAR meeting, reviewing biological invasions in the Antarctic and making management recommendations[13]. This research had been conducted under the RiSCC (Regional Sensitivity to Climate Change in Antarctic terrestrial and limnetic Ecosystems) scientific group of SCAR. The RiSCC scientists also proposed a code of conduct for fieldwork for SCAR's consideration, based on their concerns about translocation of species between sites in Antarctica (RISCC, 2004). Notably, this code of conduct has since been adopted by the Netherlands Antarctic Programme for all of their scientists.

SCAR then reported to the 2005 ATCM in Stockholm[14], at which there were also papers relating to biosecurity from Australia, IUCN, IAATO and the Council of Managers of National Antarctic Programmes (CONMAP)[15]. 2005 also saw SCAR's biology committee

[12] http://www.aad.gov.au/default.asp?casid=5483
[13] As reported at http://academic.sun.ac.za/cib/antarctica.htm
[14] See SCAR press release at http://www.scar.org/media/pressreleases/080605engrelease.html
[15] Papers from the 2005 Stockholm ATCM are available from http://www.ats.aq/28atcm/buscador.php

consider the IUCN draft "Antarctic Conservation in the 21st Century", including threats of introduced species. A final version is to be developed for SCAR consideration in 2006[16].

In addition, there will be a workshop on nonnative species in the Antarctic in April 2006 in Christchurch. Participants will table a paper on the workshop's outcomes at the 2006 ATCM in Edinburgh.[17]

1.7 Conclusions – Law and Policy relating to Antarctic Biosecurity

Provisions within Antarctic law, in particular the 1991 Environmental Protocol to the Antarctic Treaty, in principle provide strong protection against introduction of nonnative species.

However, national policies to implement these agreed objectives are patchy. In New Zealand's case, Antarctic border controls are weaker than those for entry to New Zealand, even though the level of protection agreed internationally for Antarctica is higher than New Zealand sets for itself. Australia has recently launched new biosecurity policies, greatly improving border controls.

While discussions are now underway within the Antarctic Treaty System to improve biosecurity policies, it remains to be seen whether there is a willingness among all parties to put stricter measures in place. There does appear to be a growing realisation that stronger efforts, and greater consistency across national programmes will be needed in

- monitoring for biosecurity incursions
- quarantine procedures to prevent (as far as possible) accidental introductions
- measures to prevent translocation of biological material between sites in Antarctica

Understandably, the focus has been largely on prevention of introductions, rather than eradication. In other jurisdictions eradication has proven more expensive and often impossible, suggesting that prevention is clearly the preferred option. However, even with strict biosecurity controls such as those in New Zealand's domestic law, accidental introductions do occur. To develop a complete a biosecurity policy, parties to the Antarctic Treaty System will also need to grapple with questions of

- agreed procedures for deciding when to attempt eradication, and procedures for eradications
- management procedures if eradication is not possible or desirable
- how costs for eradication or management efforts will be distributed

In New Zealand's case, consideration should be given to extending border quarantine controls to Antarctic cargo and passengers. It would need to be considered how the joint logistics pool with the United States and Italy might complicate implementation of stricter controls.

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[16] While papers are not publicly available on the internet, this intention is discussed at http://www.nioo.knaw.nl/projects/scarlsssg/docs/Stellenbosch2005/ANTARCTIC_CONSERVATION_Outline.pdf

[17] http://www.scar.org/events/Workshop%20programme1.doc.pdf

Section 2. Alien Species Threats to Antarctica

2.1 Introduction

There is a diverse range of alien species that have been introduced into the Antarctic over a number of regions. These species have varying impacts on the functioning of the ecosystems within the Antarctic. The greatest negative impact is caused by the invasive species that can cause significant loss to the native biodiversity and changes to the ecosystem process. This section covers the diversity of the nonnative species within the Antarctic and the impacts some of these species are having on the Antarctic environment. In this section the focus it on the Subantarctic Islands. This is partly because there is more data available compared with the continent but also as the Islands provide a good indication of the threats that the continent may face in the future, particularly with global climate change.

In terms of alien species within the Antarctic there are four main types as defined by Frenot *et al.,* 2005:

- Alien: introduced to an ecosystem as a result of human activity (including species that arrive by natural means to a specific ecosystem but are alien to that biographical zone).
- Transient alien: survived in small populations for a short time period but either died out naturally or were removed by human intervention.
- Persistent alien: survived established and reproduced for many years in a restricted locality, but has not expanded range from that location.
- Invasive alien: spread into native communities and displaced native species.

An invasive species can be further defined as an alien species that can have a negative impact on the environment, human activities or human health (Lee, 2002). Within the Antarctic, a number of species become transient aliens but few establish as invasive alien species.

There are a number of general characteristics of invasive species as follows:

- Fast growing
- Rapid reproduction
- High dispersal ability
- Highly competitive or aggressive behaviour
- Phenotypic plasticity (adapt quickly to a new environment)
- Tolerance of a wide range of environmental conditions
- Ability to live on a wide food range
- Single parent reproduction
- Association with humans (Campbell, 1996).

These characteristics can be seen within invasive species in the sub Antarctic such as rabbits consuming most of the native grass species *Agrostis stolonifera.*

In general the process of invasion can be divided into three stages from arrival to establishment to integration (Vermeij, 1996). Arrival involves the introduction of a species into a new area, establishment is when the new population no longer relies on dispersal from the original population and instead can survive through local reproduction and recruitment (Vermeij, 1996). Finally, integration occurs when the new population initiates and maintains ecological links with other species in the recipient area (Vermeij, 1996). Many of the Antarctic alien species are only within the first two stages of the process above.

To predict the number of invasive species that can affect a certain area we can use a general model called the 10's rule. Whereby 1 in 10 introduced species appear in the wild, 1 in 10 of those in the wild becomes established and 1 in 10 of those established will become a pest (Williamson and Fitter, 1996). This rule has been used in a number of populations worldwide and although it is a rather crude method it provides a good basis for estimating the number of invasive species into a certain area. It also shows that only a very small number of species introduced to a certain area will actually become established and become pests.

The Antarctic has been geographically isolated for millions of years and despite this, species invasions have taken place (Frenot *et al.*, 2005). The following is an investigation into the alien species within the Antarctic; these have been divided into the following: micro organism/diseases, plants, invertebrates, vertebrates and marine life.

2.2 Micro organisms/Diseases

There has been very little research into the types or abundance of either endemic or invasive microorganisms within the Antarctic and the impacts the invasive species may have on native species (Frenot *et al.*, 2005).

The study of microorganisms and diseases is an area that will need research in the future; there is great potential for invasion into the native Antarctic wildlife resulting from human activities. This could be by either direct introduction into the native wildlife, or in terms of disease, it could also be through putting stress on the wildlife thereby affecting the immunity of the species that may become susceptible to dormant diseases (Frenot *et al.*, 2005).

An example of a human microorganism found within the Antarctic is *Clostridium perfringens* (a bacterium associated with the distribution of human sewage) which is associated with the sewage outfalls at McMurdo Station on Ross Island. This bacterium was found up to 800 metres from the sewage outfall within sediments and a number of sea urchins and tunicates (Edwards, McFeters and Venkatesan, 1998).

2.3 Plants

There is no evidence of invasive plant species on the Antarctic continent, however there have been plant introductions where the plant has established for a short period but has not become invasive. It is thought that this is not so much because the plants cannot survive in this area but more to do with the isolation of the continent (Frenot *et al.*, 2005). The distance the species would have to disperse has yet proven to be too far, however invasive pant species may be seen on the continent in the future as human numbers and visits to the area increase.

There have been studies to test the viability of Arctic, alpine and temperate plant species within the Antarctic and some have shown survival for a couple of years and also reproduction (Smith, 1996). Therefore there is evidence to suggest that species could become invasive on the continent. There has been only been one known example where a plant has established on the Antarctic continent. *Poa pratensis* was an established plant for several years at Cierva Point on the Antarctic Peninsula; however it did not survive to become an invasive species (Smith, 1996).

The Subantarctic Islands however have a high number of alien plants, with 108 vascular species (13 of which are invasive) (Frenot *et al.*, 2005). The majority of these alien plants belong to families that are considered the most invasive at the global scale (Poaceae, Asteraceae, Brassicaceae and Juncaceae) (Frenot *et al.*, 2005). McDonald and Pingouins Islands are the only islands within the Subantarctic that remain alien specie free (Frenot *et al.*, 2005).

An example of an invasive plant species that has a negative impact on the Antarctic environment is the grass *Agrostis stolonifera*, this grass was accidentally introduced onto Marion Island (Subantarctic Island) in the 1950's (Gremmen, Chown and Marshall, 1998). This species invades undisturbed native habitats, replacing native species such as the bidibid (*Acaena magellanica*), and therefore has become an invasive species (Gremmen, Chown and Marshall, 1998).

2.4 Invertebrates

The alien invertebrate species found in the Antarctic follow a similar pattern to the alien plants with most species being found on the Subantarctic Islands; however there is little evidence for invertebrates within the Antarctic continent. As with the plants the most evidence is for the larger organisms.

Within the Subantarctic Islands, there is also great variability with the number and type of alien invertebrates that are found. The Kerguelen Islands have the most alien species with 30 (only seven are invasive) (Frenot *et al.*, 2005). Whereas McDonald, Pingouins and Apotres Islands have no alien invertebrate species (Frenot *et al.*, 2005), this is again similar to the patterns found with the alien plant species.

From the literature it is seen that the majority of the alien invertebrates are imported on vegetable matter, soil, pot plants, within hydroponic/glasshouse materials, with food shipments or associated with livestock (Frenot *et al.*, 2005). There have also been deliberate introductions of some species for conservations measures, such as the European rabbit flea to control rabbit numbers on Macquarie Island (Copson and Whinam, 2001). The invertebrate aliens found are most commonly Diptera, Hemiptera and Coleptera; it is thought that this representation is related to the prevalence of introductions associated with livestock (Frenot *et al.*, 2005).

The invasive invertebrate species can have a significant negative impact on the native fauna of Antarctica. The blowfly (*Calliphora vicina)* was introduced to the Kerguelen Islands in the Subantarctic; this alien species is seen to cause the decline of the native true fly (*Anatalanta aptera)* (Frenot *et al.,* 2005). As this species has a negative impact on the environment it has therefore established as an invasive species.

2.5 Vertebrates

There have been a number of accidental and deliberate introductions of alien vertebrates within the Antarctic. There is no evidence of vertebrates being introduced and subsequently establishing on continental Antarctica; however within the Subantarctic Islands there are a number of alien vertebrate species including fish, birds and mammals (Frenot *et al.*, 2005).

Introduced bird species include starlings (*Sturnus vulgaris*), paleartic mallards (*Anas platyrhynchos*) and redpoll (*Carduelis flammea*); these have all been on the Subantarctic

Islands and are all within families that have a high success rate of invading globally (Frenot *et al.,* 2005).

The Antarctic has no native terrestrial mammals; however eight invasive mammals have been introduced into the Subantarctic Islands (Frenot *et al.,* 2005). These include mice (*Mus musculus*), rats (*Rattus rattus* and *Rattus norvegicus*), cats (*Felis Catus*), mouflon (*Ovis aries, O. gmelini*), reindeer (*Rangifer tarandus*) and rabbits (*Oryctilagus cuniculus*) (Frenot *et al.,* 2005).

These invasive species have varying geographical distributions, abundance and impacts on the Subantarctic Islands. The mice were accidentally introduced through ship traffic and have the greatest range being found over five of the Subantarctic Islands. While the mouflon are only found on the Kerguelen Islands were they were deliberately introduced (Frenot *et al.*, 2005).

There have been major negative impacts from the introduced invasive vertebrate species in the Subantarctic Islands. Rabbits were introduced onto the Kerguelen Islands in 1874 and rapidly increased in numbers (Chapuis, Frenot and Lebouvier, 2004). In this area the rabbits caused soil erosion and put pressure on the native species through grazing, this resulted in the virtual disappearance of *Pringlea antiscorbutica* and *Azorella selago* (Chapuis *et al.,* 2004). The rabbits also became the main winter food source for cats that were introduced to the area in 1952, without the rabbits the cats may not have survived (Chapuis, Frenot and Lebouvier, 2004). The introduced cats had a dramatic impact on the native seabirds (including shearwater and petrels), with an estimated one million birds killed by cats each breeding season (Huyser, Ryan and Cooper, 2000). There has since been a total eradication of rabbits on the Kerguelen Islands. However as the rabbits had become an established species within the ecosystem the removal is now proving to have further implications for the ecosystem of the Kerguelen Islands (Chapuis, Frenot and Lebouvier, 2004).

2.6 Marine Life

There is great potential for the introduction of invasive species to the Antarctic marine environment due to the increasing amount of ship traffic to the region and little regulation, however as yet there is limited research in this area. The ways in which the species can travel to the Antarctic are discussed later in the transport section below.

The only known nonnative marine species within the Antarctic marine waters is the North Atlantic spider crab (*Hyas araneus)* (Tavares and De Melo, 2004). This crab was discovered during an oceanographic survey of the waters around the Antarctic Peninsula within a benthic sample (Tavares and De Melo, 2004). The crab is found in the North Atlantic and the Arctic Oceans and it is proposed that the crab travelled to the Antarctic by either ballast water from ships or on ships' sea chests (Tavares and DeMelo, 2004).

2.7 High Risk Areas

It is important to focus research on the areas that are most at risk from invasive species to try and control any negative impacts. Therefore the following areas need to receive the most attention:

- Warmer, moister areas with high nutrient richness as more species can establish under these conditions.

- Areas with high human contact, through tourism, scientific stations and fishing as there is an increase in the number of opportunities for introduced species.
- Areas that are closest to the nearest continent, as species have less distance to travel and therefore more chance of surviving. This can be through self-introduction or human aided.
- Islands ecosystems as these species are more likely to have faced few strong competitors or predators and therefore be 'naïve' towards invasive species (Stachowicz and Tilman, 2005).
- Areas that are seen to have increases in temperature (as oppose to cooling) or are predicted to with global warming. A larger number of invasive species will be able to survive in the new region (Bergstrom and Chown, 1999). In addition, the increase in temperature may further displace the native species.

All of the above point towards the sub Antarctic islands and the Antarctic Peninsula and not the Antarctic continent itself, therefore research should focus on these areas.

2.8 Future Research

Extensive study of invasive species in the Antarctic is relatively recent; therefore the research so far is limited. There is the issue of taxonomy; the taxonomy is not known for all the Antarctic species. Therefore it is difficult to estimate the number of invasive species and their effects on the native species. The research also focuses on the higher organism groups, and more visible taxa as opposed to microorganisms, such as mammals. In addition, the majority of the research is focused on the Subantarctic Islands but research is lacking on the continent (including the peninsula), this is most likely due to the fact that there are less visible invasive species on the continent at this stage.

For future research, firstly we need to have a better understanding of the native species of the Antarctic to be able to assess the impacts of invasive species. We need to focus on the high risk areas mentioned above, however to ensure an equal overview of invasive species is obtained, research is needed on the continent as well as with the lower taxonomic groups and less visible organisms. A focus on species that have come from similar environments (such as alpine and artic environments) is also important, as these species are more likely to become invasive and have negative impacts on Antarctic wildlife. Finally it is important to investigate the impacts of the alien species to consider which species may pose the greatest risk to the Antarctic environment.

2.9 Conclusion

From this review it can be seen that there is great diversity in the types of alien species that are found in the Antarctic today. These species are also having varying impacts on the native species within Antarctica. For the future we need to focus research efforts on areas that are the most vulnerable to invasive species. There are, however, efforts to assess the potential for biological invasions within the Antarctic. A proposed International Polar Year (IPY) study is focusing on "Aliens in Antarctica". This study aims to assess the propagule load (seeds, spores, and eggs) carried unintentionally by people into the Antarctic. The study will be conducted over the 2007/ 2008 summer season.

Section 3. Transport Pathways

3.1 Introduction

Over the past century the natural boundaries of Antarctica that have protected its biological diversity have slowly been broken down. From being a remote and isolated continent, more and more human activities and transport routes have been developed, making Antarctica increasingly interconnected with the rest of the world. Introductions of alien species in Antarctica have been associated with human patterns of use in the region; especially transport connections (Frenot *et al.,* 2005, Lewis *et al.,* 2005).

In this chapter we will first discuss some of the modes of transport used in the Antarctica and identify the risks they pose for the introduction of alien species. Second we will discuss the scope and rate of change in human transport for a number of activities and industry segments. Finally, we will highlight a number of observations coming from this chapter on the role of human transport systems in the introduction of alien species in Antarctica.

3.2 Modes of Transport

When an alien species decides to travel to Antarctica, apart from its preference and the natural transport options, it currently has three types of human provided transport at its disposal, i.e. ships, aircraft and plastic debris floating in the ocean. All these different types of inter-continental transport have different operators, different actual and estimated sizes and scopes, and different risks associated with them.

For transport options within the Antarctic, there are ships, smaller aircraft and plastic debris, supplemented with forms of land-based transport, such as tractors, Hagglunds and skidoos. In all of the described means of transport hitch-hiking species not only make use of the transporter itself but also of the cargo and the passengers on board. According to Frenot *et al.,* (2005) intra-continental logistics create a large and unrecognised risk for transporting indigenous biota between different regions of the continent. This is because they are believed to have a higher chance of survival as they are adapted to similar environmental conditions.

3.2.1 Ballast Water

Ships are the most commonly used means of transport in the Antarctic. Ships are used in the operation of National Antarctic Programmes (NAP's), tourism and fisheries. The use of ballast water is essential for safe shipping operations, providing stability to ships that are not fully loaded (COMNAP & IAATO, 2005). The issue of ballast water and the associated biota that travel in it around the globe has been focus of global attention and awareness (IUCN, 2005). With the above-mentioned introduction of the spider crab, Antarctica is no exception. Thousands of marine living species may be carried in ships ballast water, including bacteria and other microbes, small invertebrates, and the eggs, cyst and larvae of various species. Moreover, ballast water discharge is associated with the transfer of diseases (COMNAP & IAATO, 2005).

Because of the global risks associated with ballast water discharge recently the International Convention for the Control and Management of Ships' Ballast Water and Sediments was adopted by the International Maritime Organisation (IUCN, 2005). The convention requires all ships to implement a Ballast Water and Sediments Management Plan and carry out management procedures to a given standard. According to the IUCN (2005) the standards that have been adopted present a minimum level of improvement. Moreover, the convention has not yet been enforced.

In a recently held survey conducted among COMNAP and IAATO members, the ballast water practices of more than half of the vessels operated by these organisations were investigated. 87.5% claimed that no ballast water is discharged in the Treaty area; 7.5% claimed that no ballast water from outside the Treaty area is discharged; and 5% claimed that ballast water is only discharged in the open ocean (COMNAP & IAATO, 2005). The study also confirmed that all vessels operated in the Antarctic Treaty Area must follow the newly set guidelines on ballast water discharge set out by the IMO.

Lewis *et al.*, (2005) claim that ballast water may not play an important role in the introduction of alien marine species in Antarctica because of the assumption that most of the transporters off-loads cargo and brings ballast water back north. Although this assumption may be true for many National Antarctic Programmes, it might not be the case for other transporters, such as fisheries.

3.2.2 Hull Fouling

Hull fouling communities are species that settle on the outside of the ship's hull. Species most likely to travel this way are marine benthic communities. According to Lewis *et al.*, (2005) hull fouling constitutes the highest risk of alien species introduction in the Antarctic ecosystem. The survival rate of fouling communities has been little studied. It is known that they are able to develop in temperate ports and survive voyages to Subantarctic waters (Lewis *et al.*, 2005). Hull fouling is not only important for the exchange of species between southern and northern ecosystems but also within Antarctic waters.

No international regulations exist for the issue of hull fouling (IUCN 2005). As prevention against hull fouling, toxic paints are used worldwide on the ships hull. However, recently, researchers have found the toxic substance tributyltin (TBT) in Antarctic marine sediment. According to the researchers the paint is chipping off icebreakers as they ram through thick pack ice. TBT could be very harmful for marine life when released in high concentration (ENS, 2004). Lewis *et al.*, (2004) claim that for icebreakers visiting Antarctic stations toxic paints are probably not necessary for preventing hull fouling communities to reach the Antarctic coastline as they are scraped off the vessels by the sea ice. However, when servicing Subantarctic Islands the use of toxic paints could be preferred over the introduction of invasive species.

Another observation made by the IUCN (2005) is that recreational vessels fall outside of the IMO mandate. Considering the size of this global fleet of vessels and the increasing interest in Antarctica and the Southern Ocean this highlights a significant risk for invasive species introduction in the area.

3.2.3 Cargo

Alien species hitch-hike on the cargo shipped or flown to Antarctic research stations. Researchers at the Australian Antarctic Programme show that the cargo shipped to the Subantarctic Islands is able to pick up large quantities of spider webs, live spiders, seeds, and plant material while being stored (Whinam, Chilcott and Bergstrom, 2005). In addition, food inspections found fungal infections, insect infestations and dead insects on many of the fresh fruits and vegetables. Cargo shipped or flown to Antarctic research stations is presumably no different. Depending on the environmental conditions of the destination, these species could pose a threat.

3.2.4 Passengers

Alien species hitch-hike on the clothing and boots of passengers. The same Australian researchers inspected the equipment and clothing of expeditioners going to the Subantarctic Islands and found propagules in and on outdoor equipment, daypacks, clothing and boots. The highest risk item identified was Velcro fasteners, collecting many seeds and plant fragments. The inspection of passengers found a number of shocking results. One single expeditioner carried nine different species and 309 propagules. Another expeditioner carried 63 propagules from one single species (Whinam, Chilcott and Bergstrom, 2005).

3.2.5 Plastic rafts

Plastic debris floating around in the oceans has been associated with the introduction of alien marine species (Lewis *et al.*, 2005). Kelp rafts and driftwood have been a natural cause for the introduction of species, the increasing amount of plastic debris in the Southern Ocean more than doubles this natural process. Research states that in the past decade the amount of plastic debris in the Southern Ocean have possibly increased by a hundred-fold (Barnes, 2002). There is a considerable range of species associated with plastic rafts, mostly coastal benthic species.

Lewis *et al.,* (2005) claim that kelp and plastic rafts are dependent on ocean currents and wind. The Polar Front creates uni-directional currents and winds that form a barrier that is not easy to cross. Therefore, the chances that plastic rafts will create a successful continental passage for alien species to the Antarctic are small. Moreover, the longer these species spend on the open ocean, the smaller their chance for survival. However, as a regional transporter plastic rafts could be quite successful, as well as for Subantarctic Islands just above the Polar Front.

3.3 Tourism

Tourism visitor numbers to Antarctica have grown significantly over the last two decades (see figure 1). As Figure 1 shows the largest segment of the tourism industry is ship based with or without landings. Alongside the growth of tourist numbers, the number of tour operators involved, vessels used and journeys made to the Antarctic has grown (see figure 2). Moreover, the tourism industry has diversified servicing different segments and using different modes of transport.

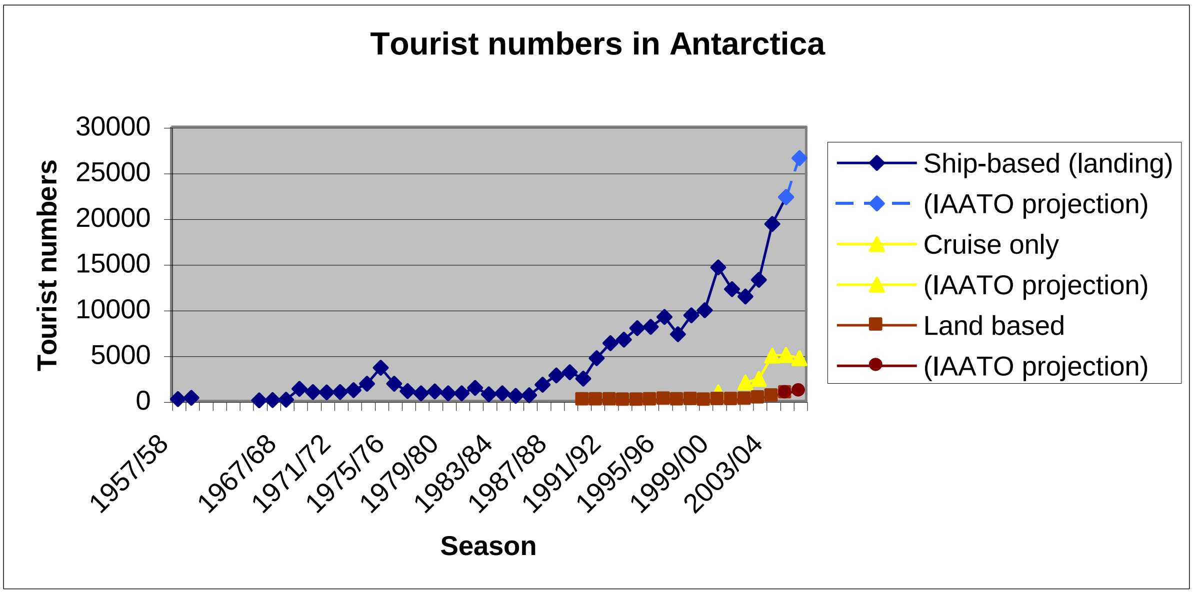

Figure 1: Tourist numbers in Antarctica from 1957/58 to 2004/05 (Enzenbacher, 1993, Headland, 2005, IAATO, 2005).

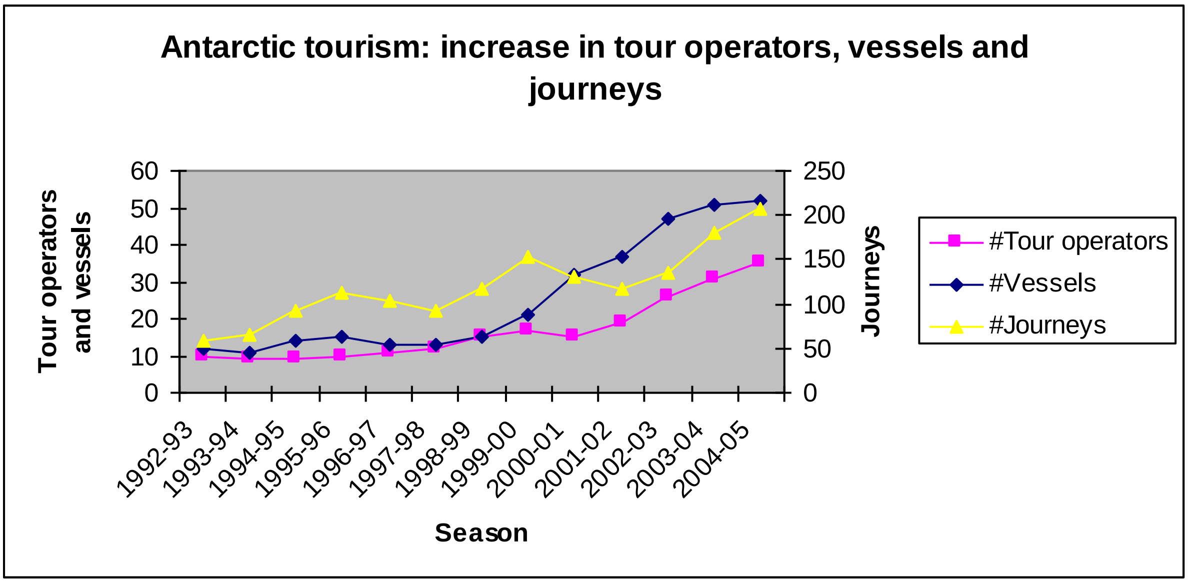

Figure 2: Antarctic tourism trends in operators, vessels and voyages (IAATO, 2005)

The tourists generally originate from the United States, the United Kingdom, Germany, Australia, Japan, Canada and Switzerland. All of these countries have zones of temperate climates, cold climates, or alpine climates. This is important, since they could be carrying taxa of biota from these environments on their clothing and shoes. In addition, Antarctic tourists presumably have an interest in remote and high latitude or altitude places. The chances that they visited such environments within 6 months before embarking for Antarctica exist (Frenot *et al.*, 2005).

Figure 3 shows the spatial distribution of tourism activities in the 2003/04 season. It becomes clear that most of the tourism activities take place on islands off the coast of the Antarctic Peninsula.

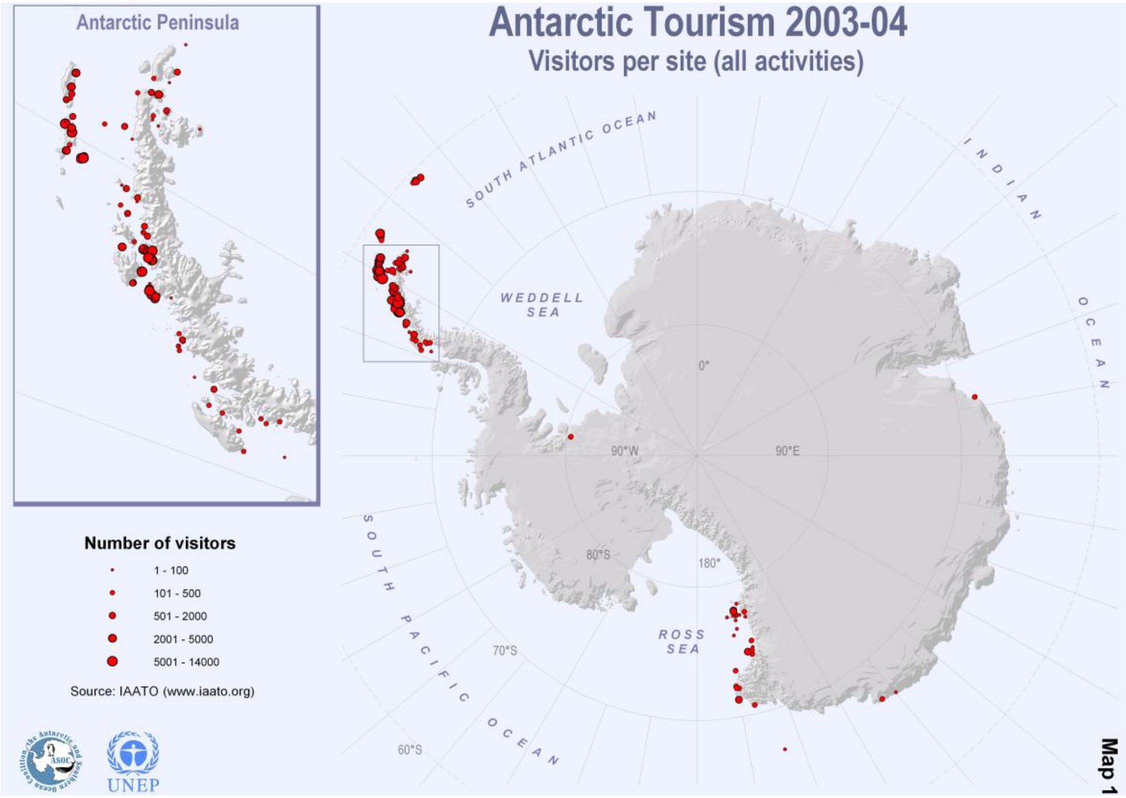

Figure 3: Spatial distribution of Antarctic tourism activities (ASOC/UNEP, 2005)

A number of developments and characteristics of the tourism activities in Antarctica can be of importance to the introduction of alien species. Most of the tourist vessels cruise along the coast of the Antarctic Peninsula and visit landing sites on the continent and islands. Often visits to Subantarctic Islands are included in the itinerary. Since the wildlife of Antarctica is one of the key attractions, many of the activities take place close to the biodiversity. Most of the ship-based voyages take place in the Antarctic Peninsula in a limited number of landing sites, increasing the intensity of visitation. The number of places that are visited is increasing. The range of activities carried out in these landing sites is increasing. In the Antarctic off-season tour operators often focus on Arctic ship-based tourism, increasing the connectedness between the two ecosystems and its biota (Frenot *et al*., 2005).

Aircraft are used by a limited number of tour operators in Antarctica. Antarctic Logistics and Expeditions (ALE) charters an intercontinental aircraft from Punta Arenas, in Southern Chile, to Patriot Hills in Antarctica. From Patriot Hills a number of field camps are serviced using two smaller aircraft. DAP runs tourist flights from Punta Arenas to King George Island (South Shetland Islands) where tourists visit stations or embark on cruise vessels (IAATO, 2005).

Tourism operations currently account for the largest share of human transport connections in Antarctica. This does not necessarily mean that they pose the greatest risk for introducing alien species. We have to note that through the self-regulation of IAATO, the tour operators have a set of clear and sound management strategies in place to prevent the introduction of alien species. However, the figures indicate that the tourism industry is very likely to continue to grow in the future.

3.4 National Antarctic Programmes

Currently, 26 National Antarctic Programmes run 82 stations across Antarctica (see figure 4) (COMNAP, 2006). All of these stations have to be supplied with people and cargo using a variety of ships and aircraft. The Antarctic Peninsula area has the highest density of Antarctic science stations. According to Frenot *et al.*, (2005) in the 2001/02 season the NAPs had 4390 people working in the Antarctic and Subantarctic. About 1361 people were working in the Antarctic Peninsula and about 1200 people in the largest station, McMurdo in the Ross Sea Region. The remaining people were spread out over the rest of the stations.

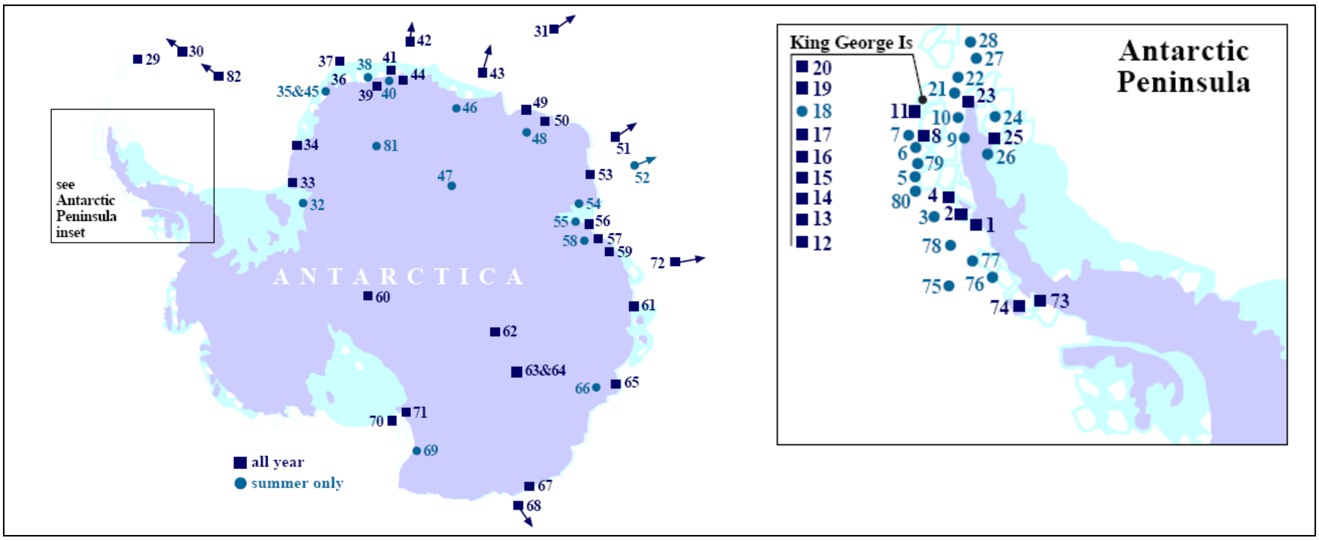

Figure 4: National Antarctic Programme stations in Antarctica. COMNAP, (2006)

Although there are less people transported than in the tourism industry and less ships are involved, ships do leave from a whole range of different ports in the world. Many of the ice-strengthened vessels are used in the Arctic in the Antarctic off-season. Both the NAP's and the tour operators seem to have sound practices and awareness on the issue of ballast water discharge and hull fouling.

There are currently nine NAPs that make use of aircraft for intercontinental transport, departing from airports in Southern Chile, Southern Argentina, The Falklands, South Africa and New Zealand. In addition, the Australian Antarctic Programme will soon start flights from Tasmania. The largest airlink is maintained by the United States, New Zealand and Italy, operating flights from Christchurch to the Ross Sea Region (Frenot *et al.*, 2005). Air links connect Southern Hemisphere airports with Antarctica within a 3 to 9 hour period. The large numbers of people transported to Antarctica with fast and efficient air links provide hitch – hiking options on boots, clothing, baggage and cargo. Without appropriate quarantine measures in place this could create pathways for a whole range of alien organisms (Frenot *et al.*, 2005).

NAP's often visit more places within the region, including Subantarctic Islands, supplying cargo and dropping off scientists at various stations. Science parties work very close to biodiversity. Science parties also move within the continent by using different vehicles and aircraft. During the International Polar Year in 2007 and 2008, the NAP logistics are assumed to increase significantly.

3.5 Fisheries

Compared to the rest of the world, fisheries are limited in Antarctica. Fishing vessels go down to fish for krill and toothfish. The fishing industry is also active in the territorial waters of the Subantarctic Islands, the Falkland Islands and South Georgia. Data is not readily available expressing how many ships comprise the Antarctic fishing industry.

Fishermen usually do not go ashore and stay on their ships. However, their ships maybe carrying alien species because of ballast water and hull fouling. Fishing ships originate from a wide range of countries. Fishing in the southern ocean is managed by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), however, to date, issues of alien species introductions have not been considered at any CCAMLR meeting (IUCN 2005). The various governing bodies of the Antarctic Treaty System and the United Nations involved in human logistics issues could potentially cause for confusion, as it is not clear at this point who is doing what.

Because fishing for toothfish is such a lucrative business, there are many illegal fishing vessels (IUU) in the Southern Ocean. These IUU vessels are not regulated and it is not known how great their role is for the introduction of alien species (IUCN 2005). It is also uncertain whether the number of IUU fishing vessels will increase or decrease in the future. The number of legal toothfish vessels has increased rapidly over the last decade (Gilbert, 2006). In addition, the krill fishing industry is believed to increase in the future because of growing market demands (Gascon and Werner 2005).

3.6 Conclusion

In table 1, an overview is given of the human transporters and their associated risks with regard to the introduction of alien species in the Antarctic. The various numbers in the table are specified for the 2004/05 season.

It becomes clear that the overall picture of human logistics in Antarctica is by no means complete. There remain many gaps in the data availability of who is going where, doing what. It is therefore not clear what mode of transport is currently posing the greatest risk for the introduction of invasive species.

The literature suggests expected growth in al the discussed transport segments. The tourism industry is the largest and fastest growing provider of human logistics in terms of transporting people. The National Antarctic Programs are the largest provider of human logistics in terms of cargo. In the International Polar Year the logistics of NAP's are expected to increase significantly. In addition, the role of Southern Ocean fisheries and human disposed plastic debris remain uncertain. The increase in Antarctic logistics provides hitch-hiking opportunities for both terrestrial and marine species. Evidence is slowly mounting that many species do.

We do know that most of the Antarctic logistics take place in the Antarctic Peninsula area. This area was earlier identified as a high risk area for the introduction of invasive species because of its high rate of warming because of climate change. The overall picture of intra-continental logistics remains a black box. However, intra-continental spread of species is identified as a large risk within the Antarctic.

Type of transport	Operator	Estimated size in 2004/05	Associated risks
Ship	NAP's	Number of ships: 44 Number of operators: 21 Number of journeys: ? Passengers landed: ?	-ballast water discharge -hull fouling -clothing and boots contamination -cargo
	Tour operators	Number of ships: 52 Number of operators: 35 Number of journeys: 207 Passengers landed: 22.297 Non-IAATO and sailors: ?	-ballast water discharge -hull fouling -clothing and boots contamination -cargo
	Fisheries	Legal fisheries: ? IUU: ?	-ballast water discharge -hull fouling
Aircraft	NAP's	Number of operators: 16 Inter-continental: 13 Intra-continental: 33 Number of passengers: ?	-clothing and boots contamination -cargo
	Tour operators	Number of operators: +/-2 Inter-continental: +/-2 Intra-continental: +/-2 Number of passengers: 878	-clothing and boots contamination -cargo
Land-based vehicles	NAP's	Not known	-clothing and boots contamination -cargo
	Tour operators	Not known	-clothing and boots contamination -cargo
Plastic debris	? (humanity)	Millions (more than doubling the natural rafts)	-rafting in the Subantarctic -rafting below the Polar front

Table 1: Assessment of the human transport connections to and within the Antarctic continent

Section 4. Biosecurity management practice

4.1 Introduction

Managing Antarctic invasive species has already begun, but the existing controls in their entirety are not adequate. In the Madrid Protocol, national program managers have committed to an invasive species-free continent, but this ambitious aspiration as of yet has not been articulated in policy and specific management plans in most cases. As the situation currently stands, Antarctic invasive species are still at the stage of research and data collection, or in the event of an invasion, are handled on a case-by-case basis by national programs.

As discussed above, the scope of potential nonnative species in the Antarctic is immense. While some species are clearly visible and therefore easier to manage—and their management will be discussed in the bulk of this section—the range of potential invasive species includes the microscopic and cellular. One review article articulates the potential use of polymerase chain reaction-based technologies to discover "natural" and "invasive" (specifically anthropogenic) microbes and DNA strains (Baker, Ah Tow, and Cowan, 2003). To deal with invasive species at this level is to present a situation that is almost entirely unmanageable. Consider the management implications of the following sentences: "there is a huge diversity of microorganisms inhabiting the mouth, throat, and nose. Many of these microbes are ejected from the nasal passages, throat, and oral cavity during sneezing, coughing or loud talking" (Tannock, 1995 in Baker, Ah Tow and Cowan, 2003). The very presence of humans in the Antarctic introduces thousands of microorganisms that are carried on the human body. However, this scope is too broad for the present; this section will instead assume that a human presence on the Antarctic is a given, and will grapple with more immediate and visible nonnative species threats.

The present invasive species management approach as it stands is prevention-oriented. It is ideal to avoid nonnative species invasions in the Antarctic entirely. However, invasive species are already present in the Antarctic, and further, it is relatively certain that more and larger invasions will occur in the near future. Therefore, it is necessary to continue and enhance current prevention practices, as well as devise Antarctic Treaty-wide management plans for managing outbreaks when they occur. This section, then, focuses on management practices in three parts: 1) the current standard bearers for invasive species prevention, IAATO member tourist operations, 2) a case study detailing how the Australian Antarctic Division handled a specific invasion at Casey Station, and 3) a more abstract case study based on the "greening" of the Antarctic Peninsula, connecting current climate change to changes in species distribution, and how management practices may fit into this scenario.

4.2 Prevention Management: IAATO Bootwashing Stations

The International Association of Antarctica Tour Operators (IAATO) has voluntarily adopted practices to lessen the likelihood of tourists carrying nonnative species to Antarctic sites. Tourists comprise the bulk of human presence in Antarctic each year: in the 2004-2005 season, there were about 24,000 tourists, as compared to 4, 390 Antarctic national program staff and scientists in the 2001-2002 season (SCAR, 2005). Therefore, having all IAATO member vessels practicing preventative measures against nonnative species invasions makes a significant impact as far as reducing biological risks as well as educating a significant portion of people travelling to the Antarctic.

The primary practice adopted by IAATO members is boot washing. Some attention is also paid to clothing decontamination, as well as the decontamination of large equipment pieces by steam cleaning (IAATO, 2005). Tourists are also briefed predeparture about cleaning their gear and their possible impacts on Antarctic ecosystems. At the end of each landing visit, tourists are instructed to disinfect their boots by first scrubbing material off the boots with a brush and second, stepping into a tray of diluted disinfectant. A three year study of the chemical disinfectant wash Virkon S showed definitive reductions in the number of boots carrying bacteria as well as the amount of bacterial growth that boots displayed (Curry *et al.*, 2005). Curry *et al.*, in 2005 determined that boot washing stations were most effective when boots were disinfected prior to any Antarctic landings and then fully disinfected with the Virkon S wash after each landing (ibid).

The focus of IAATO's boot washing practices is the penguin rookeries and other high-density sites of Antarctic wildlife. IAATO's goal is to both limit the introduction of nonnative species from elsewhere to these Antarctic wildlife sites as well as to reduce cross-contamination of microbes between Antarctic sites (IAATO, 2005). IAATO has offered their management guidelines for consideration at several Antarctic Treaty Consultative Meetings; a continent-wide adoption of these practices coming into bases from other continents and in situations where people travel between sites could well serve as an effective preventative measure, especially among bird colonies.

4.3. Invasion Management: the Mushroom Gnat at Casey Station

The Australian Antarctic Division has been trying several eradication techniques to rid Casey Station of a population of mushroom gnats that have been proliferating in the waste treatment system since 1998. The first gnats are believed to have arrived as eggs on fresh vegetables (Australian Antarctic Division, 24 March 2005).

Before the 2005 eradication attempt, believed to be successful, base workers tried to rid the base of the mushroom gnat by stirring the sewage waste to drown the eggs and the gnats. Fly papers were hung, and insecticides were regularly sprayed.

The presence of the mushroom gnat posed several problems, even though it was widely believed that it could not survive Antarctic conditions outside the waste treatment centre, and therefore did not pose a major invasive risk to the continent. However, Australian Environmental Manager Tom Maggs stated in an interview that:

> We know a little bit about the insects that live in the moss beds around Casey. And Casey's surrounded by very rich moss beds which are good invertebrate habitat. So there's always the possibility that something may get to Antarctica, may escape to the environment and get established and we really need to avoid that (Jeanes, May 18 2005).

Furthermore, besides the immediate ecological threat to Casey Station's moss beds, the Australian Antarctic Division recognized that the presence of the mushroom gnats broke the Madrid Protocol's commitment to keep Antarctica completely free of invasive species (Australian Antarctic Division, March 2005 "fly eradication campaign").

To eradicate this invasion required significant temporary alterations in base life as well as some other logistical concerns. The eradication campaign occurred in two phases: first, the waste treatment plant's tanks were cleaned and treated with hypochlorite while the building containing the plant was fumigated with insecticide in its entirety (Australian Antarctic Division, 24 March 2005). Next, the water supply was shut of to the main living and eating quarters, named the "Red Shed". The station news describes the alteration of daily life at Casey Station:

> For ten days we could use no water there, except for minimal amounts in the kitchen, while its tanks and pipes were filled and flushed with hypochlorite. For a shower we had to climb over a high snow drift to get to the tankhouse, and for toilets we needed to visit the operations or science building. The Red Shed had to be evacuated by everyone not wearing full breathing apparatus for five hours each morning while fumigation took place, and meal times were altered to take this into account. We ate off paper plates to save washing, and use of cooking pots was kept to a minimum (Australian Antarctic Division, March 2005 "fly eradication campaign").

The eradication program significantly altered daily life at Casey Station for ten days and required significant amounts of logistical changes to usual operations. Furthermore, the station lowered its station population during the eradication attempt by scheduling several field operations, primarily maintenance and field training activities, to minimize impacts. Overall, the mushroom gnat eradication plan was carefully designed to eradicate thoroughly the pest with as few impacts on staff and the national program as possible.

4.4 Management Challenges: "The Greening of the Antarctic Peninsula"

A key problem that is anticipated to increase is that of the spread of vascular plants on the Antarctic Peninsula. The Antarctic Peninsula has had significant increases in temperature and water precipitation, indicating an overall warming trend. Furthermore, the Antarctic Peninsula hosts the overwhelming majority of tourists, as well as the most scientists and support staff of any Antarctic region. This combination of hosting the only known Antarctic vascular plants, warming temperatures, and heavy and increasing human visitation makes the area poised for significant environmental threats, including invasive species.

Unlike the importation of avian flu virus to a penguin colony from abroad, it is more difficult, if not impossible, to pin direct anthropogenic sources to the "greening of the Antarctic peninsula." Indeed, this case raises more questions than it answers, and opens up potential directions that Antarctic nonnative species prevention and eradication management measures can take.

Under the Madrid Protocol, it is forbidden to introduce plants to any part of the Antarctic. However, "unintentional dispersal" may be caused through human activities as well as by natural agents such as wind and birds (Smith, 1996). "Unintentional dispersal" can also bridge human and natural agents in terms of anthropogenic climate change: as the climate changes on the Antarctic Peninsula, natural agents help propagate vascular plant colonies.

The two flowering plants, the Antarctic hair grass (*Deschampsia antarctica)* and the Antarctic pearlwort (*Colobanthus quitensis*) have shown increases in actual organism numbers, community sites, and summer growing season length since early last decade (Science, 1994). This news piece concludes with a quote from Lewis Smith that, in comparison with northern high latitude sites, "we can expect to see an increase in species diversity as spores from foreign species that blow in and get stuck in the ice reach the soil and germinate" (ibid).

In 1997, a report was published announcing a newly discovered colony of Antarctic pearlwort and linked this colony with the increasing summer temperatures on the Antarctic Peninsula. The authors stated that:

> the presence of apparently suitable but uncolonized sites in the proximity of established populations of vascular plants, combined with increasing mean summer air temperatures on the Antarctic Peninsula, suggest that expansion of existing

populations and the establishment of new populations on the Antarctic Peninsula is likely to continue (Grobe, Ruhland, and Day, May 1997).

Existing Antarctic plant communities are expanding and colonizing as Antarctic Peninsula temperatures increase: is this a natural or anthropogenic case? Are management interventions necessary?

The other factor to consider besides increased range and numbers of native plant species on the Antarctic Peninsula is the introduction of new plant species. With the warming of the Antarctic Peninsula, more plant species may be able to establish in previously too-hostile environs, including those transported through human activities. A recent review on Antarctic invasive species describes the current state of research on this issue, claiming that "to date, most ecological evidence, whilst extremely suggestive, remains circumstantial" (Frenot *et al.*, 2005). While further study is needed, if the greening of the Antarctic Peninsula is to be managed, plans need to be decided as soon as possible.

4.5. Conclusion

The management practices detailed above demonstrate the willingness of people visiting and living in the Antarctic to protect the Antarctic environment from nonnative species. The example of the "greening of the Antarctic Peninsula" demonstrates some key problems that may emerge in Antarctic biosecurity issues in the years to come. It is important to mitigate these problems before they occur.

First, scope needs to be considered among nonnative species. For example, should environmental managers manage from the smallest microorganism emerging from human "loud talking" through large and visible organisms? What is the scope of anthropogenic introductions: everyone may agree that intentionally planting Arctic grasses constitutes an eradication case, but what about grass seeds naturally dispersed through birds and winds, thriving on the Antarctic Peninsula due to human-caused warming?

Second, the types of management strategies in use need to be considered. As it stands, current management practices are overwhelmingly prevention oriented. Mitigation plans for inevitable invasions also need to be considered, so that these may easily be put into practice when needed. Under the Madrid Protocol, eradication seems to be the only acceptable mitigation plan. Might there be instances where eradication is impossible? The Committee for Environmental Protection should consider management practices that take into account *controlling* invasions in addition to outright eradication in these cases.

Finally, all management practices should be planned with an eye towards the impacts these practices may have on the Antarctic. Significant logistical and financial commitments are necessary in invasion cases. Furthermore, if a species invades an ecosystem completely, what are the ecological ramifications of removing it? Elsewhere, studies have shown that removal programs have caused secondary effects among food webs and other ecosystem roles (Zavaleta, Hobbs and Mooney, 2001). While such potential problems should not stymie swift and effective action, eradication programs should be analyzed holistically.

5. Discussion

Biological invasions are complex processes in which a variety of factors play a role. In the course of this report we have separately identified and discussed a number of factors that will influence the future of biodiversity in Antarctica: policy and management, species characteristics, transport pathways, and climate. Although these have been discussed sequentially they are clearly linked, as represented in Figure 5 below. Some of these factors and considerations are well known, others provide us with high levels of uncertainty.

For a species to become established or invasive in Antarctica, all of these factors need to be in alignment. You need the right sort of species, a transport pathway, the right climate on arrival, and a level of management and policy that allows the invasion to go unchallenged.

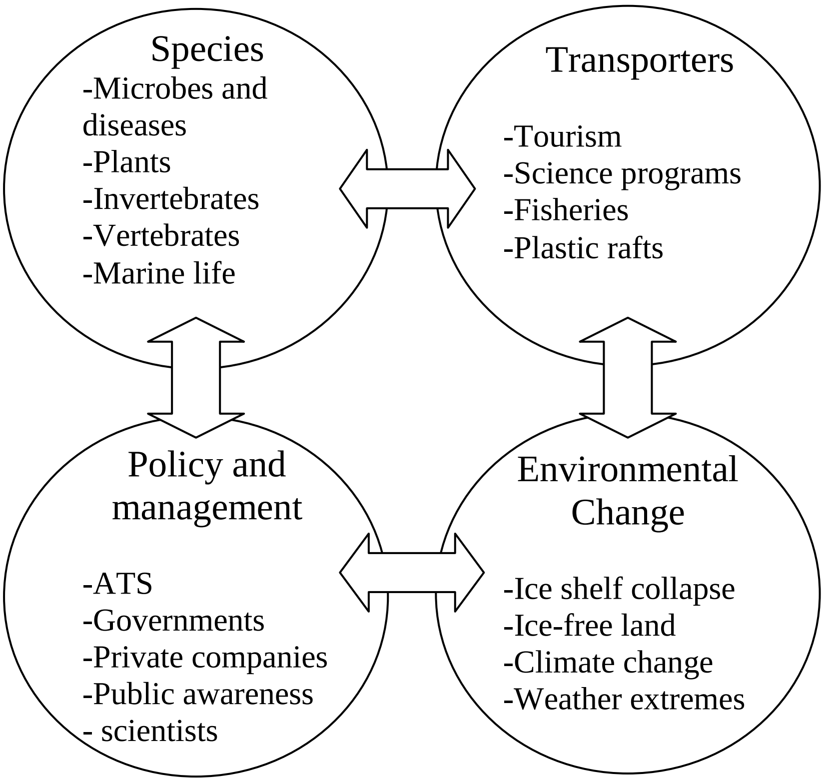

Figure 5: Factors and their interlinkages influencing Antarctic biosecurity

This gives us an indication of where attention should be focused in efforts to prevent the arrival of nonnative species. We have no control over species characteristics, and little control over climate. If we assume that transport links to the Antarctic will continue, pathways for introduction of species will remain. However we have significant influence over the form these transport links take, and the rules that govern them. So, that is where most of the effort should go in terms of management and regulation.

To make good policy and management decisions however, detailed knowledge is needed on the details of potential invasive species threats (and the native species that might be threatened), the Antarctic climate and the way it might change, how species exploit transport pathways, and how we can optimise transport linkages to minimise risk. So, even though we do not have *control* over these areas, *research* into them is essential for good decision-making.

6. Conclusions and Recommendations

Throughout this paper we have encountered a mix of issues that are well known, and those for which information is lacking. In this conclusion section we have chosen to summarise issues in terms of what we know, and what we don't know, before finally formulating some recommendations.

6.1 What we know

With regard to law and policy, it is clear that the international agreements within the Antarctic Treaty System for the prevention and eradication of alien species in Antarctica are very strict. However, the domestic policies that Parties to the Antarctic Treaty have put in place vary considerably, and overall are not currently adequate to meet the strict objectives agreed under the Environment Protocol. New Zealand has different control standards for its own borders than it has for Antarctica. Improvements for policymaking are currently under discussion.

From Section 2 we learned that there are a number of non-native species in the Antarctic, and that in the Peninsula area some of these have become invasive. As far as we are aware, none of the non-native species on the Antarctic continent have become invasive. Environmental change is affecting Antarctica, particularly in the Antarctic Peninsula, and will continue to do so.

Like the environmental changes, most of the transport activity is in the Antarctic Peninsula. A range of different operators are using a variety of transport modes. Tourism is the largest transporter of people, but may not have the largest impact because of good practices. National Programmes are the largest transporters in terms of cargo. For all of the transport pathways, activity levels are increasing and are set to continue increasing.

Management practices to tackle introductions of non-native species are lacking. Those management practices that exist focus on prevention, rather than on eradication or management when introductions do occur. It has become clear that there is a serious threat and that the current levels of control are inadequate.

Overall, we conclude that introduction of nonnative species poses as considerable threat, and that current controls are inadequate.

6.2 What we don't know

Although discussions are underway aimed at improving biosecurity controls, it is yet to be seen whether there is a willingness amongst all consultative parties to put measures in place to fulfil Madrid Protocol obligations with regard to invasive species. It is also not clear precisely what level of increased protection will be needed to meet the Madrid Protocol requirements.

In general, there is a knowledge deficiency with regard to the taxonomy of Antarctic species, particularly lower and non-visible taxa. Less is known about species on the continent than the Subantarctic islands. While we know that the climate is changing, it is not known how much the climate change will change, and exactly how this will affect the distribution of species and the introduction of invasive species.

In general, there is a lack of data to monitor the overall utilisation of transport, especially of the National Antarctic Programmes and fisheries operations. It is not known what role IUU fisheries might have in the introduction of invasive species. We do not know what transport channel provides the greatest risk. We know even less about the risks associated with intra-continental transport.

With regard to management practices, it is not clear what the scope of management should be. Are we only managing visible threats or also microbial invasions? Do we intervene when a non-native species arrives, or only when it becomes invasive? Do we want to distinguish between human introduced species and nonnative species? The potential impact of management practices (e.g. attempted eradications) on the ecosystem are also poorly understood, and can do more damage than good.

Overall, we conclude that there is a lack of data and information needed to make biosecurity management decisions, in relation to both species and transport pathways. The scope of management needed is not currently well defined. We do not know which risks might be most important.

6.3 What we recommend

Despite the lack of data identified above, we consider that the threat of nonnative species introduction is clear, and that basic precautionary measures should be taken now. Further research and policy decisions will also be needed, but this can occur in parallel with introduction of basic prevention measures.

Recommendation 1 – Good practices currently demonstrated by some parties should be adopted universally.
Instead of waiting until the gaps in the knowledge are filled, measures that are currently being practiced on a voluntary basis should be implemented throughout the Antarctic Treaty System, as a precautionary measure. These management practices include: bootwashing, steam cleaning equipment, quarantine provisions for cargo, modifications to clothing, and codes of conduct to reduce translocation between sites.

Recommendation 2 – A monitoring/surveillance system to detect nonnative species introductions is needed.
Early detection of introductions will maximise the opportunity for eradication before species become established.

Recommendation 3 – Further Research is required.
The current lack of data on native Antarctic species, potential species threats and transport pathways will be a limiting factor in formulating biosecurity policies. More work on all these areas is needed.

Recommendation 4 – Standard biosecurity policies should be developed through the Antarctic Treaty System

To minimise the likelihood of invasions, biosecurity policies will need to be standardised across the Antarctic Treaty Area. This should include rules for transporting cargo and passengers, and codes of conduct for field operations.
In addition, eradication and management plans will need to be developed, before a major invasion occurs.
Internationally, a number of issues are likely to be contentious, such as

- the scope of management (do we control for microorganisms?),
- how to introduce a framework for managing incursions where eradication is not possible or desirable, given that the Environment Protocol specifies that eradication is required.
- How responsibility for eradication and management of invasions will be decided, and how costs will be allocated.
- With regard to climate change, where to draw the line between natural and human-introduced changes, and what this means in terms of management decisions.

We would stress again that implementation of basic prevention measures (e.g. border controls, boot washing) should not be delayed while these discussion occur.

Recommendation 5 – New Zealand should consider extending its quarantine border controls to Antarctic travel

New Zealand has strict domestic biosecurity arrangements to prevent introduction of nonnative species to New Zealand. Extending these to cover Antarctic operations should be considered.
The shared logistics pool with the United States and Italy could complicate implementation of stricter controls, however it should be noted that full inspections are already required for Antarctic cargo and passengers entering New Zealand. Extending this to cover outward travel should be relatively straightforward.

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Appendix 1. Text of International Treaties Relating to Introduction of Nonnative species to Antarctica

<u>Agreed Measures for the Conservation of Antarctic Fauna and Flora (1964) [came into force 1982]</u>

Article IX [Introduction of non-indigenous species, parasites and diseases]

1. Each participating Government shall prohibit the bringing into the Treaty Area of any species of animal or plant not indigenous to that Area, except in accordance with a permit.
2. Permits under paragraph 1 of this Article shall be drawn in terms as specific as possible and shall be issued to allow the importation only of the animals and plants listed in Annex C. When any such animal or plant might cause harmful interference with the natural system if left unsupervised within the Treaty Area, such permits shall require that it be kept under controlled conditions and, after it has served its purpose, it shall be removed from the Treaty Area or destroyed.
3. Nothing in paragraphs 1 or 2 of this Article shall apply to the importation of food into the Treaty Area so long as animals and plants used for this purpose are kept under controlled conditions.
4. Each participating Government undertakes to ensure that all reasonable precautions shall be taken to prevent the accidental introduction of parasites and diseases into the Treaty Area. In particular, the precautions listed in Annex D shall be taken.

Annex C: Importation of Animals and Plants

The following animals and plants may be imported into the Treaty Area in accordance with permits issued under Article IX(2) of these Agreed Measures:

a. sledge dogs
b. domestic animals and plants
c. laboratory animals and plants including viruses, bacteria, yeasts and fungi.

Annex D: Precautions to prevent accidental introduction of parasites and diseases into the Treaty Area

The following precautions shall be taken:

1. *Dogs*. All dogs imported into the Treaty Area shall be inoculated against the following diseases:
   a. distemper
   b. contagious canine hepatitis
   c. rabies
   d. leptospirosis (*L. canicola* and *L. icterohaemorragicae*)

   Each dog shall be inoculated at least two months before the time of its arrival in the Treaty Area.

2. Poultry. Notwithstanding the provisions of Article IX(3) of these Agreed Measures, no living poultry shall be brought into the Treaty Area after 1st July 1966.

Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), 1980 [came into force 1982]

Article II(3)

Any harvesting and associated activities in the area to which this Convention applies shall be conducted in accordance with the provisions of this Convention and with the following principles of conservation:
[…]
(c) prevention of changes or minimisation of the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades, taking into account the state of available knowledge of the direct and indirect impact of harvesting, the effect of the introduction of alien species, 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.

United Nations Convention on the Law of the Sea (UNCLOS), 1982 [came into force 1994]

Article 196(1)
States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or 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.

Convention on Biological Diversity (CBD), 1992 [came into force 1993]

Article 8(h)

Each contracting party shall, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species.

Environmental Protocol to the Antarctic Treaty, 1991 [came into force 1997]

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(1): **Environmental Principles**

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.

Annex II, Article 4: Introduction of Nonnative 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 shelfs, 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 April 1, 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 I 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.

Annex II, 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:

(a) domestic plants; and

(b) laboratory animals and plants including viruses, bacteria, yeasts and fungi.

Annex II, Appendix C: Precautions to Prevent Introductions 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.