RESEARCH/REVIEW ARTICLE

Alien invasions in Antarctica—is anyone liable?

Kevin A. Hughes & Peter Convey

British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB30ET, UK

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Correspondence
Kevin A. Hughes, British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB30ET, UK. E-mail: kehu@bas.ac.uk

Abstract

The introduction of non-native species to Antarctica in association with human activities is a major threat to indigenous biodiversity and the region's unique ecosystems, as has been well-demonstrated in other ecosystems globally. Existing legislation contained in the Protocol on Environmental Protection to the Antarctic Treaty does not specifically make the eradication of non-native species mandatory, although it is implicit that human-assisted introductions should not take place. Furthermore, to date, eradications of non-native species in the Treaty area have been infrequent and slow to progress. In 2005 an additional Annex (VI) to the Protocol was agreed concerning "Liability arising from environmental emergencies." This annex focusses on prevention of environmental emergencies, contingency planning and reclaiming costs incurred when responding to an environmental emergency caused by another operator within the Antarctic Treaty area. However, the types of environmental emergencies covered by the annex are not defined. In this paper we highlight potential difficulties with the application of Annex VI in the context of non-native species control and eradication, including, for example, whether a non-native species introduction would be classified as an "environmental emergency" and therefore be considered under the terms of the annex. Even if this were the case, we conclude that the slow pace of approval of the annex by Antarctic Treaty Parties may prevent it coming into force for many years and, once in force, in its current form it is unlikely to be useful for reclaiming costs associated with the eradication or management of a non-native species.

To access the supplementary material for this article, please see Supplementary files under Article Tools online.

Antarctica is the most pristine continent remaining on the planet, yet is under pressure from environmental impacts originating both from within and outside the region (Bargagli 2005; Tin et al. 2009; Aronson et al. 2011; Tin et al. 2013). In particular, the introduction of invasive non-native species could present a major threat to the continent's indigenous biodiversity, and it is essential that steps are taken to control and, if possible, eradicate any introduced species as soon as possible after their discovery (Chown, Huiskes et al. 2012; Chown, Lee et al. 2012; Hughes, Huiskes et al. 2013). In this paper we aim to (1) detail the international instruments currently in force within the Antarctic Treaty System relating to non-native species and (2) examine the potential applicability of Annex VI ("Liability arising from environmental emergencies") to the Protocol on Environmental Protection to the Antarctic Treaty (also known as the Environmental Protocol or Madrid Protocol), for Parties operating in the region with regard to non-native species introductions.

Antarctic ecosystems

Only 0.34% of the Antarctic continent is ice-free and it is within this area of ca. 44 000 km^2 that Antarctica's unique terrestrial biological communities are found. Antarctic terrestrial systems are characterized by a low biodiversity (Convey 2013). Trees and most higher plants are absent from the continent, and the generally sparse vegetation is dominated by mosses and liverworts, with flowering plants represented by only two species, the grass

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Deschampsia antarctica and the cushion plant *Colobanthus quitensis*. All vertebrate animals in Antarctica (e.g., seals, marine bird species) rely on the marine environment for food and true terrestrial animals are limited to two species of dipteran and Acari (mites), Collembola (springtails), Tardigrada (waterbears), Nematoda, Rotifera and protozoans. Microbial communities dominate in Antarctica. As environmental conditions become increasingly severe, generally with distance from the coast or altitude, biodiversity becomes limited to microorganisms (algae, bacteria, cyanobacteria, viruses and protozoa) found within the poorly developed soils, and fissures and voids in rocks and other locations where liquid water may be present (Vincent 1988; Wynn-Williams 1996; Hughes & Lawley 2003). Lichens (a microbial symbiosis of fungal and algal species) are found throughout Antarctica, with different species occupying all but the most extreme terrestrial habitats. Recent research has led to the realization that there is distinct regionalization in Antarctic terrestrial biodiversity (Convey & Stevens 2007; Convey et al. 2008), often of ancient origin. Fifteen different Antarctic Conservation Biogeographic Regions have been identified, each containing a substantially different combination of cosmopolitan and local endemic species (Terauds et al. 2012). While Antarctica's terrestrial fauna and flora are typically cryptic and lack the "charismatic" elements more familiar from temperate and tropical regions, the spatial area of habitat is small compared to the size of the continent, and designation of protected areas is of critical importance.

In contrast with terrestrial ecosystems, Antarctica's marine environments are much more biodiverse. Benthic habitats, in particular, may possess biodiversity and biomass equivalent to some of the richest locations found globally, second only to tropical coral reefs (Clarke & Johnston 2003). Marine habitats experience chronically low but stable sea water temperatures, that are rarely beyond a few degrees either side of 0°C (Peck et al. 2006). High levels of marine primary productivity during the austral summer, in the form of algal blooms, provide a food source for pelagic marine invertebrate species such as krill and salps that in turn support fish and higher predators including penguins, whales, seals and flying bird species.

Non-native species introductions

Global human impacts apparent in Antarctica include climate change, ocean acidification, ozone depletion and ocean and atmospheric pollution dispersed over long distances, while local impacts include the historic overexploitation of living marine resources, pollution, degradation of habitat and disturbance of wildlife (for reviews see Bargagli 2005; Tin et al. 2009; Aronson et al. 2011; Convey et al. 2012). The amount and extent of human activity within the Antarctic Treaty area (formally defined as the area south of latitude 60°S) has increased in recent decades, both with a rise in the amount of ship and land-based tourism, and with the construction of new national governmental operator research stations in previously unimpacted locations and expansion of their operational footprints (Hughes, Fretwell et al. 2011; Convey et al. 2012). In the recent past, tourism peaked in the 2007/08 austral summer with over 37 000 tourist landings, predominantly within the Antarctic Peninsula region, but the numbers then contracted slightly, associated with the global economic downturn (IAATO 2013). Nevertheless, the decline has stabilized and numbers are likely to return to their previous upward trend. National operators currently have over 75 research stations that may be occupied year-round or during the austral summer season, plus numerous refuges, huts and temporary field camps (COMNAP 2013a). Over 4000 scientists and support staff may be present in Antarctica during the summer, with populations falling to ca. 1000 during the winter.

In recent decades, environmental emergencies within the Antarctic Treaty area have been associated mainly with the activities of national operators, although incidents involving tourist vessels have occurred, such as the sinking of MS *Explorer* in 2007 (Chile 2008; Aronson et al. 2011). The most significant environmental incident in the modern era in Antarctica was the sinking of the Argentinian supply vessel *Bahia Paraiso* in 1989, which released 600 000 litres of petroleum (Kennicutt et al. 1991; Kennicutt & Sweet 1992). In the same year 260 000 litres of fuel were spilled on Williams Field on the Ross Ice Shelf, 13 km from McMurdo Station (Wilkness 1990).

Added to pollution incidents, the unintentional introduction of non-native species is potentially a major threat to indigenous Antarctic biodiversity. Due to the spatial distribution of human visitation and climate change impacts, some regions—the northern Antarctic Peninsula and its offshore islands, in particular—may be more at risk than others (Frenot et al. 2005; Convey 2008; Hughes & Convey 2010; Cowan et al. 2011; Chown, Huiskes et al. 2012; Chown, Lee et al. 2012). Once non-native species are introduced, they may become established and, in some cases, become invasive through expansion of their distribution and displacement of indigenous biodiversity. Non-native species can be introduced inadvertently to Antarctic terrestrial environments associated with imported cargo, vehicles, fresh foods, scientific equipment and personal clothing and effects (Lee & Chown 2009a, 2009b; Hughes et al. 2010; Hughes, Lee et al. 2011;

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Chown, Huiskes et al. 2012; Tsujimoto & Imura 2012). Although less well characterized and apparently infrequent within Antarctica, introductions to marine environments may occur through transport on ship hulls or in ballast water (Lewis et al. 2003; Lewis et al. 2006; United Kingdom 2006; Lee & Chown 2007). Antarctica currently hosts very few non-native species compared to other areas of the Earth (e.g., Corte 1961; Olech 1996; Hughes & Worland 2010; Greenslade et al. 2012; Molina-Montenegro et al. 2012), but the increasing magnitude and distribution of human activity in the region is expected to increase the likelihood of non-native species introductions (Frenot et al. 2005; Hughes, Huiskes et al. 2014; Chown, Huiskes et al. 2012; Chown, Lee et al. 2012). Furthermore, climate change, particularly over the Antarctic Peninsula region but also over continental Antarctica, may increase the risk of species establishment and subsequent invasion (Convey et al. 2009; Steig et al. 2009; Turner et al. 2009; Convey 2011; Chown, Huiskes et al. 2012). Native Antarctic terrestrial communities typically have low diversity and are thought to have low functional redundancy as well as containing "empty" niches (Convey 2013). Their long history of evolutionary isolation is evidenced by high levels of endemism across most component groups of biota (Convey et al. 2008; Pugh & Convey 2008), while the severe environmental conditions have resulted in the predominance of "adversity selected" life history characteristics, a feature of which is poor competitive ability and vulnerability to invasion by more effective competitors (Kennedy 1993; Convey 1996). As a result, identifying methods to reduce the likelihood of alien species introductions has been a focus of the Committee for Environmental Protection (CEP) at the Antarctic Treaty Consultative Meetings (ATCMs) over recent years.

Legislation concerning non-native species—precedents from outside Antarctica

Outside the Antarctic Treaty area, national legislation and regional and international instruments exist concerning the introduction and/or control of non-native species (Shine et al. 2000; Fasham & Trumper 2001; Miller et al. 2006). In some cases national legislation may have been developed in response to the Convention on Biological Diversity (CBD), which was signed in 1992 and entered into force in 1993, and which requires its 193 Parties to "prevent the introduction of, control and eradicate alien species, which threaten local or regional biodiversity." (The CBD applies formally only to sovereign territory and as national territorial claims within Antarctica are placed in abeyance under the Antarctic Treaty, the CBD itself does not apply to Antarctica despite the majority of Antarctic Treaty Parties also being CBD signatory nations.) However, in some cases, domestic legislation may not be integrated into a coherent framework, making it difficult to enforce and therefore largely ineffective (Manchester & Bullock 2000; Miller et al. 2006; Hulme et al. 2008). Furthermore, domestic legislation may not make it an explicit requirement that non-native species are controlled or eradicated for reasons of ecological or environmental conservation and protection (Fasham & Trumer 2001). Few nations have domestic legislation whereby costs resulting from the introduction and/or eradication of a non-native species can be reclaimed from those who were responsible for the introduction. However, New Zealand was one of the first nations to develop an integrated framework for identifying non-native species and managing the associated risks across all sectors, which came into effect through the Biosecurity Act (1993; available at http://legislation.govt.nz/act/public/1993/0095/latest/DLM314623.html). The Act's Pest Management Strategy determines how a non-native species is to be controlled or eradicated and sets out how this should be funded, with the aim of sharing cost fairly between those responsible for the introduction and those who would benefit from the species eradication or control (Fasham & Trumper 2001).

Globally, many governments have been slow to enact effective biosecurity legislation, particularly as human activity over many centuries or millennia has already introduced many hundreds or thousands of non-native species to some countries. In contrast, Antarctica has had only a brief period of human occupation and non-native species are still few compared to other parts of the Earth, making the development of an integrated framework for non-native species management for the continent both important and achievable.

Antarctic governance and legal instruments

The Antarctic Treaty has been signed by 50 Parties (nations), whose populations constitute approximately 65% of the world's population. Twenty-nine Parties are Consultative Parties, including the original 12 Treaty signatory Parties and a further 17 Parties that have acceded to the Treaty by demonstrating their interest in Antarctica by conducting substantial research activity there (as set out in Article 9[2]). The 21 Non-consultative Parties are invited to attend the ATCMs, but only Consultative Parties are entitled to participate in decision making, which must be by consensus.

Within the Antarctic Treaty System, for an international instrument to come into effect it must be approved by all the Parties that had Consultative status when the

instrument was adopted originally. As a result, it can take many years for international instruments to come into effect. For example, the Environmental Protocol was signed on 4 October 1991, but did not enter into force until approved by each Party (using their own definition of what this entails) on 14 January 1998.

The Environmental Protocol

The Environmental Protocol is the main legal instrument concerned with the protection of the Antarctic environment within the Antarctic Treaty area. The Protocol has been approved by all 29 Consultative Parties to the Antarctic Treaty but, of the 21 Non-consultative Parties, it has been approved by only six. Further, the Environmental Protocol does not apply to nations that are not signatories to the Antarctic Treaty. The Environmental Protocol has five annexes currently in effect, which set out minimum environmental standards concerning environmental impact assessment (Annex I), conservation of Antarctic fauna and flora (Annex II), waste disposal (Annex III), prevention of marine pollution (Annex IV) and the protected area system (Annex V).

In subsequent sections we highlight text within the Environmental Protocol that is of relevance to non-native species introductions and describe Annex VI—"Liability arising from environmental emergencies," which has yet to enter into force. We then go on to discuss issues that may deserve more consideration when applying this new international instrument to non-native species introductions.

Annex I: Environmental impact assessment. The activities of all signatory nations within the Antarctic Treaty area, including tourism and national operator activities, must be formally permitted by the appropriate national authority and have undergone an environmental impact assessment in accordance with Annex I of the Environmental Protocol. The level of environmental impact assessment undertaken for any activity in Antarctic depends upon whether the activity is likely to result in an impact that is less, equivalent to, or greater than "minor or transitory." Annex I does not mention non-native species introductions specifically; however, over time, an introduced species may cause environmental impact that is at least, if not substantially greater than, "minor" and/or longer lasting than "transitory," and these potential consequences should be recognized during the environmental impact assessment process, as recommended in the "Guidelines for environmental impact in Antarctica" (available at http://ats.aq/documents/recatt/Att266_e.pdf).

Annex II: Conservation of fauna and flora. Annex II prohibits the intentional introduction of non-indigenous plants and animals to land, ice shelves or into water within the Antarctic Treaty area unless for a defined scientific purpose and in accordance with a permit (Annex II, Article 4). Furthermore, Measure 16 (2009), which amends Annex II, prohibits the intentional introduction of all species of living organisms not native to the Antarctic Treaty area. Little attention is given to the issue of unintentional or accidental introduction of non-native species. Article 4(6) states that Parties should take precautions to prevent the introduction of microorganisms not present in the native flora and fauna. These precautions include checking that poultry imported for food is free of disease and is disposed of in a manner that eliminates risk to native flora and fauna, and that importation of non-sterile soil is avoided to the maximum extent possible. The Environmental Protocol makes no explicit mention of the transfer of native organisms from one Antarctic region to another, although it does state that activities shall be limited to ensure that "the diversity of species, as well as the habitats essential to their existence, and the balance of the ecological systems existing within the Antarctic Treaty area are maintained" (Annex II, Article 3[3c]). In other words, in relation to their activities, Parties should take steps to reduce to a minimum the risks to the Antarctic environment, including those associated with the introduction of non-native species, and ensure that ecosystems are maintained in their natural state.

Annex IV: Prevention of marine pollution. Annex IV establishes provisions to prevent marine pollution within the Antarctic Treaty area but does not mention non-native species specifically. However, it does state that sewage (and associated non-native microorganisms) and food waste must not be released within 12 nautical miles of the nearest land or ice shelf.

Annex V: Area protection and management. Annex V sets out the protected area system for Antarctica but does not address non-native species specifically; however, designated protected areas must be accompanied by a management plan that may contain biosecurity measures intended to protect the values for which the Area was designated (Hughes & Convey 2010). To assist those preparing management plans, the issue of non-native species is mentioned in the "Guide to the preparation of management plans for Antarctic Specially Protected Areas" (section 7[vi]; available at http://ats.aq/documents/recatt/Att477_e.pdf).

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Annex VI: Liability arising from environmental emergencies. At the 28th ATCM a further annex to the Environmental Protocol was agreed. This was Annex VI—"Liability arising from environmental emergencies," also known as the Liability Annex (available at http://www.ats.aq/e/ep.htm; see also Supplementary file). Annex VI has not yet come in to force, as it has not been approved by all Consultative Parties, and therefore has not been tested in any court. In contrast to other liability instruments, the scope of the Liability Annex is very limited, specifically to the costs of emergency response. The Liability Annex applies to environmental emergencies in the Antarctic Treaty area which relate to scientific research programmes, tourism and all other governmental and non-governmental activities (Vöneky 2008). The preamble of the annex recalls the "importance of preventing, minimising and containing the impact of environmental emergencies." The primary aim of the Liability Annex is to act as a deterrent for those who operate irresponsibly in Antarctica, and it imposes financial liability on operators which fail to take response action, effectively establishing a "polluter pays" principle.

Once the annex becomes effective, in theory it will be possible to recoup costs incurred from the clean-up or remediation of pollution or environmental damage resulting from environmental emergencies caused by the actions of other signatory nations or their non-state operators within the Antarctic Treaty area. However, the range of environmental emergencies covered by the annex is not listed specifically, although later reference to ships suggests that those who drafted the text envisaged the annex to encompass marine incidents, including oil spills, and terrestrial pollution events.

Non-native species and the Liability Annex

Why are the annexes currently in force insufficient to deal with non-native species issues?

Crucially, measures for reinstatement of the damaged environment are not included specifically in the annexes currently in force (Annexes I–V). Moreover, control and/or eradication of non-native species is not a specified mandatory requirement under Annex II, although recommended in non-mandatory guidelines contained within the *CEP non-native species manual* (CEP 2011; adopted by the ATCM through Resolution 6 [2011]). As noted earlier, Annex II does contain a requirement that Parties maintain Antarctic species diversity, habitats and ecological systems (Article 3[3c]), but this is limited in its effectiveness.

To conform with Article 3(3c), Parties should prevent unintentional non-native species introductions and, if necessary, take management action to control or eradicate any species that have been introduced. However, this is not stated explicitly and examination of past examples of response action following the discovery of a non-native species indicates that often little, or no, practical action is taken (Smith 1996; Hughes & Worland 2010; United Kingdom 2013). For example, the non-native grass *Poa pratensis* has not been removed from the vicinity of the Argentinian Primavera Station at Cierva Point on the Antarctic Peninsula following its introduction in 1954/55, although discussions on eradication have been initiated (Corte 1961; Pertierra et al. 2013), and neither has *Poa annua* in the vicinity of Arctowski Station, King George Island, South Shetland Islands (Olech 1996; Olech & Chwedorzewska 2011). In contrast, the Liability Annex is much more explicit, with Article 5 stating specifically that response action by an operator that has caused an environmental emergency should be prompt and effective.

The implementation and enforcement of the requirements contained in the annexes currently in force is controlled fully by each individual Party. Despite legal obligations, Parties may, or may not, be inclined to take action to enforce the legislation. For example, Annex II largely does not permit intentional non-native species introductions, but some Parties do not enforce this requirement and non-native decorative plants are visible on some research stations (see figure 5.2 in Hughes, Huiskes et al. 2014). In contrast, should a liability instrument be in force that was considered applicable to the issue of non-native species, then Parties may have an incentive to make non-native species control and eradication a priority issue, particularly if they consider it possible that a second Party might become involved and then attempt to claim back any costs.

Application of the Liability Annex to environmental emergencies involving non-native species

The risks and consequences of a non-native species introduction, as an "environmental emergency," may not have been considered in any depth (if at all) by the legal and policy groups during the greater part of negotiations of Annex VI (Aust & Shears 1996). The issue of the unintentional introduction of macroscopic non-native species became a major priority for the CEP only from 2004 onward (Australia 2004, 2005), and, in particular, after the publication of the influential scientific review paper by Frenot et al. (2005), which clearly set out the scale of the non-native species problem in Antarctica

and the sub-Antarctic islands. A workshop entitled Non-native Species in Antarctica, hosted by New Zealand in 2006, further cemented resolve between scientist and policy makers to tackle the issue (New Zealand 2006; Rogan-Finnemore 2008). Therefore, although the issue of non-native species introductions may not have been a focus of those who drafted the Liability Annex, it may also be possible, in principal at least, to use this international instrument for preventing, minimizing and containing the impact of non-native species introductions and to recoup the costs associated with the removal or control of non-native species that have not been eradicated by those responsible for their introduction. However, when the wording of the Liability Annex is read in the context of non-native species introductions, it is clear that the annex presents many potential issues for those operating within the Antarctic Treaty area.

At what point does a non-native species introduction become an environmental emergency?

An "environmental emergency" is defined as "an accidental event that results in, or imminently threatens to result in, any significant and harmful impact on the Antarctic environment" (Annex VI, Article 2[b]). Unlike a catastrophic oil spill, the impacts of which are generally initially great but may dissipate over time, the impacts of non-native species in Antarctica may only become apparent long after the initial, usually minor, introduction event (see Fig. 1). This temporal element is crucial to the question of whether a non-native species introduction constitutes an environmental emergency under the definitions of the annex. If the annex covers only the immediate consequences of sudden accidents or incidents, as suggested by de la Fayette (2010), and not cumulative impact from a continuous situation, then non-native species may fall outside the scope of the annex.

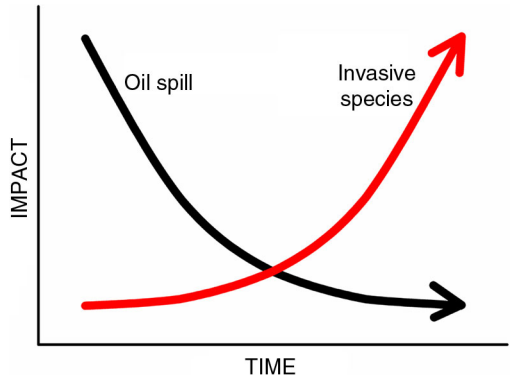

Fig. 1 Schematic representation of the relative impacts over time of two serious environmental emergencies: marine oil spill and introduction of an invasive species to Antarctica. Oil spills at sea may cause substantial damage to local wildlife, but with time, the oil evaporates or dissipates and impacts generally become reduced. In contrast, the environmental impacts associated with the early stages of colonization by a non-native species are low or non-existent, but should the organism become established and then invasive, the consequences for indigenous biological communities may be widespread, irreversible and the impact significantly greater than minor or transitory.

Taking a different perspective, it could be argued also that an introduced non-native species should not be considered an environmental emergency until it starts to become invasive (i.e., spreads and impacts negatively upon indigenous species and ecosystems) as, before then, impacts are likely to be trivial and limited in spatial scale. Non-native species may remain in a persistent state (i.e., surviving and reproducing at a restricted locality, with no expansion of the area colonized over time) for many years before either some genetic change occurs or a physiological threshold is crossed that allows it to become invasive (Olech 2003; Frenot et al. 2005; Hughes & Worland 2010; Olech & Chewedorzewska 2011). For example, climate warming may increase the likelihood of a non-native plant switching to invasive status and spreading more widely, as has already been observed in an analogous fashion with recent population expansion in some indigenous plants on the Antarctic Peninsula (Fowbert & Smith 1994; Convey 2006; Parnikoza et al. 2009). With adequate long-term monitoring, the onset of this switch could be detected and the "imminent threat" of "significant and harmful impact on the Antarctic environment" might make the annex applicable. However, from a practical perspective, rather than initiating a long-term monitoring programme focussed on a newly discovered non-native species, it would likely be less effort to simply eradicate the species as soon after its discovery as possible, as recommended by the CEP (2011).

Consequently, there is a potential case that the presence of even a single individual of a confirmed non-native species should be considered an "environmental emergency in waiting," and trigger prompt management action, thereby pre-empting the potential application of Annex VI (which itself states that response action by an operator that has caused an environmental emergency should be prompt and effective [Article 5]). If left unmanaged the non-native species may replicate, spread and become invasive before eradication can be funded, planned and attempted (as has already likely occurred with the grass *Poa annua* near Arctowski Station, King George Island, and the flightless midge *Eretmoptera murphyi* on Signy Island, South Orkney Islands (Hughes, Worland et al. 2013).

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When will the annex come into effect?

Although the Liability Annex has been adopted as a legally binding measure, it will not enter into force until the Consultative Parties have approved it (Article 2[b]). Approval of each Consultative Party takes place when it deposits a note signifying its approval of the international instrument with the Depositary Government of the Antarctic Treaty. However, the process of approval differs between Parties. For some Parties, such as the UK, an international instrument is only approved once it has been incorporated into domestic law. However, for other Parties approval is the same as initial adoption; for example, Chile and South Africa have adopted and, therefore, approved the Protocol on Environmental Protection to the Antarctic Treaty whilst still not having passed it fully into domestic legislation. In the past the Parties have been slow in making adopted international instruments effective. For example, ATCM Recommendation XVIII-1, which provides guidelines for tourism, is still not effective 20 years after it was adopted initially at Kyoto in 1994. Measure 1 (2005) concerns the Liability Annex, and so far only eight Parties have approved the measure out of the 28 Parties that adopted it in 2005, making it unlikely that the annex will become effective within the next decade.

As the annex cannot be applied retrospectively, all non-native species known already to be present in Antarctica—some of which were almost certainly introduced by, for example, Argentina, Poland, the UK and Uruguay (Corte 1961; Olech 1996; Hughes & Worland 2010; Volonterio et al. 2013)—and any introduced in the years until the annex comes into force will not be subject to this annex.

Preventative measures and response action

Given an assumption that the Liability Annex might be applicable to non-native species introductions at some stage, the annex states that any preventative measures and response action should be "reasonable," taking into consideration the "rate of natural recovery" of the Antarctic environment, and also be technologically and economically feasible (Article 2[e]). Once a species is introduced, natural recovery of the Antarctic environment to its pre-introduction state may occur if the species dies out, most likely due to physical factors; however, should a species become invasive then ongoing habitat alteration, rather than natural recovery, may occur over time. The longer a non-native species is allowed to persist in Antarctica, the more likely it is that its distribution range will increase both through natural processes and by further anthropogenic transfer. Therefore, if no action is taken by either the responsible operators or another operator at some point following the introduction, eradication of a non-native species may become neither technologically nor economically feasible.

Annex II requires that "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." While it is important that measures are taken to prevent microbial introductions (including pathogenic species that may cause disease in wildlife), once introduced, eradication would likely be unfeasible or impossible, in contrast to an introduced macro-organism such as a grass or invertebrate, which may realistically be controlled by eradication attempts.

Measures to reduce the risk of an environmental emergency

Parties are required to ensure their operators take measures to reduce the risk of environmental emergencies and their potential adverse impacts (Annex VI, Article 3). Listed measures include the following: (1) "specialised structures or equipment incorporated into . . . facilities and means of transport," which in the context of non-native species could include designated quarantine areas for the inspection or storage of imported material, or equipment for removing propagules from cargo and equipment; (2) "specialised procedures incorporated into the operation and maintenance of facilities and means of transport," which could include appropriate biosecurity procedures; and (3) "specialised training of personnel," which could include education on the risk associated with non-native species and steps that can be taken to reduce this risk (e.g., cleaning of cargo, vehicles and equipment, boot washing and careful management of fresh foods [see COMNAP & SCAR 2010]).

Contingency planning

Article 4 sets out the need for contingency plans to help respond to environmental emergencies but, to date, little discussion of practical contingency planning has occurred within the CEP or COMNAP with regard to non-native species and it is doubtful that many, if any, such contingency plans exist within the Treaty Parties. However, the *CEP non-native species manual* (CEP 2011), which provides information and non-mandatory guidelines on non-native species and biosecurity, does mention the preparation of a "rapid response guideline" as an area of potential future work (see Annex I, point 17).

Allocation of liability and reclaiming costs

The voluntary *CEP non-native species manual* (CEP 2011) states that "responses to introductions should be undertaken as a priority, to prevent an increase in the species' distribution range and to make eradication simpler, cost effective and more likely to succeed." However, assuming an introduction can be attributed to the actions of an operator, and that eradication is feasible and would not itself cause excessive environmental damage, it is unlikely that the responsible operator could be compelled to eradicate the non-native species under Annex II alone.

Articles 6 and 7 of Annex VI concern the allocation of liability following an environmental emergency and legal actions to reclaim costs. If non-native species are eradicated at the earliest stages of introduction, costs are likely to be trivial in comparison with the larger-scale actions required inevitably once a species has become established over a larger area. However, if a non-state operator does not take these initial eradication steps, it is feasible that a different Party could suggest that they intend to undertake a response action (i.e., eradication) and reclaim costs through the domestic courts using national legislation that incorporates the Liability Annex into national law, thereby giving the non-state operator a financial incentive to take prompt action to remove the non-native species. As discussed earlier, whether the small scale presence of non-native species consistent with an initial introduction event would constitute an environmental emergency as defined in Article 2 may be questioned. If a state operator was responsible for the introduction, its Party may be reluctant to engage in a lengthy and potentially time-consuming engagement with the legal system surrounding Annex VI, or to subject themselves to reputational damage, and rather take the potentially simpler and easier option of ensuring eradication at an early stage, as would be required under Annex II, Article 3(3c).

It is likely that only very clear-cut cases of environmental negligence will be pursued under the annex. It may be difficult to prove—to an appropriate legal standard—responsibility for a non-native species introduction. This may be true particularly at locations under the control of one operator, but visited regularly by ships and/or aircraft belonging to other operators, including those operated by the tourism industry and national operators. Examples include Fildes Peninsula on King George Island and, in the same archipelago, Deception Island, as well as Rothera Research Station, Adelaide Island. In addition, the potential for colonization via natural pathways may complicate attribution to the operator in question (Hughes & Convey 2012).

Who is, or is not, covered by the Liability Annex?

The annex does not apply to fishing vessels and ships transiting through the Antarctic Treaty area; however, these vessels could be sources of non-native species introductions to the marine environment (Article 1). Furthermore, the application of the "sovereign immunity rule" whereby ships or aircraft operated by a Party for governmental non-commercial activities are beyond the jurisdiction of the annex (Article 6[5]), is relevant as the majority of ships and aircraft operating in Antarctica are owned or operated by states. Nevertheless, state operators are still obliged to take prompt and effective response action and are not exempt from the planning and contingency arrangements in the annex.

Are the potentially available funds sufficient for adequate non-native species eradication or control?

Article 9(1b), sets out the limit of liability for an environmental emergency arising from an event which does not involve a ship at three million Special Drawing Rights (currently ca. 4.5 million USD). This should be more than sufficient to undertake a simple one off eradication programme over a limited spatial scale, but may not be adequate for a larger-scale multi-year eradication of a non-native species belonging to a more mobile biological group (e.g., some invertebrates) or one which is able to disperse progeny rapidly. In the marine environment, eradications of marine species are almost always unsuccessful (see IUCN 2013), and if attempted in Antarctic waters are likely to be extremely expensive.

Diplomatic concerns

In a situation where one Party considers it is appropriate to initiate action under the Liability Annex, the claim will quickly fail if support is not obtained from all other Consultative Parties, as Article 12 states that reimbursements for expenses arising from the response to an environmental emergency shall be approved by way of a Decision, which requires consensus agreement by all Consultative Parties. Achieving this level of agreement may be extremely difficult, given the interactions between Parties both at and away from the meeting table at the ATCMs. Furthermore, payment of costs from the fund held by the Antarctic Treaty Secretariat relies on the Party whose operators caused the environmental emergency also approving the Decision to release funds to the Party that undertook the response action. In other words, it may be possible for the Party found liable to block payment from the fund by not approving the Decision.

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Perceived importance of biosecurity issues

Currently, there is a strong financial incentive for Parties to implement strict procedures to prevent a shipping incident (where the ship may be put at risk) or an oil spill (as fuel has a high value in Antarctica), as the cost of an incident may be high, even before clean-up costs are taken into consideration. Policy makers have highlighted the importance of non-native species issues and have worked with COMNAP to generate guidelines to reduce the risk of non-native species introductions (COMNAP & SCAR 2010; CEP 2011). However, the introduction of a non-native species incurs no immediate financial cost to a Party, while ongoing biosecurity measures may be considered expensive, inconvenient and time-consuming. As a result biosecurity implementation may not be prioritized, or an introduction even recognized as an environmental emergency with the associated requirements for contingency planning, as laid out in the Liability Annex. This may leave operators open to later potential claims.

Are eradication attempts always justified?

There are well-considered arguments for rapid action following the identification of an anthropogenically introduced non-native species within the Treaty area, specifically to prevent further spread (see Fig. 1). However, over-zealous removal of "supposed" non-native species without appropriate research may be problematic and in some instances may prevent natural colonization when mistakes are made (Hughes & Convey 2012).

In another scenario, if a non-native species eradication is likely to cause substantial damage to the indigenous biota in the affected area, it may be difficult to justify approving the introduced species' removal. For instance, following years of inaction regarding the establishment of *Poa annua* on King George Island (Olech & Chwedorzewska 2011) and the chironomid midge *Eretmoptera murphyi* and the enchytraeid worm *Christensenidrilus blocki* on Signy Island (Hughes & Worland 2010), it could be argued that the scale of damage that would now inevitably be caused to local ecosystems by any eradication attempt cannot be justified. This illustrates a situation in which different interpretations of Annex II come into conflict. For example, attempting the eradication of a non-native species using methods normally used elsewhere (such as digging up or use of herbicides or pesticides) may damage habitats which, within the area concerned, would be contrary to the Annex II requirement to maintain the species diversity, habitat and balance of Antarctic ecological systems (Article 3[3c]). Crucially, however, should the invasive species not be eradicated and, rather, be spread to other Antarctic locations, far greater impacts might result over a considerably larger spatial scale. There are no guidelines on how to deal with the conflicts arising from the implementation of the Environmental Protocol, although the issue has been identified as an area for further work by the CEP (2011).

Other legal issues may need consideration before eradications may proceed. Pesticides, which may be essential for successful eradications, are not permitted within the Treaty area other than for "scientific, medical or hygiene purposes" (Annex III, Article 7). Furthermore, permits can be given by appropriate national authorities to undertake harmful interference with native flora and fauna, but only (1) to provide specimens for scientific study, (2) to supply specimens for museums and other educational establishments, or (3) to "provide for the unavoidable consequence of scientific activities ... or of the construction and operation of scientific support facilities." Can we consider the introduction of a non-native species an "unavoidable" consequence of our activities in Antarctica? Parties may see environmental impacts as an inevitable consequence of undertaking science in Antarctica and justified by the benefits this research brings. It may be more difficult to justify any introductions that come about through tourist activities, from this perspective. Such complications may make Parties reluctant to resort to potentially costly enquiry procedures or arbitration, as described in Annex VI, Article 7(5a).

Failed eradication attempts

The non-native black fungus midge *Lycoriella* sp. was first reported to have colonized the sewage system at Casey Station (Australia) in 1998, but several subsequent attempts to eradicate it have failed (Hughes et al. 2005). In the case of some other species, the likelihood of a successful eradication might also be low. For example, the fly *Trichocera maculipennis* found recently both in the sewage system and outside the Uruguayan General Artigas Station on Fildes Peninsula (Volonterio et al. 2013) may be virtually impossible to eradicate now, given that it is a flying insect that has probably established in the environment, and is likely to be highly pre-adapted to maritime Antarctic conditions given its natural distribution, including high-latitude boreal locations. It may be that a Party could reclaim costs from an operator responsible for an introduction, even if the Party's response action was ultimately unsuccessful, as it could be claimed that full eradication is impossible in practical terms, but that management action to control or limit spread of the species was taken instead. However, longer term control and management will not be chargeable as liability of the operator ends 15 years after the initiation of the response action (Article 7[1]).

Environmental emergencies resulting from food importation and cultivation

Currently, the importation of foods (excluding livestock) for human consumption within Antarctica is not subject to the measures to prevent intentional non-native species introductions set out in Annex II, Article 4, of the Protocol ("Introduction of non-native species, parasites and diseases"). However, it should be noted that the exemption of food products from Article 4 is only granted provided that foods are kept under carefully controlled conditions and are disposed of in accordance with Annex III ("Waste disposal and waste management") and Appendix C to Annex II ("Precautions to prevent introductions of micro-organisms"). It is unclear if Parties that fail to conform with these requirements, with the result that a non-native species becomes introduced to the Antarctic environment, could be held liable under the Liability Annex. Furthermore, hydroponic facilities present at several Antarctic research stations have in the past been closed down due to infestations by non-native invertebrates, and it is possible that these species may be released outside the hydroponic facility, as has happened within the sub-Antarctic islands (Frenot et al. 2005; Greenslade 2006; Hughes & Convey 2012; COMNAP 2013b). Such environmental incidents highlight the need for adequate contingency planning, which is also a requirement of the Liability Annex.

Conclusions

Given the potential threat to Antarctic marine and terrestrial ecosystems presented by the introduction of non-native species, the ATCM (and in particular through the CEP) has devoted considerable time to raising awareness of the risks presented by non-native species and to developing guidelines to reduce the risk of non-native species impacts. However, much of this work took place in the years after the Liability Annex was adopted in 2005. Therefore, it is likely that those who drafted the Liability Annex did not appreciate fully the broad range of environmental emergencies that could arise, and were focussing predominantly on (particularly, catastrophic) pollution events and not on non-native species impacts.

The slow pace of approval of the Liability Annex by Antarctic Treaty Parties, so far, may prevent the instrument coming into force for many years. Furthermore, even once the annex enters into force, in its current form it is unlikely to be useful for reclaiming costs associated with the eradication or management of a non-native species, due particularly to a lack of clarity on the scope of the annex and the complex nature of non-native species invasions.

The ATCM's Decision 4 (2010), concerning "Liability arising from environmental emergencies," asked the CEP "to consider environmental issues related to the practicality of repair or remediation of environmental damage in the circumstances of Antarctica, in order to assist the ATCM in adopting an informed decision in 2015 related to the resumption of the negotiations." This Decision presents a useful opportunity for the issues relating to environmental emergencies and liability concerning non-native species (many of which have been highlighted here) to be considered more fully. However, given the vulnerability of Antarctic ecosystems to non-native species, it is hoped that biosecurity standards improve across all Parties and operators long before these negotiations conclude.

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