



## OPEN ACCESS

### EDITED BY

Ioannis A. Giantsis,  
Aristotle University of Thessaloniki,  
Greece

### REVIEWED BY

Chantelle Doyle,  
University of New South Wales, Australia  
Amelie Robert,  
University of Picardie Jules Verne, France

### \*CORRESPONDENCE

Ondrej Gomola,  
✉ academia@ondrejg.com

RECEIVED 23 February 2026

REVISED 22 April 2026

ACCEPTED 29 April 2026

PUBLISHED 25 May 2026

### CITATION

Gomola O and Hughes KA (2026) Grass is not always greener: enablers and barriers of non-native species governance and management in Antarctica.  
*Front. Environ. Sci.* 14:1816091.  
doi: 10.3389/fenvs.2026.1816091

### COPYRIGHT

© 2026 Gomola and Hughes. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](#). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

# Grass is not always greener: enablers and barriers of non-native species governance and management in Antarctica

Ondrej Gomola<sup>1\*</sup> and Kevin A. Hughes<sup>2</sup>

<sup>1</sup>International Institute for Industrial Environmental Economics, Lund University, Lund, Sweden, <sup>2</sup>British Antarctic Survey, Natural Environment Research Council, Cambridge, United Kingdom

Increasing human activity and climate change in Antarctica may increase the rates of non-native species introduction and establishment, resulting in potentially irreversible changes in marine and terrestrial ecological communities. The Protocol on Environmental Protection to the Antarctic Treaty prohibits the introduction of non-native species without a permit and mandates their removal if introduced. Despite this, management action to address non-native species introductions may be slow, in part due to the complexities of multi-Party governance. Here we examined the enablers and barriers of non-native species management in Antarctica, focusing on introduced plants. Using data gathered from fifteen semi-structured expert interviews and reflexive thematic analysis, we identified three broad categories of enablers and barriers. Enablers included use of established multi-level governance frameworks, the activities of dedicated and skilled individuals underpinning them and the implementation of appropriate environmental management measures. Barriers included the substantial differences in countries' levels of engagement with the non-native species issue, constraints in countries' management experience and capacity and shortcomings in policy communication and implementation both between and within stakeholders. We identified a gap in the reporting of non-native species management efforts alongside inconsistent management responses. This gap creates opportunities to strengthen information sharing and expertise. In an increasingly politicised Antarctic Treaty system, management of non-native species may present a largely uncontested issue around which common ground may be found and expanded.

### KEYWORDS

alien, Antarctic Treaty system, control, decision-making, eradication, invasive

## 1 Introduction

### 1.1 Non-native species in the Antarctic Treaty area

Antarctica is one of the last areas of relatively untouched wilderness on the planet (Leihy et al., 2020). Nevertheless, expanding human activities including scientific research and logistics, fishing and tourism result in a commensurate increase in pressure on fragile marine and terrestrial ecosystems (Tin et al., 2009; Grant et al., 2021). One impact of human activities on Antarctic environments is the inadvertent introduction of non-native species which can threaten the intrinsic values of native ecosystems (Hughes et al., 2020) as well as their scientific value (Sindel et al., 2018).

Here we define non-native species as organisms that are intentionally or inadvertently introduced through human activities to new locations outside their natural distribution or dispersal ranges, while invasive species are non-native species that subsequently expand their populations and distribution ranges with negative impacts upon native communities (Pyšek et al., 2020). Among other effects, non-native species can decrease the abundance of native species and potentially lead to their extinction (Convey and Peck, 2019). Recently, Hughes et al. (2025) collated 240 introduction events at locations within the Antarctic Treaty area encompassing 112 different species. The majority of these species were either removed or died out naturally, leaving 20 known established non-native species within the Treaty area today. All but one of those 20 species are invertebrates, and all are located in the Antarctic Peninsula, South Orkney Islands or South Shetland Islands.

No attempts have been made to control or eradicate invertebrates that have established in the Antarctic environment largely due to a lack of suitable control methods (Hughes et al., 2025). In contrast, many non-native plants have been successfully eradicated (see Table 1), made possible due to (a) the availability of simple mechanical control methods such as hand pulling, (b) the small number (<5) of plants necessitating removal at a given location and/or (c) the limited area that has been colonised (<1 m<sup>2</sup>). Nevertheless, with a small number of notable exceptions, non-native plants introduced to the Antarctic Treaty area have generally been managed largely in an “opportunistic or *ad hoc* manner” (Hughes et al., 2015, p. 1045). Accentuated by climate change, warmer and wetter conditions may increase the likelihood of future non-native species establishment, making the further development of effective management practices a priority that is readily achievable (Chown et al., 2022; Lee et al., 2022a; 2022b).

## 1.2 The Antarctic Treaty system

The Antarctic Treaty (henceforth “Treaty”) was signed in 1959 and entered into force in 1961. It sets out the governance of matters within the Antarctic Treaty area (the area south of 60°S latitude) and established that Antarctica is to be used for exclusively peaceful endeavours (Dupuy and Viñuales, 2018; Hughes et al., 2023). The Treaty currently has 58 Parties of which 29, known as Consultative Parties, have the right to participate in governance through consensus-based decision-making at the annual Antarctic Treaty Consultative Meeting, known as the ATCM (Antarctic Treaty Secretariat, 2025a).

The Protocol on Environmental Protection to the Antarctic Treaty (henceforth “Protocol”) was adopted in 1991, entered into force in 1998 and designates Antarctica as a “natural reserve, devoted to peace and science” (Protocol, Art. 2). The Protocol serves as the primary legal instrument for environmental management in the Antarctic region and established the Committee for Environmental Protection (CEP), which serves as an advisory body to the ATCM on Protocol implementation and all environmental matters. Annex II to the Protocol on the Conservation of Fauna and Flora prohibits the introduction of non-native species except under permit and mandates their removal unless doing so would cause greater environmental harm (Annex II, Article 4). However, gaps in the Protocol

remain, such as the lack of explicit provisions for the transfer of native species across Antarctica’s different biogeographical regions (Terauds et al., 2012; Hughes and Convey, 2014; Hughes et al., 2019; 2020). Furthermore, the Protocol does not define what ‘greater environmental harm’ could entail with regard to the management and eradication of non-native species (Hughes and Convey, 2014).

The eradication of existing non-native species and prevention of new introductions represent critical challenges for preserving the continent’s ecological value and ensuring compliance with international law. The CEP has accorded the topic of non-native species a high priority in its Climate Change Response Work Programme and Five-year Work Plan (Antarctic Treaty Secretariat, 2025b). Specifically, the Committee has provided information on the management of non-native species under a Prevention, Monitoring, Response framework, through its *Non-native Species Manual* (see, e.g., Antarctic Treaty Secretariat, 2019). Nevertheless, repeated incursions of non-native species into the Antarctic Treaty area continue to take place, with calls from scholars for improved planning, monitoring, response, information dissemination, coordination and management practices (Hughes et al., 2015; McGeoch et al., 2015).

## 1.3 Antarctic governance in practice

Antarctic governance is both complex, multi-level and spans traditional organisational and national boundaries that intersect “the epistemic boundaries of [the] science and policy worlds” (Gardiner et al., 2024b, p. 15). This decentralised governance structure poses significant challenges to the effective management of non-native species, particularly as responsibilities are often dispersed between actors or ambiguously delineated. The unique confluence of legislative, ecological, geopolitical and scientific arenas brings a complex set of challenges, the understanding of which is key for the future effective governance and management of the Antarctic environment. Antarctic governance is also characterised by enduring multilateralism, longstanding (although potentially weakening) international collaboration across geopolitical divides and the involvement of non-state actors in the policymaking process (Loukacheva, 2013; Dodds, 2017).

At the same time, Antarctic environmental governance is under pressure from external and internal forces. Although environmental challenges affecting the continent are growing (see, e.g., Kubiszewski et al., 2024; Roland et al., 2024), scholars consistently argue that Antarctic environmental policy- and decision-making lag behind the speed and scale at which these challenges are unfolding (O’Reilly, 2021; Mancilla and Jabour, 2023; Liggett et al., 2024). With no new legal instruments established within the Treaty System for more than 3 decades (Hemmings, 2009), the environmental challenges facing the continent leave little room for idling (Mancilla and Jabour, 2023; Liggett et al., 2024).

The reasons behind the Treaty system’s lethargic policymaking could include the consensus-based decision-making acting as a roadblock against progress (Yermakova, 2021), leaving conservation efforts hostage to geopolitics (Reform, 2018; Harvey, 2020; Liverpool, 2023; Mancilla and Jabour, 2023). The Treaty System is also not immune to global challenges such as the COVID-19 pandemic and the war in Ukraine which may stymie policymaking efforts further (Liggett et al., 2024; Frame and

TABLE 1 Examples of well-documented plant eradication efforts within the Antarctic Treaty area. Data obtained from the Scientific Committee on Antarctic Research (SCAR) database 'Non-native species introduced to Antarctica' (available at: <https://saer-non-nativespecies.data.bas.ac.uk/?p=369:1:12959644233589>).

Species	Location(s)	Unilateral or multi-Party response	Notes	References	
1	<i>Poa annua</i>	Gabriel gonzález videla station, paradise bay, northern antarctic peninsula	Unilateral (Chile)	One plant was recorded in 2007/08 and four plants in 2009/2010. All were removed in early 2010. Two new <i>P. annua</i> individuals were recorded in 2013/14 and removed	<a href="#">Molina-Montenegro et al. (2012)</a> , <a href="#">Molina-Montenegro et al. (2015)</a>
2	<i>Poa annua</i>	Almirante Brown station, paradise bay, northern antarctic peninsula	Unilateral (Chile)	Two plants were reported in 2009/10 and removed	<a href="#">Molina-Montenegro et al. (2012)</a>
3	<i>Poa annua</i>	General bernardo O'Higgins station, trinity peninsula, northern antarctic peninsula	Unilateral (Chile)	A single plant was reported in 2007/08 and two plants in 2009/10. All were removed in early 2010	<a href="#">Molina-Montenegro et al. (2012)</a>
4	<i>Poa annua</i>	Hillier moss, gourlay peninsula, signy island, south orkney islands	Multilateral (Italy and the United Kingdom)	A single clump, composed of two individual plants, was observed on 5 March 2018, and removed on 12 March 2018	<a href="#">Malfasi et al. (2020)</a>
5	<i>Poa flabellata</i>	Waterpipe hut, three lakes valley, signy island, south orkney islands	Multilateral (Italy and the United Kingdom)	A single clump of the tussock grass <i>Poa flabellate</i> was reported at the end of December 2025 and removed in January 2026	<a href="#">Hughes (2026)</a>
6	<i>Poa pratensis</i>	Primavera station, cierva point, palmer archipelago, antarctic peninsula	Multilateral (Argentina, Spain and the United Kingdom)	Introduced in association with a transplantation experiment in 1954/55. Between 1991 and 2012, the plant colony expanded in size from 0.18 to 0.53 m <sup>2</sup> , before being removed in January 2015	<a href="#">Corte (1961)</a> ; <a href="#">Smith (1996)</a> ; <a href="#">Pertierra et al. (2013)</a> , <a href="#">Pertierra et al. (2017)</a>
7	<i>Puccinellia</i> sp	Refuge, 25 km from syowa station, enderby land, east Antarctica	Unilateral (Japan)	Discovered 1995/96 and identified originally as <i>Poa trivialis</i> . Removed in 2007 and reidentified as <i>Puccinellia</i> sp	<a href="#">Japan (1996)</a> ; <a href="#">Tsujiimoto et al. (2010)</a>
8	<i>Poa annua</i>	Admiralty bay, king george island, south shetland islands	Unilateral (Poland)	Introduced to arctowski station in 1984/85. In 2008/09 distribution expanded into antarctic specially protected area no. 128 western shore of admiralty bay. Eradication efforts commenced in 2014/15 and are ongoing	<a href="#">Olech (2003)</a> ; <a href="#">Olech and Chwedorzewska (2011)</a> ; <a href="#">Galera et al. (2017)</a> , <a href="#">Galera et al. (2019)</a> , <a href="#">Galera et al. (2021)</a>
9	<i>Nassauvia magellanica</i>	Whalers bay, deception island	Multilateral (United Kingdom, with logistical support from Spain)	The plant was reported in early 2009 and eradicated early in 2010. Doubt remains over whether the plant was introduced via natural or anthropogenic means	<a href="#">Lewis Smith et al. (2011)</a> ; <a href="#">Hughes and Convey (2012)</a>
10	Unidentified grasses	Fildes peninsula, king george island, south shetland islands	Unilateral (Germany)	The unidentified grasses were eradicated from the vicinity of the Chinese and Russian stations on the 10 February 2006	<a href="#">Peter et al. (2008)</a>

Hemmings, 2020; Fedchuk et al., 2022; Liverpool, 2023; Hughes and Convey, 2020).

The management of non-native species is situated firmly within this multifaceted and challenging governance context. Fundamentally, non-native species management and governance take place through established multi-level governance structures, with decisions made across different actors rather than a centralised decision-making body. Given the challenges that the management of non-native species presents for the CEP, Treaty Parties, researchers and environmental managers, here we investigated the barriers and enablers of non-native species management in Antarctica, focussing on non-native plants through expert interviews. Doing so will enable the identification of areas of further international collaboration and provide fertile ground for further environmental protection initiatives to be developed.

## 2 Materials and methods

This study investigated the management and governance of non-native species, with a particular focus on plants, within the Antarctic Treaty system. Plants were selected as the focal group of study because numerous documented cases of successful eradication exist (see Table 1), making them especially valuable for deriving lessons to inform future environmental management efforts.

As part of the research, fifteen semi-structured expert interviews with seventeen interviewees (one interview included three participants) were conducted during February and March 2025. The interview guides (provided as [Supplementary Material](#)) were developed based on the results of the literature review, placing particular emphasis on the interlinkages within the Antarctic multi-level governance regime. Twelve interviews were held online and three were held in person. All interviews were conducted in accordance with the data handling guidelines of the British Antarctic Survey and all participants provided informed consent to participate in the research. Interviewees were chosen using the well-established purposeful sampling method (Creswell and Creswell, 2017; Flick, 2022), and all experts selected based on their knowledge of and direct engagement with the subject matter. Emphasis was placed on inviting interviewees from diverse professional backgrounds to this study, ensuring that the final interviewee pool represented a cross-section of Antarctic

stakeholder views. For example, an interviewee could have been selected because of their experience in Antarctic policymaking (e.g., by being a CEP delegate) or ecology (e.g., by having conducted on-the-ground research). The interviewees were first chosen from the networks of the study authors. Following the initial interviews, further participants were recruited through snowball sampling (Parker et al., 2019; Flick, 2022). Subsequently, a second round of interviewee invitations was sent out to expand the diversity of the interviewee pool. The number of active practitioners in the studied field is limited. Therefore, to preserve interviewees' anonymity, specific national and institutional affiliations are not disclosed in this text.

While many interviewees had experience across several branches of Antarctic environmental management and governance, here they are categorised according to their primary field of expertise. Nine interviewees had backgrounds primarily in policymaking (P1 to P9), while four were involved mainly with scientific research (S1 to S4). Two interviewees were affiliated with non-governmental actors working with Antarctic topics (N1 and N2), while a further two interviewees had direct experience of non-native plant eradications in a sub-Antarctic context (EP1 and EP2). Throughout this article, pseudonyms enclosed in parentheses are used to refer to interview participants, visualised in Figure 1. Interviews were recorded and subsequently transcribed using the GoodTape platform. This resulted in the generation of an imperfect verbatim transcript that necessitated thorough manual validation (Flick, 2022). Through member checking (Creswell and Creswell, 2017), every interviewee was sent their interview transcript and was invited to verify the quality of the data.

The study employed a reflexive thematic analysis approach (see Braun and Clarke, 2006; 2022), with the interview data being initially coded inductively. Subsequently, descriptive deductive codes were generated from the data following the progression of the research process and the development of a conceptual framework. This resulted in a bottom-up approach where codes emerged directly from the data and a top-down approach where the data were seen through an interpretive lens. The coding process itself was conducted using Quirkos, resulting in 328 inductive codes. These were subsequently transferred to Atlas.ti for refinement and to create, sort and categorise 66 final code groups. These code groups were compiled and exported into Excel to form six overarching categories (or what Braun and Clarke (2022), p. 99) call "central

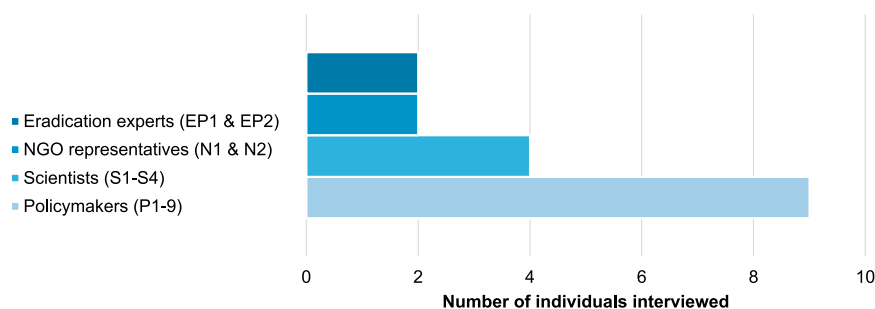
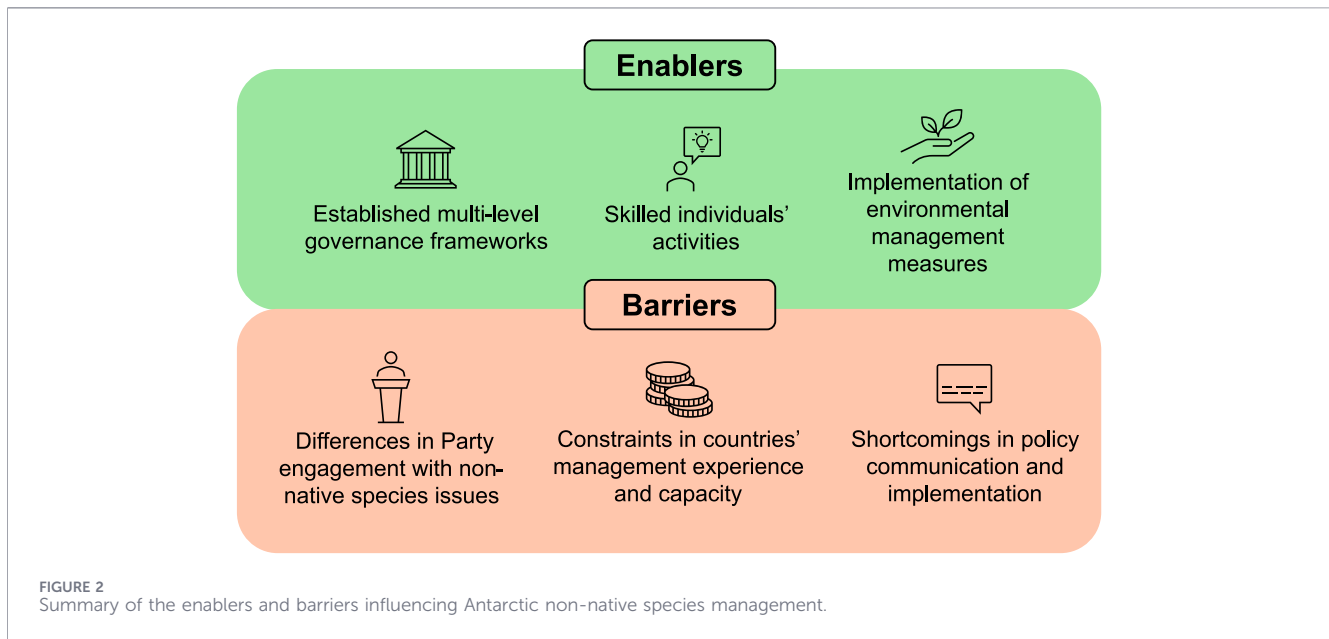


FIGURE 1  
Number of individuals interviewed in this study according to their field of expertise.



organising concepts”. The categories consisted of three barriers and three enablers to Antarctic non-native species management (see [Figure 2](#)).

Beyond the inherent limitations of qualitative research, such as the subjectivity of coding ([Creswell and Creswell, 2017](#)), this study has several methodological constraints. The interviewee pool consists of seventeen participants with interviewees primarily being recruited through the professional networks of the study authors, resulting in participants based in Europe and Oceania being overrepresented in the interviewee pool. The subsequent use of snowball sampling may have further reinforced the effects of this overrepresentation through the reliance on existing professional networks ([Parker et al., 2019](#)). Nonetheless, this study's approach is considered practical for identifying key informants in specialised fields with limited expert populations ([Flick, 2022](#)).

## 3 Results

### 3.1 Enablers of non-native species management

#### 3.1.1 Established multi-level governance frameworks

All the interviewees recognised the importance of Antarctic governance regimes in facilitating non-native species management. Within the Antarctic Treaty system, relevant policymaking was highlighted as being clearly driven by the CEP and ATCM. The interviewees noted the International Polar Year (2007/08) ‘Aliens in Antarctica’ project as being particularly beneficial for non-native species research and subsequent policymaking (see [Chown et al., 2012](#); [Hughes et al., 2010; 2011](#); [Huiskes et al., 2014](#)). While many interviewees conceded that the Antarctic governance regime may be slow, a subset of interviewees believed it to be well adapted to its

function, with S3 summarising the situation by suggesting that the Antarctic Treaty system “is not responsive enough but then if you look at the rest of the world and [...] there's not even a discussion about alien species in most countries at all”. Views were therefore divided regarding whether the governance regime itself needs reform to deliver improvements in non-native species management.

Interviewees noted that the multi-level governance framework of the Antarctic Treaty system, international cooperation and inter-institutional dialogue further facilitated non-native species management, with information sharing and inter- and intra-National Antarctic Programme (NAP) communication playing a crucial role. Four interviewees mentioned the indispensability of the Scientific Committee on Antarctic Research (SCAR) in the facilitation of Antarctic science, while several others referred to multi-level linkages between the policymaking fora of the Antarctic Treaty system and other affiliated organisations, including the Council of Managers of National Antarctic Programs (COMNAP), the International Association of Antarctica Tour Operators (IAATO) and SCAR. While these organisations play important roles in contemporary non-native species management, one interviewee also stressed the historical impact on non-native species management of external organisations. The International Union for Conservation of Nature (IUCN), for instance, “originally put in a paper on non-native species [to the ATCM] and [...] brought the attention to the issue” (P3); see [Clout and De Poorter \(2008\)](#), p. 34) for a comprehensive list of IUCN contributions on this topic.

Some interviewees noted that while Antarctica's governance is implemented through a plethora of stakeholders, the established policy framework remains flexible and provides sufficient room for Parties' individual actions. Furthermore, the ATS is underpinned by a “gentleman's agreement” whereby Parties can follow regulations to the letter or, conversely, act unilaterally with few consequences (S3). For example, P1 said “I think the system [...] is flexible enough to change [the] course of the discussions, if necessary, to ensure quicker decisions because of something is more immediate [sic]”.

Four interviewees highlighted the flexibility of Antarctic governance to respond to novel challenges, not least non-native species incursions but also recent threats of H5N1 avian influenza within the Treaty area (Banyard et al., 2024; Wille et al., 2025). However, stakeholders' value systems that underpin non-native species management efforts and environmental decision-making evolve over time and policy frameworks must be able to adapt accordingly. With this in mind, P9 cites the example of non-native plant transplantation experiments taking place on Antarctic soil before the coming into force of the Protocol (see, e.g., Edwards, 1980; Joshi and Banerjee, 1988; Smith, 1996) as a stark contrast to contemporary conservation approaches.

In the context of non-native plant management, unilateralism appears to function as an enabler rather than a barrier. Five interviewees considered unilateralism to be a positive feature of the Antarctic Treaty system regarding the management of non-native species, while four interviewees see unilateralism as being a necessary and even expected feature of the Treaty system, particularly if Parties are to aim for going beyond compliance. P4 summarises the sentiment when they said, "I doubt that any Parties would be concerned if another Party had taken [non-native plant removal] action without consultation". This was stated in light of the widely held understanding amongst interviewees that to limit a novel non-native plant incursion's spread, implementing management measures quickly increases their effectiveness.

### 3.1.2 Individuals' human capital

The interview data highlighted the role of individuals, their skills and knowledge in empowering non-native species management in Antarctica. Moreover, five interviewees suggested that the most power in managing non-native species lies in the hands of individuals. Specifically, over 80% of interviewees underscored the importance of skills in the management of non-native species, with multidisciplinary staff being indispensable to the navigation of the complex Antarctic multi-level governance landscape. This includes the diverse institutional frameworks, scientific domains and policy processes that characterise the environmental management of the region.

### 3.1.3 Implementation of environmental management measures

The practical management of non-native plant incursions in Antarctica can be an inherently complex enterprise. Many interviewees reported that biosecurity (i.e., the prevention of non-native species introductions) was a crucial component of any non-native plant management strategy, with some strongly emphasising the centrality of biosecurity within their own NAP's operational priorities. Three interviewees emphasised the importance of adequate staff training to deliver effective biosecurity measures and increase awareness about the hazards of non-native species. Environmental monitoring, rapid responses and the use of environmental permits and impact assessments were also considered essential enablers. Some interviewees suggested that ideally, these should be directly incorporated into the multiple layers of NAPs' operations (P6) and should involve stakeholders across the Antarctic multi-level governance regime (P4).

P1 suggested that non-native species management was enhanced when there was "a very short line between who sits in the governance structures and those who are on the ground". Most interviewees described prevention, monitoring, response and permitting as separate aspects of non-native species management, whereas one interviewee (P7) emphasised that their NAP's environmental management plan treats these elements as interconnected components of a comprehensive biosecurity strategy. In short, there was a discrepancy between whether interviewees viewed non-native species management as a series of standalone policies or as an integrated framework. This reflected a broader lack of clarity about how different Parties implement non-native species management measures.

## 3.2 Barriers to non-native species management

### 3.2.1 Differences in Party engagement with non-native species issues

Most interviewees suggested that non-native species, and plants in particular, will likely become more problematic and present an increased risk to the Antarctic environment in the future, with almost two-thirds specifically citing climate change as an aggravating factor in their spread. However, a sub-set considered non-native plant incursions to be a relatively minor environmental concern and a largely politically uncontentious topic. Several interviewees reported that Parties' efforts in the management of non-native species vary widely with some individual Parties not dedicating sufficient resources towards the management of the issue. According to P8, Parties can be categorised into three broad groups: first, "certain countries have identified that [non-native species are] a problem that has to be faced", second those that "are not aware" of the issue and third, there is a group of countries that are "probably not that worried about the problem". The interview data highlighted several possible reasons for Parties' differing levels of engagement: (a) differences in socioeconomic factors that play a key role in shaping Parties' non-native species management programmes; (b) ecosystem diversity in the areas surrounding Parties' research stations (for example, non-native species establishment may be considered less of an issue in areas of permanent ice or more climatically extreme locations); (c) Parties' domestic experience of managing non-native species outside of the Antarctic context; (d) the relative importance of Antarctic affairs in domestic political priorities; and (e) linguistic and cultural barriers affecting the dissemination of relevant scientific and policy information. Several interviewees highlighted that these challenges are further exacerbated by substantial differences in the sizes of NAPs and their respective operational capacities and structures. The effective management of non-native species may face additional barriers that may include lukewarm support from home government hierarchies or implementation barriers stemming from domestic legal frameworks.

Interviewees noted that adequate non-native species management efforts can be stymied further by the fact that some Parties engage in what could be described as 'performative environmental governance' (the "theatrical deployment of language, symbols, and gestures to foster an impression of good

governance” (Ding, 2020, p. 525)). Furthermore, some Parties’ employ ‘visibility-driven’ decision-making where they prioritise actions that are highly visible to other stakeholders at the expense of essential but seemingly mundane environmental management tasks. Some interviewees, on the other hand, believed that the international pressures faced by individual Parties through the Antarctic Treaty system can serve a positive purpose vis-à-vis non-native species management. From a Party’s perspective, S3 said that “[...] you are concerned [about non-native species] because you want to protect the system, but you also may be concerned because it may look bad on you [sic] and also it may cost you”.

Geopolitics and a broader politicisation of ATCMs provides a further barrier to non-native species management. Recognising that the Antarctic Treaty system is a political brainchild and that ATCMs are exercises in global politics, S3 said “there’s going to be people who oppose to something just because it’s a political manoeuvre [...] some governments are going to support [non-native species management] just because some other governments are against it”. While the burden of geopolitics may be substantial, P3 said: “I think a lot of the tensions now are fairly major geopolitical ones that are not easy to change within the context of the Treaty system [...] trying to find common scientific ground is one way of addressing that”. Non-native species management may therefore be one way of finding common ground upon which to build broader consensus.

### 3.2.2 Constraints in countries’ management experience and capacity

Interviewees emphasised that skilled staff are indispensable to non-native species management. However, they also highlighted the limited pool of individuals with expertise in non-native species research, management and identification as a significant shortcoming of broader management efforts. S1 observed that non-native species identification is both a labour-intensive and skill-dependent endeavour and incursions may not be identified because of a dearth of individuals with the necessary skills available to do so. While multidisciplinary is often praised as a strength of NAP personnel, it can be a double-edged sword, as staff may have broad responsibilities and may not necessarily prioritise non-native species management (P9). Knowledge gaps relevant to non-native species, highlighted by interviewees, included: (a) gaps in understanding of species’ characteristics and life histories and therefore the most effective management methods; (b) the challenges of differentiating between invasive and non-invasive non-native species; (c) understanding of whether a non-native species has colonised Antarctica naturally or was a human-mediated introduction; and (d) the ecotoxicology of different herbicides in polar environments, should their use be deemed legitimate.

One of the primary factors driving differences in non-native species management across Parties may be the uneven distribution of relevant skills among and within NAPs of different sizes and operational capacities. Smaller NAPs may be more vulnerable to biosecurity incidents simply because their smaller operational scale results in a “different capacity to implement actions to diminish the risk of a mistake” (P8). N2 also highlighted that some countries

“have very large programmes, and they have all sorts of people, all sorts of researchers working there, but other countries have much more modest programmes”, thus limiting the number of researchers and skilled staff available.

### 3.2.3 Shortcomings in policy communication and implementation

Many interviewees suggested that shortcomings exist in communication between stakeholders within the Antarctic governance regime, with five interviewees noting an inadequate level of communication or collaboration between NAPs. P4 said: “[...] there is a lack of understanding in practice about what Parties are doing and how effective that is”, and N2 said “I wonder about the actual surveillance and monitoring, whether that actually occurs”. One interviewee (P7) suggested that communication deficiencies may exist due to the increasing use of non-binding Resolutions, rather than binding Measures, the latter of which should be implemented through domestic legislation and includes a requirement to notify Parties how they have been implemented. Rather “Resolutions have no kind of feedback mechanism, so it’s difficult to know how and to what extent each of those Parties are implementing those Resolutions [...]” (P7). As a further issue, communication between policymakers and SCAR was highlighted as often suboptimal. P3 stated that “sometimes, the CEP makes requests for SCAR to do something that I think are not very well framed sometimes or they’re so big that it’s quite difficult for SCAR to actually respond”.

Over half of interviewees highlighted the wide gap between some Parties’ engagement in policymaking discussions and their implementation of policies on the ground. P2 suggested that “[...] there are Parties that do not do their due diligence in [...] implementing biosecurity or undertaking basic checks around their station” while P4 said that “there is not really a baseline understanding of the current practices of [...] how those guidelines or other practices are implemented across the suite of national programs”. In other words, even if a Party fully implements an agreed policy, it remains challenging to understand how this was achieved due to a lack of communication and oversight. Some interviewees suggested that a fully-fledged compliance mechanism would assist with addressing this issue and that a lack thereof was mentioned repeatedly as a shortcoming of the current governance system. Interviewees observed that while an inspection mechanism exists in the Antarctic Treaty system, “those inspections are usually quite polite [...] it’s very unusual that they make pretty strong, blunt statements about what they see in their inspections” which then get “glossed over” in the Treaty system’s policymaking fora (N2).

Non-native species management “relies on people actually having the resources to do the work, which is not always possible” (P3). Ten interviewees raised the issue of adequate funding of non-native species management endeavours, with decision-making about environmental management resources allocation undertaken against a backdrop of other competing scientific and operational needs. P7 noted that “[...] how much [sic] resources a [NAP] has, for example, might dictate how much time, money and effort they can spend developing a strong biosecurity program”.

## 4 Discussion

This study used expert interviews to shed light on the enablers and barriers to the delivery of effective governance and practical management of non-natives species in Antarctica, with a focus on non-native plants.

Interviewees were largely positive regarding the usefulness of existing governance structures in providing a mechanism for engaging in non-native species issues, including information sharing and discussion of collaborative activities by Parties and Observer organisations such as SCAR, COMNAP and IAATO. In contrast to many other issues of concern regarding Antarctic environment protection, the CEP has been comparatively active when discussing non-native species and wildlife disease, with over 162 CEP papers submitted by Parties and Observers under the topic ‘Non-native species and quarantine’ since 1998 (see: <https://www.ats.aq/devAS/Meetings/DocDatabase?lang=e>).

However, progress in policy development has still been considered slow and the academic literature has repeatedly cautioned that the Antarctic Treaty system risks becoming, or may already be, a laggard in policymaking in relation to modern environmental protection standards, employing a reactive rather than proactive stance (Hemmings, 2009; Chown et al., 2017; Leihy et al., 2020; Ferrada, 2023). Furthermore, Leihy et al. (2025) noted that Antarctic non-native species introduction rates have not increased as rapidly as visitor numbers over the past c. 30 years, suggesting some success in existing biosecurity measures. However, their models indicate that the number of introductions continues to rise, underscoring the need for stricter biosecurity enforcement as socio-environmental change accelerates. Despite this, in recent decades, the ATCM has dealt with Antarctic issues increasingly through non-binding agreements (Ferrada, 2023), which “diminishes accountability and transparency, significantly reducing the parties’ abilities to understand and measure their performance, including the outcomes and impacts of decisions” (Gardiner et al., 2024a, p. 1). Additionally, no new binding legal instruments have been established in the Antarctic Treaty system, including on non-native species, since the Protocol was adopted in 1991, despite increasing environmental challenges (O’Reilly, 2013; Lee et al., 2017; Stuecker et al., 2018; Kubiszewski et al., 2024; Roland et al., 2024). In part, this may be due to the realities of using consensus-based decision-making (Ferrada, 2023; Tanaka, 2023). According to Tamm (2018), p. 336, “consensus is both the glue that holds the Antarctic Treaty and Protocol together and the force that waters down the content of hard law”. Timely decisions are particularly difficult in situations that involve diverging viewpoints and national interests (Madani and Shibata, 2023) and, even when adopted, ratification of binding agreements can take years or even decades (Gardiner et al., 2024a). Still, some scholars see this inertia as a sign of the Treaty system’s ingrained flexibility allowing Parties to continue collaboration without legislative innovation (Ferrada, 2023).

Despite a lack of novel binding agreements, the use of non-binding legal instruments may provide Parties with flexibility and enable rapid unilateral action, as has been demonstrated by single-Party eradications of several non-native species (see Table 1; Hughes et al., 2005; Bergstrom et al., 2018) and the recent response by many Parties to H5N1 avian influenza where swift action was needed to reduce the risk of human-mediated transmission of the virus (Banyard et al., 2024; CCAMLR and SCAR, 2025). Hughes et al.

(2015) suggested that the ability to act unilaterally enables a rapid response to a non-native species introduction and is advocated by the CEP’s *Non-native species manual* (Antarctic Treaty Secretariat, 2019). However, the universal application of this rapid approach has been questioned (Caplat et al., 2012).

Few cases of past collaborative responses to non-native species introductions exist, but the prime example is the eradication of *Poa pratensis* at Cierva Point on the Antarctic Peninsula (Pertierra et al., 2013; 2017). Pertierra et al. (2017), p. 54) noted that the “3–4 years management process for *Poa pratensis*, after decades of disregarded persistence, may be incompatible with effective management/eradication/monitoring of species which are more invasive and which may disperse more rapidly”. Despite the delay, the eradication was successful. It is not always possible to eradicate non-native plant incursions in Antarctica, however, with the example of *Poa annua* at Arctowski Research Station on King George Island. First observed in 1984/85, eradication efforts are still ongoing because of a delayed response (see Galera et al., 2017; 2019; 2021). Given the potentially much more rapid rate at which established non-native invertebrates may disperse in Antarctica, a delayed response is likely to have even more serious negative consequences for management action and control (Hughes and Pertierra, 2016; León et al., 2021). Taking this into consideration, a unilateral approach is not only permissible within the bounds of the Antarctic Treaty system’s existing framework but may be an expected course of action.

Given there is virtual unanimity among Parties that non-native species are a threat to Antarctic ecosystems (the *Non-native Species Manual* was adopted by consensus), then prevention, monitoring and response efforts should be proceeding smoothly. However, Parties’ engagement on this and many other environmental topics varies significantly. Some Parties (possibly a minority) take their non-native species commitments under the Protocol seriously and are proactive and effective across their governance, research and environmental management responsibilities. Nevertheless, interviewees suggested that while some Parties are openly supportive of environmental policies’ adoption, they pay little heed to their implementation, even extending to the open flouting of agreed rules (such as by the cultivation of decorative plants on Antarctic research stations; see Figure 1F in Hughes et al., 2015). The obtrusive presence of (geo)politics within the Antarctic Treaty system presents further challenges, such as performative environmental governance.

While it has been suggested by some interviewees that certain Treaty Parties are not engaging in adequate management of non-native species, it remains a relatively uncontroversial issue. Nonetheless, efforts to manage Antarctic non-native species and the Antarctic environment more generally suffer from a misalignment of incentives, a diagnosis commonly attributed to environmental public goods (Keohane, 2015). Taken broadly, almost everyone benefits from stringent environmental management in Antarctica as it helps maintain its ecosystem services (Pertierra et al., 2021) and ensures the continent remains a ‘natural reserve, devoted to peace and science’ (see Protocol, Art. 2). However, like with other environmental public goods, Parties benefit from Antarctic environmental management regardless of whether they contribute to it, thus incentivising free riding. In the context of non-native species management, this potentially explains some of the disparity in involvement among Parties, despite seemingly unanimous agreement on the topic’s urgency and importance.

Interviewees highlighted that skilled individuals, including policymakers, researchers and environmental managers, are necessary to deliver effective policy development and practical management of non-native species. In particular, interviewees mentioned the critical role of a handful of individuals that spearhead initiatives and operate as “boundary spanners” (Gardiner et al., 2024b, p. 1). These skilled individuals bridge the gaps between multi-level governance structures, scientific research, policy development and on-the-ground non-native species management. However, interviewees noted that it may be difficult for individuals working for less-resourced NAPs to develop such skills, resulting in knowledge gaps in non-native species’ taxonomies, eradication and management methodologies. It may also increase the risk of biosecurity breaches and inadequate non-native species monitoring. Capacity constraints as crucial determinants of Parties’ engagement is not a characteristic unique to non-native species management, with Gardiner et al. (2024b) noting similar shortcomings for Antarctic knowledge exchange. The dependence on a small pool of boundary spanning experts capable of fulfilling these integrative roles raises concerns about the Treaty system’s long-term sustainability, knowledge continuity and resilience regarding non-native species and Antarctic environmental protection more generally.

Bastmeijer (2018) observed that the Antarctic Treaty system’s compliance mechanisms leave much to be desired, which has substantial implications for non-native species management and delivery of effective biosecurity measures. In other settings, compliance mechanisms employ both “carrots and sticks”, but in the Antarctic Treaty system, compliance mechanisms are mainly constructed of what Tamm (2018), p. 336 calls “carrots and a spirit of cooperation”. Under the Antarctic Treaty, Parties are entitled to inspect each other’s Antarctic infrastructure for regulatory compliance, with environmental inadequacies occasionally identified (Braun et al., 2017). However, the Treaty is generally unclear on any remedial mechanisms or sanctions on non-compliant Parties (Joyner, 1997). As identified by the interviewees, NAPs face financial, governance-related and operational constraints (Nyåstad and Sánchez, 2014; O’Neill, 2017), and when faced with competing demands on resources, they simply lack the capacity to develop extensive biosecurity and non-native species management programmes beyond the (sometimes rudimentary) measures they currently put in place. Studies have consistently noted a persistent discord between the rhetorical commitments and concrete actions of Parties, clearly demonstrating a lack of urgency necessary to adequately respond to environmental challenges (Mancilla and Jabour, 2023; Liggett et al., 2024).

In sum, then, Antarctica represents one of the last remaining near-pristine natural areas on Earth. However, its fragile ecosystems are increasingly threatened by a combination of pressures including climate change and anthropogenic activity, both which increase the risk of non-native species incursions and their subsequent potential deleterious environmental impacts. To prevent such incursions and to handle those already taking place, governance and management structures have been devised and implemented by many stakeholders at multiple levels across the multi-level governance regime. Nevertheless, interviewees reported that fickle engagement, (geo)politics, capacity constraints and inconsistent communication

have limited the effectiveness of non-native species management. These barriers are counterbalanced in some cases by robust governance structures navigated by skilled boundary spanning individuals and well-developed environmental management practices. The insights obtained from analysing the governance and management of non-native species issues may, in some cases, reflect strengths and shortcomings relevant to the broader Antarctic Treaty system.

Given its seemingly low level of contention compared to other issues within the Antarctic Treaty system, our study has found that non-native species management can be seen as an area of cross-Party ‘common scientific ground’. It could therefore serve as a constructive area for building consensus between Parties amid current and future (geo)political tensions. Its relatively technical nature and shared environmental goals make it a promising avenue for collaboration among Parties even in the face of broader political or institutional disagreements. This is becoming increasingly necessary given contemporary pressures on Antarctic ecosystems are expected to worsen in the coming decades. With these factors in mind, the following actions are recommended:

- Continued the development of information and guidelines (including the CEP *Non-native Species Manual*) within the bodies of the Antarctic Treaty system to inform non-native species management actions by Parties acting individually and in collaboration.
- Establish skill- and knowledge-sharing initiatives such as cross-Party trainings, seminars and workshops to help level the playing field and reduce capacity-dependent environmental management gaps between NAPs
- Develop greater communication and transparency regarding non-native species management practices between NAPs, including the further sharing of practical experience of biosecurity, monitoring and response to incursions.
- Prioritise funding by (a) national Antarctic programmes to provide effective non-native species management and (b) research funding bodies to deliver relevant and necessary scientific knowledge and expertise.

## Data availability statement

The interview guide used in this study is available in the [Supplementary Material](#).

## Ethics statement

All interviews were conducted in accordance with the data handling guidelines of the British Antarctic Survey and all participants provided informed consent to participate in the research.

## Author contributions

OG: Writing – original draft, Writing – review and editing. KH: Writing – review and editing.

## Funding

The author(s) declared that financial support was received for this work and/or its publication. KH was supported through Natural Environment Research Council (NERC) core funding to the Environment Office of the British Antarctic Survey.

## Acknowledgements

This paper stems from one of the research questions of the lead author's master's thesis, see Gomola (2025). Matthias Lehner, Peter Convey, Brian Sindel and Daniela Liggett are gratefully acknowledged for early discussions on the project. This paper is a contribution to the 'Human Impacts and Sustainability' research theme of the Scientific Committee on Antarctic Research (SCAR) Scientific Research Programme 'Integrated Science to Inform Antarctic and Southern Ocean Conservation' (Ant-ICON). The authors are grateful to two reviewers for their insightful feedback on a previous version of this manuscript.

## Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

- Antarctic Treaty Secretariat (2019). Non-native species manual. Available online at: [https://documents.ats.aq/ATCM42/WW/ATCM42\\_WW008\\_e.pdf](https://documents.ats.aq/ATCM42/WW/ATCM42_WW008_e.pdf) (Accessed February 10, 2025).
- Antarctic Treaty Secretariat (2025a). *Parties. Secretariat of the Antarctic Treaty*. Available online at: <https://www.ats.aq/devAS/Parties?lang=e> (Accessed February 10, 2025).
- Antarctic Treaty Secretariat (2025b). *The Committee for Environmental Protection*. Available online at: <https://www.ats.aq/e/committee.html> (Accessed November 24, 2025).
- Banyard, A. C., Bennison, A., Byrne, A. M. P., Reid, S. M., Lynton-Jenkins, J. G., Mollett, B., et al. (2024). Detection and spread of high pathogenicity avian influenza virus H5N1 in the Antarctic region. *Nat. Commun.* 15, 7433. doi:10.1038/s41467-024-51490-8
- Bastmeijer, K. (2018). Introduction: the Madrid protocol 1998–2018. The need to address 'the success syndrome'. *Polar J.* 8, 230–240. doi:10.1080/2154896X.2018.1542861
- Bergstrom, D. M., Sharman, A., Shaw, J. D., Houghton, M., Janion-Scheepers, C., Achurch, H., et al. (2018). Detection and eradication of a non-native *Collembola* incursion in a hydroponics facility in east Antarctica. *Biol. Invasions* 20, 293–298. doi:10.1007/s10530-017-1551-9
- Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol.* 3, 77–101. doi:10.1191/1478088706qp0630a
- Braun, V., and Clarke, V. (2022). *Thematic Analysis: A Practical Guide*.
- Braun, C., Hertel, F., and Peter, H.-U. (2017). "Environmental management: the fildes peninsula paradigm," in *Handbook on the Politics of Antarctica*. Editors K. Dodds, A. D. Hemmings, and P. Roberts (Cheltenham: Edward Elgar Publishing), 351–367.
- Caplat, P., Coutts, S., and Buckley, Y. M. (2012). Modeling population dynamics, landscape structure, and management decisions for controlling the spread of invasive plants. *Ann. N. Y. Acad. Sci.* 1249, 72–83. doi:10.1111/j.1749-6632.2011.06313.x
- Ccamlr, COMNAPSCAR (2025). Update on high pathogenicity Avian influenza in Antarctica 2024/25 - working paper 50 - Antarctic treaty consultative meeting 47. Available online at: [https://documents.ats.aq/ATCM47/wp/ATCM47\\_wp050\\_e.docx](https://documents.ats.aq/ATCM47/wp/ATCM47_wp050_e.docx) (Accessed November 24, 2025).
- Chown, S. L., Huiskes, A. H. L., Gremmen, N. J. M., Lee, J. E., Terauds, A., Crosbie, K., et al. (2012). Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. *Proc. Natl. Acad. Sci. U.S.A.* 109, 4938–4943. doi:10.1073/pnas.1119787109

## Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2026.1816091/full#supplementary-material>

- Chown, S. L., Brooks, C. M., Terauds, A., Bohec, C. L., Klaveren-Impagliazzo, C. van, Whittington, J. D., et al. (2017). Antarctica and the strategic plan for biodiversity. *PLOS Biol.* 15, e2001656. doi:10.1371/journal.pbio.2001656
- Chown, S. L., Leihy, R. I., Naish, T. R., Brooks, C. M., Convey, P., Henley, B. J., et al. (2022). *Antarctic Climate Change and the Environment: A Decadal Synopsis and Recommendations for Action*. Cambridge: Scientific Committee on Antarctic Research. Available online at: <https://nora.nerc.ac.uk/id/eprint/532562/> (Accessed December 4, 2024).
- Clout, M., and De Poorter, M. (2008). "Invasive alien species: global lessons and Antarctic implications," in *Non-Native Species in the Antarctic: Proceedings*. Editor M. Rogan-Finnemore (Christchurch: University of Canterbury), 1–52.
- Convey, P., and Peck, L. S. (2019). Antarctic environmental change and biological responses. *Sci. Adv.* 5, eaaz0888. doi:10.1126/sciadv.aaz0888
- Corte, A. (1961). La primera fanerogama adventicia hallada en el continente Antártico. *Inst. Antártico Argent.*
- Creswell, J. W., and Creswell, J. D. (2017). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Thousand Oaks, CA: Sage publications.
- Ding, I. (2020). Performative governance. *World Polit.* 72, 525–556. doi:10.1017/S0043887120000131
- Dodds, K. (2017). "Antarctic geopolitics," in *Handbook on the Politics of Antarctica*. Editors A. D. Hemmings, P. Roberts, and K. Dodds (Cheltenham: Edward Elgar Publishing), 199–214.
- Dupuy, P.-M., and Viñuales, J. E. (2018). *International Environmental Law*. Cambridge University Press. doi:10.1017/9781108399821
- Edwards, J. A. (1980). An experimental introduction of vascular plants from South Georgia to the maritime Antarctic. *Br. Antarct. Surv. Bull.* 49, 73–80.
- Fedchuk, A., Cheberkus, D., and Zhrebchuk, S. (2022). Russian aggression against Ukraine: a new challenge facing Antarctic governance. *Ukrainian Antarct. J.* 20, 241–253. doi:10.33275/1727-7485.2.2022.702
- Ferrada, L. V. (2023). "The Antarctic treaty consultative meetings as a forum of law-making," in *The Routledge Handbook of Polar Law* (London: Routledge).
- Flick, U. (2022). *Doing Interview Research: The Essential how to Guide*. London: SAGE Publications Ltd. Available online at: <https://www.torrossa.com/it/resources/an/5282194> (Accessed January 17, 2025).

- Frame, B., and Hemmings, A. D. (2020). Coronavirus at the end of the world: Antarctica matters. *Soc. Sci. & Humanit. Open* 2, 100054. doi:10.1016/j.ssho.2020.100054
- Galera, H., Wódkiewicz, M., Czyż, E., Łapiński, S., Kowalska, M. E., Pasik, M., et al. (2017). First step to eradication of *Poa annua* L. from Point Thomas oasis (King George Island, South Shetlands, Antarctica). *Polar Biol.* 40, 939–945. doi:10.1007/s00300-016-2006-y
- Galera, H., Rudak, A., Czyż, E. A., Chwedorzewska, K. J., Znoj, A., and Wódkiewicz, M. (2019). The role of the soil seed store in the survival of an invasive population of *Poa annua* at Point Thomas oasis, King George Island, maritime Antarctica. *Glob. Ecol. Conserv.* 19, e00679. doi:10.1016/j.gecco.2019.e00679
- Galera, H., Znoj, A., Chwedorzewska, K. J., and Wódkiewicz, M. (2021). Evaluation of factors influencing the eradication of annual bluegrass (*Poa annua* L.) from Point Thomas Oasis, King George Island, Maritime Antarctica. *Polar Biol.* 44, 2255–2268. doi:10.1007/s00300-021-02941-1
- Gardiner, N. B., Gilbert, N., Liggett, D., and Bode, M. (2024a). Measuring the performance of Antarctic treaty decision-making. *Conserv. Biol.* 39, e14349. doi:10.1111/cobi.14349
- Gardiner, N. B., Liggett, D., Gilbert, N., and Cvitanovic, C. (2024b). Practitioners' perspectives on the enablers and barriers to successful Antarctic science-policy knowledge exchange. *Environ. Policy Gov.* 35, 1–20. doi:10.1002/et.2143
- Gomola, O. (2025). Grass is not always greener: the management and governance of non-native plants in Antarctica. *IIIIEE Master Thesis*. Available online at: <http://lup.lub.lu.se/student-papers/record/9204482> (Accessed October 29, 2025).
- Grant, S. M., Waller, C. L., Morley, S. A., Barnes, D. K. A., Brasier, M. J., Double, M. C., et al. (2021). Local drivers of change in Southern Ocean ecosystems: human activities and policy implications. *Front. Ecol. Evol.* 9, 624518. doi:10.3389/fevo.2021.624518
- Harvey, C. (2020). Once again, new Antarctic reserves fail to win backing. *Sci. Mag.* doi:10.1126/science.abf5407
- Hemmings, A. D. (2009). From the new geopolitics of resources to nanotechnology: emerging challenges of globalism in Antarctica. *Yearb. Polar Law Online* 1, 55–72. doi:10.1163/22116427-91000007
- Hughes, K. A. (2026). *Personal Communication: Liaison with Researchers from the British Antarctic Survey and the Italian National Antarctic Research Program*.
- Hughes, K. A., and Convey, P. (2012). Determining the native/non-native status of newly discovered terrestrial and freshwater species in Antarctica – current knowledge, methodology and management action. *J. Environ. Manag.* 93, 52–66. doi:10.1016/j.jenvman.2011.08.017
- Hughes, K. A., and Convey, P. (2014). Alien invasions in Antarctica—is anyone liable? *Polar Res.* 33, 22103. doi:10.3402/polar.v33.22103
- Hughes, K. A., and Convey, P. (2020). Implications of the COVID-19 pandemic for Antarctica. *Antarct. Sci.* 32, 426–439. doi:10.1017/S095410202000053X
- Hughes, K. A., and Pertierra, L. R. (2016). Evaluation of non-native species policy development and implementation within the Antarctic treaty area. *Biol. Conserv.* 200, 149–159. doi:10.1016/j.biocon.2016.03.011
- Hughes, K. A., Walsh, S., Convey, P., Richards, S., and Bergstrom, D. M. (2005). Alien fly populations established at two Antarctic research stations. *Polar Biol.* 28, 568–570. doi:10.1007/s00300-005-0720-y
- Hughes, K. A., Lee, J. E., Ware, C., Kiefer, K., and Bergstrom, D. M. (2010). Impact of anthropogenic transportation to Antarctica on alien seed viability. *Polar Biol.* 33, 1125–1130. doi:10.1007/s00300-010-0801-4
- Hughes, K. A., Lee, J. E., Tsujimoto, M., Imura, S., Bergstrom, D. M., Ware, C., et al. (2011). Food for thought: risks of non-native species transfer to the Antarctic region with fresh produce. *Biol. Conserv.* 144, 1682–1689. doi:10.1016/j.biocon.2011.03.001
- Hughes, K. A., Pertierra, L. R., Molina-Montenegro, M. A., and Convey, P. (2015). Biological invasions in terrestrial Antarctica: what is the current status and can we respond? *Biodivers. Conserv.* 24, 1031–1055. doi:10.1007/s10531-015-0896-6
- Hughes, K. A., Convey, P., Pertierra, L. R., Vega, G. C., Aragón, P., and Olalla-Tárraga, M. Á. (2019). Human-mediated dispersal of terrestrial species between Antarctic biogeographic regions: a preliminary risk assessment. *J. Environ. Manag.* 232, 73–89. doi:10.1016/j.jenvman.2018.10.095
- Hughes, K. A., Pescotto, O. L., Peyton, J., Adriaens, T., Cottier-Cook, E. J., Key, G., et al. (2020). Invasive non-native species likely to threaten biodiversity and ecosystems in the Antarctic Peninsula region. *Glob. Change Biol.* 26, 2702–2716. doi:10.1111/gcb.14938
- Hughes, K. A., Lowther, A., Gilbert, N., Waluda, C. M., and Lee, J. R. (2023). Communicating the best available science to inform Antarctic policy and management: a practical introduction for researchers. *Antarct. Sci.* 35, 438–472. doi:10.1017/S095410202300024X
- Hughes, K. A., Convey, P., and Lee, J. R. (2025). Status assessment of non-native terrestrial species in Antarctica. *NeoBiota* 98, 197–222. doi:10.3897/neobiota.98.139894
- Huiskes, A. H. L., Gremmen, N. J. M., Bergstrom, D. M., Frenot, Y., Hughes, K. A., Imura, S., et al. (2014). Aliens in Antarctica: assessing transfer of plant propagules by human visitors to reduce invasion risk. *Biol. Conserv.* 171, 278–284. doi:10.1016/j.biocon.2014.01.038
- Japan (1996). “A grass (seed plant) found in Syowa Station area, East Antarctica,” in *Information Paper 66, Antarctic Treaty Consultative Meeting XX*. Available online at: [https://documents.ats.aq/ATCM20/ip/ATCM20\\_ip066\\_e.pdf](https://documents.ats.aq/ATCM20/ip/ATCM20_ip066_e.pdf) (Accessed January 17, 2026).
- Joshi, M. C., and Banerjee, B. K. (1988). Fifth Indian Expedition to Antarctica. *Sci. Rep.* Department of Ocean Development, Technical Publication No. 5, 473–487.
- Joyner, C. C. (1997). Recommended measures under the Antarctic treaty: hardening compliance with soft international law. *Mich. J. Int'l L.* 19, 401–444.
- Keohane, R. O. (2015). The global politics of climate change: challenge for political science. *PS Political Sci. & Polit.* 48, 19–26. doi:10.1017/S1049096514001541
- Kubiszewski, I., Adams, V. M., Baird, R., Boothroyd, A., Costanza, R., MacDonald, D. H., et al. (2024). Cascading tipping points of Antarctica and the Southern Ocean. *Ambio* 54, 642–659. doi:10.1007/s13280-024-02101-9
- Lee, J. R., Raymond, B., Bracegirdle, T. J., Chadès, I., Fuller, R. A., Shaw, J. D., et al. (2017). Climate change drives expansion of antarctic ice-free habitat. *Nature* 547, 49–54. doi:10.1038/nature22996
- Lee, J. R., Terauds, A., Carwardine, J., Shaw, J. D., Fuller, R. A., Possingham, H. P., et al. (2020). Threat management priorities for conserving Antarctic biodiversity. *PLOS Biol.* 20, e3001921. doi:10.1371/journal.pbio.3001921
- Lee, J. R., Waterman, M. J., Shaw, J. D., Bergstrom, D. M., Lynch, H. J., Wall, D. H., et al. (2022b). Islands in the ice: potential impacts of habitat transformation on Antarctic biodiversity. *Glob. Change Biol.* 28, 5865–5880. doi:10.1111/gcb.16331
- Leihy, R. I., Coetzee, B. W. T., Morgan, F., Raymond, B., Shaw, J. D., Terauds, A., et al. (2020). Antarctica's wilderness fails to capture continent's biodiversity. *Nature* 583, 567–571. doi:10.1038/s41586-020-2506-3
- Leihy, R. I., McGeoch, M. A., Clarke, D. A., Peake, L., Buba, Y., Belmaker, J., et al. (2025). Antarctic biosecurity policy effectively manages the rates of alien introductions. *Earth's Future* 13, e2024EF005405. doi:10.1029/2024EF005405
- León, M. R.-D., Hughes, K. A., Morelli, E., and Convey, P. (2021). International response under the antarctic treaty system to the establishment of A non-native fly in Antarctica. *Environ. Manag.* 67, 1043–1059. doi:10.1007/s00267-021-01464-z
- Lewis Smith, R. I., and Richardson, M. (2011). Fuegoian plants in Antarctica: natural or anthropogenically assisted immigrants? *Biol. Invasions* 13, 1–5. doi:10.1007/s10530-010-9784-x
- Liggett, D., Frame, B., Convey, P., and Hughes, K. A. (2024). How the COVID-19 pandemic signaled the demise of Antarctic exceptionalism. *Sci. Adv.* 10, eadk4424. doi:10.1126/sciadv.adk4424
- Liverpool, L. (2023). Russia's war in Ukraine is disrupting Antarctic science. *Nature* 621, 453. doi:10.1038/d41586-023-02764-6
- Loukacheva, N. (2013). *Polar Law Textbook II*. Copenhagen: Nordic Council of Ministers. Available online at: <https://urn.kb.se/resolve?urn=urn:nbn:se:norden:org:diva-720> (Accessed March 6, 2025).
- Madani, Z., and Shibata, A. (2023). International law, climate change and the Antarctic treaty system: re-contemplating governance questions apropos of the mounting challenges. *Antarct. Sci.* 35, 374–389. doi:10.1017/S0954102023000226
- Malfasi, F., Convey, P., Zaccara, S., and Cannone, N. (2020). Establishment and eradication of an alien plant species in Antarctica: *Poa annua* at Signy Island. *Biodivers. Conserv.* 29, 173–186. doi:10.1007/s10531-019-01877-7
- Mancilla, A., and Jabour, J. A. (2023). Turned 60, is the Antarctic treaty system in good health? *Geogr. J.* 189, 2–6. doi:10.1111/geoj.12501
- McGeoch, M. A., Shaw, J. D., Terauds, A., Lee, J. E., and Chown, S. L. (2015). Monitoring biological invasion across the broader Antarctic: a baseline and indicator framework. *Glob. Environ. Change* 32, 108–125. doi:10.1016/j.gloenvcha.2014.12.012
- Molina-Montenegro, M. A., Carrasco-Urra, F., Rodrigo, C., Convey, P., Valladares, F., and Gianoli, E. (2012). Occurrence of the non-native annual bluegrass on the Antarctic mainland and its negative effects on native plants. *Conserv. Biol.* 26, 717–723. doi:10.1111/j.1523-1739.2012.01865.x
- Molina-Montenegro, M. A., Pertierra, L. R., Razeto-Barry, P., Díaz, J., Finot, V. L., and Torres-Díaz, C. (2015). A recolonization record of the invasive *Poa annua* in Paradise Bay, Antarctic Peninsula: modeling of the potential spreading risk. *Polar Biol.* 38, 1091–1096. doi:10.1007/s00300-015-1668-1
- Nyåstad, B., and Sánchez, R. A. (2014). “Future challenges in environmental management of national antarctic programs,” in *Antarctic Futures: Human Engagement with the Antarctic Environment*. Editors T. Tin, D. Liggett, P. T. Maher, and M. Lamers (Dordrecht: Springer Netherlands), 287–306. doi:10.1007/978-94-007-6582-5
- Olech, M. (2003). “Expansion of alien vascular plant *Poa annua* L. in the vicinity of the Henryk Arctowski Station—a consequence of climate change,” in *The Functioning of Polar Ecosystems as Viewed against Global Environmental Changes. XXIX International Polar Symposium* (Krakow: Jagiellonian University), 89–90.
- Olech, M., and Chwedorzewska, K. J. (2011). Short note: the first appearance and establishment of an alien vascular plant in natural habitats on the forefield of a retreating glacier in Antarctica. *Antarct. Sci.* 23, 153–154. doi:10.1017/s0954102010000982

- O'Neill, T. A. (2017). Protection of antarctic soil environments: a review of the current issues and future challenges for the environmental protocol. *Environ. Sci. & Policy* 76, 153–164. doi:10.1016/j.envsci.2017.06.017
- O'Reilly, J. (2013). Antarctic climate futures: how Terra incognita becomes Terra clima. *Polar J.* 3, 384–398. doi:10.1080/2154896X.2013.868090
- O'Reilly, J. (2021). Climate action in the antarctic treaty system: responding to the Madrid protocol and the contemporary crisis. *Antarct. Aff.* 8, 23–32.
- Parker, C., Scott, S., and Geddes, A. (2019). *Snowball Sampling*. SAGE research methods foundations. doi:10.4135/9781526421036831710
- Pertierra, L. R., Lara, F., Benayas, J., and Hughes, K. A. (2013). *Poa pratensis* L., current status of the longest-established non-native vascular plant in the Antarctic. *Polar Biol.* 36, 1473–1481. doi:10.1007/s00300-013-1367-8
- Pertierra, L. R., Hughes, K. A., Tejedro, P., Enriquez, N., Lucíañez, M. J., and Benayas, J. (2017). Eradication of the non-native *Poa pratensis* colony at Cierva Point, Antarctica: a case study of international cooperation and practical management in an area under multi-party governance. *Environ. Sci. & Policy* 69, 50–56. doi:10.1016/j.envsci.2016.12.009
- Pertierra, L. R., Santos-Martin, F., Hughes, K. A., Avila, C., Caceres, J. O., De Filippo, D., et al. (2021). Ecosystem services in Antarctica: global assessment of the current state, future challenges and managing opportunities. *Ecosyst. Serv.* 49, 101299. doi:10.1016/j.ecoser.2021.101299
- Peter, H.-U., Buesser, C., Mustafa, O., and Pfeiffer, S. (2008). Risk assessment for the Fildes Peninsula and Ardley Island, and development of management plans for their designation as specially protected or specially managed areas. *Ger. Fed. Environ. Agency, Dessau*. Available online at: <https://www.uba.de/n7472en>.
- Pyšek, P., Hulme, P. E., Simberloff, D., Bacher, S., Blackburn, T. M., Carlton, J. T., et al. (2020). Scientists' warning on invasive alien species. *Biol. Rev.* 95, 1511–1534. doi:10.1111/brv.12627
- Reform (2018). Reform the antarctic treaty. *Nature* 558, 161. doi:10.1038/d41586-018-05368-7
- Roland, T. P., Bartlett, O. T., Charman, D. J., Anderson, K., Hodgson, D. A., Amesbury, M. J., et al. (2024). Sustained greening of the Antarctic Peninsula observed from satellites. *Nat. Geosci.* 17, 1–6. doi:10.1038/s41561-024-01564-5
- Sindel, B. M., Kristiansen, P. E., Wilson, S. C., Shaw, J. D., and Williams, L. K. (2018). Managing invasive plants on sub-Antarctic plants on sub-Antarctic macquarie. *Rangel. J.* 39, 537–549. doi:10.1071/RJ17073
- Smith, R. I. L. (1996). Introduced plants in Antarctica: potential impacts and conservation issues. *Biol. Conserv.* 76, 135–146. doi:10.1016/0006-3207(95)00099-2
- Stuecker, M. F., Bitz, C. M., Armour, K. C., Proistosescu, C., Kang, S. M., Xie, S.-P., et al. (2018). Polar amplification dominated by local forcing and feedbacks. *Nat. Clim. Change* 8, 1076–1081. doi:10.1038/s41558-018-0339-y
- Tamm, S. (2018). Peace vs. compliance in Antarctica: inspections and the environment. *Polar J.* 8, 333–350. doi:10.1080/2154896X.2018.1541551
- Tanaka, Y. (2023). "Two models on environmental protection of the polar regions," in *The Routledge Handbook of Polar Law* (London: Routledge).
- Terauds, A., Chown, S. L., Morgan, F., J. Peat, H., Watts, D. J., Keys, H., et al. (2012). Conservation biogeography of the antarctic. *Divers. Distributions* 18, 726–741. doi:10.1111/j.1472-4642.2012.00925.x
- Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., et al. (2009). Impacts of local human activities on the antarctic environment. *Antarct. Sci.* 21, 3–33. doi:10.1017/S0954102009001722
- Tsujimoto, M., Imura, S., and Kanda, H. (2010). "Molecular systematics of a non-native vascular plant found near the syowa station, Antarctica," in *Poster at the International Polar Year Oslo Science Conference* (Oslo, Norway).
- Wille, M., Dewar, M. L., Claes, F., Thielen, P., and Karlsson, E. A. (2025). A call to innovate Antarctic avian influenza surveillance. *Trends Ecol. & Evol.* 40, 248–254. doi:10.1016/j.tree.2024.11.005
- Yermakova, Y. (2021). Legitimacy of the antarctic treaty system: is it time for a reform? *Polar J.* 11, 342–359. doi:10.1080/2154896X.2021.1977048