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Antarctic Affairs

Antarctic Affairs is the academic magazine of the Antarctic and Southern Ocean Coalition (ASOC) and Agenda Antártica, which aims to publish and disseminate the most prominent and influential research in relation to Antarctica. The journal publishes articles, reviews and official documents in English and Spanish. The purpose of this publication is also to stimulate research that contributes to environmental protection of Antarctica and the Southern Ocean.

AGENDA ANTÁRTICA

Agenda Antártica is a non-governmental organization based in Buenos Aires that works for environmental conservation of the Antarctic continent and the Southern Ocean, the promotion of research in Antarctica and the preservation of peace in the southern region. Agenda Antártica was founded in 2012 and is constantly developing research, outreach and advocacy at national, regional and international forums through publications, seminars, social networking and promotion of telecommunications. For more information about Agenda Antártica, visit: www.agendaantartica.org

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The Antarctic and Southern Ocean Coalition (ASOC) was founded in 1978 by five environmental organizations in the US, UK, Australia and New Zealand, promoting a World Park vision for protecting Antarctica and the Southern Ocean. ASOC has worked since 1978 to ensure that the Antarctic Continent, its surrounding islands and the great Southern Ocean survive as the world's last unspoiled wilderness, a global commons for the heritage of future generations. ASOC is an invited observer to the meetings of the Antarctic Treaty and CCAMLR. The Secretariat of the ASOC, which includes 21 organizations in 11 countries, is based in Washington, D.C. For more information about ASOC, visit: www.asoc.org

Cover Photo *Photographer: Chadden Hunter. Title: A family of orca 'spy-hop' in cracks in the Ross Sea ice shelf, Antartica (taken during the filming of BBC's Frozen Planet series) 2010'.*

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Antarctic Affairs

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Message from the Managing Editor

Dear Readers:

Welcome to the seventh edition of Antarctic Affairs. This volume is devoted to one of the most important topics in Antarctic governance discussions: the environmental protection of the white continent. In this edition, there are articles by both academics and government representatives that publish on a diversity of perspectives regarding this topic.

The first article in this edition is by Patricia Ortúzar, Head of the Argentine Antarctic Division, where she analyses the evolution of environmental protection within the Antarctic Treaty System over the last decades. This article represents an excellent introduction to the theme of this volume by showing the different stages and visions of environmental protection in Antarctica.

The second article is authored by Ewan McIvor, of the Australian Antarctic Division, who was chairman of the Committee of Environmental Protection (CEP) of the Environmental Protocol to the Antarctic Treaty. McIvor discusses the relationship between science and environmental protection in Antarctica and places particular emphasis on explaining the Committee's role in helping Antarctic Parties address new, emerging and ongoing environmental challenges, based on the best scientific information available.

The third article in this issue is written by Birgit Njåstad of the Norwegian Polar Institute and current chairman of the CEP. Njåstad explores the evolution of discussions on climate change over the years and how the CEP has worked to organize and prioritize its efforts in this regard. The author reviews the Committee's ongoing efforts to develop strategies and actions against anthropogenic climate change that is already having an impact on Antarctica and is likely to be the greatest threat to the values of this unique nature reserve in the future.

The following article was written by Alvaro Soutullo and Mariana Ríos from UdelaR de Uruguay. The authors focus on environmental regulations and management of the impact of tourism on the Antarctic environment. In their article, the authors summarize the lessons learned and recommendations based on the experience left by Antarctic tourism in recent years. Soutullo and Ríos, in turn, propose that the idea of creating a body similar to CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) should be explored to regulate tourism activity.

The fifth article in this edition is in charge of Lucas Ruberto, Lucas Martínez Álvarez, Francisco Massot and Walter Mac Cormack of the Argentine Antarctic Institute and the National Scientifit and Technical Research Council (CONICET). The authors present the importance of correctly managing hydrocarbon contamination in Antarctic soil, and highlight the fact that the soils around the scientific stations show different levels of contamination caused by fuels derived from petroleum, such as diesel. The authors propose the use of bioremediation, especially biopiles, as an effective technique to remove contaminants from the soil.

Finally, I would like to thank all the authors, translators, and the Editorial Committee for making possible the publication of this new edition of Antarctic Affairs.

Juan José Lucci

ASOC Prologue

Antarctica is undoubtedly one of the regions most affected by the impacts of climate change on the planet. In addition, in recent years Antarctica has experienced a significant increase in human activities, including the proliferation of research stations and science programs, as well as an increase in tourism activities.

Although Antarctica has been designated as an area destined for peace and science, at the time of its designation the impacts of climate change were not as apparent as they are today. With the implementation of the Protocol of Environmental Protection to the Antarctic Treaty (or Madrid Protocol), the Parties to the Treaty took an important step in protecting Antarctica. The Madrid Protocol entered into force on January 14, 1998 and within its main articles establishes that the protection of the Antarctic environment and dependent and associated ecosystems, and the intrinsic value of Antarctica, including its wildlife and aesthetic values, as well as its value as an area for conducting scientific research should be fundamental considerations for the planning and implementation of the majority of the activities carried out in the Antarctic Treaty Area. For the application and monitoring of the guidelines of the Protocol, the Committee for Environmental Protection (CEP) was created. The task of this committee is to centralize and prioritize the research activities of the member countries of the Antarctic Treaty, as well as to provide a space for discussion regarding the emerging environmental challenges to which Antarctica is subjected.

From ASOC we conduct with great concern a constant monitoring of the issues related to the implementation of the Madrid Protocol and the effects of climate change on Antarctica and its waters. The impacts derived from climate change clearly represent one of the greatest challenges facing this region. Thus, ASOC works to raise the profile of Antarctic climate change problems through public advocacy, attendance to Antarctic governance meetings, and dissemination of updated information on this matter to governments.

In this edition, we decided to gather the experience and perspective of key experts who have been in charge of chairing the Committee on Environmental Protection to obtain a vision of how this committee has evolved, the challenges it faced, the current situation and how it might evolve in the future. We also include examples of some perspectives related to specific environmental protection activities.

We hope that this new edition of Antarctic Affairs will help readers to gain a greater understanding of the fundamental aspects and challenges of environmental monitoring in Antarctica.

*Dr. Rodolfo Werner**
Editor
** Advisor to The Pew Charitable Trusts and the Antarctic and Southern Ocean Coalition (ASOC); Member of the Board and scientific advisor of the Antarctic Wildlife Research Fund; Director of the Advisory Council of Agenda Antartica; Guest speaker for Lindblad Expeditions/National Geographic.*

A Perspective on Antarctic Environmental Protection in a Changing World

Patricia Ortúzar

Abstract

This article offers a short summary of the approaches that guided the Antarctic environmental protection since its early days, especially with regards to the Antarctic Treaty and the Committee on Environmental Protection (CEP). The relevance that different issues have taken over recent decades –from protection of Antarctic fauna and reduction of environmental impact of research stations, to mitigation of the effects of climate change- responds not only to changes in world views regarding conservation but also to the advancement of science that has become central to discussions of environmental protection in Antarctica.

Key words

Committee on Environmental Protection, Antarctic Treaty, Antarctic Environmental Protection, Madrid Protocol.

Introduction

The environmental protection of the Antarctic has come a long way since the first measures for its preservation were implemented. When the Antarctic Treaty came into force in 1961, environmental protection was not the primary focus of the Treaty. However, Article IX provides for the creation of measures aimed at "preservation and conservation of living resources in Antarctica", which opened the door to later create the system developed by the Madrid Protocol, the rules and tools arising from its implementation, and other Conventions related to the Antarctic Treaty System.

In this way, the view on protection has changed or adapted to the issues and situations that have come up and has become part of the government and scientific agenda during recent decades. This way of thinking and approach to preservation has gradually been reflected in the decisions and in the regulations passed within the Antarctic Treaty since 1961. In this sense, the Committee on Environmental Protection (hereinafter, the CEP), created by Article 11 of the Madrid Protocol in 1998--which aims to advise and to provide recommendations to the Parties on the implementation of the Madrid Protocol--has had a key role in the development of our current view about the Antarctic environment protection.

This article offers a short summary of the approaches that guided the Antarctic environmental protection, in particular the Antarctic Treaty and the CEP.

The Beginning

Since the first Antarctic Treaty Consultative Meeting -hereinafter, ATCM- (ATCM I - Canberra, 1961) adoption of the "General Rules of Conduct for Preservation and Conservation of Living Resources in Antarctica" (Recommendation I-VIII) was the first indication that the Antarctic Treaty would not only be an agreement to prevent the Antarctic continent from being a source of international discord, but it would also mean that its members would consider the issue of the environmental protection of the continent.

At the Antarctic Treaty Consultative Meeting held in 1964, the "Measures for the Conservation of Antarctic Fauna and Flora" (Recommendation III-VIII -ATCM III - Brussels, 1964) were adopted, which established the basis for the creation of an Annex to the Madrid Protocol, "Conservation of Antarctic Fauna and Flora".

Recommendation VIII-11 (ATCM VIII - Oslo, 1975), "Man's Impact on the Antarctic Environment", had an Annex with measures to require management of waste produced by anthropic activities in Antarctica; while these measures may be deemed unacceptable nowadays, they contributed to highlighting the environmental contamination potential of waste, and to encouraging the consideration of waste management as a regular part of activities.

If we analyze these measures today, we can see that their focus was on protecting natural values from the implications of local activities, such as direct damage caused to local fauna due to specimen collection for scientific study, or due to contamination by activities performed by the Antarctica stations. It is worth bearing in mind that until early 20th century, commercial exploitation of seals and whales had significantly reduced the population of those species. These days, governmental activities, such as establishment of Antarctic stations and scientific research, are seen as sources of potential environmental impact. Regulating extractive activities in the continent was also at the core of important regulations; some were successful, such as the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), while others were unsuccessful, such as the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA).

The Environmental Protection Protocol to the Antarctic Treaty (Madrid Protocol)

The Antarctic Treaty Protocol on Environmental Protection, signed in Madrid in 1991 and brought into effect in 1998, was a historical landmark for environmental protection in Antarctica, as it allowed for the prioritization of environmental preservation through the establishment of binding conservation measures

Among its principles, the Protocol stated that environmental protection, as well as its dependent and associated ecosystems, should be essential considerations in the planning and conduct of activities performed within the Antarctic Treaty Area. Also, it gave scientific research a priority status, ensuring that Antarctic values were preserved for scientific research.

The Protocol coming into force meant, among other things, that Antarctic stations had to be adjusted to the Protocol's new demands. As a result, dogs were removed from many stations, waste treatment equipment was installed, progressive withdrawal of open-air waste disposal containers was considered, and activities to improve oil facilities were started.

With work performed by CEP and assistance provided by observers and experts such as SCAR and COMNAP, new tools were introduced over the years to make the Protocol implementation easier.
The work of the CEP produced new environmental management and protection tools related to, among other things, flora and fauna, waste management, protected areas management, and the preservation of historical sites. Activities that were increasing, such as tourism, obtained a permanent place in the Committee's agenda.

The world in Antarctica: Introducing Climate Change in the Agenda

In the 21stcentury, with all eyes on a growing body of scientific evidence, as well as negotiations and agreements reached in other international organizations, key voices within the Antarctic Treaty System pushed to shift a focus from activities undertaken locally in Antarctica, to those taking place in other places around the world that were having an impact on the region via anthropogenic climate change.

When climate change was introduced, members sought to define the right approach to addressing this issue, with the understanding that the cause of climate change was not within the Antarctic Treaty Area, and that other international agreements have the tools to stop climate change. Still, climate change effects were understood by country members as something to be worked on.

The Scientific Committee on Antarctic Research (SCAR) produced an assessment report of the Program on the Antarctic Climate Change and the Environment (ACCE), and submitted it to the Antarctic Treaty in 2009 (See Turner et. al., 2009). This report was essential to broadening understanding of the impacts of climate change, as was the Antarctic Treaty Meeting of Experts (ATME) held in Svolvær, Norway in April 2010. The purpose of this meeting was to analyze key scientific concepts on climate change and its effects on the Antarctic land and marine environment. It also examined the effects that climate change was having on Antarctic activities management and their monitoring needs, as well as planning of risk scenarios and assessment.

In its conclusions, the ATME agreed that climate change and its effects on Antarctic governance and management were relevant and important to discuss under the Antarctic Treaty System. It was also highlighted at the meeting that climate change should be a separate item in the agendas of the CEP and ATCM.

Given that the causes of climate change could not have been addressed in the Antarctic Treaty, it focused instead on analyzing the consequences of climate change and on developing tools to support adaptation to climate change, whenever possible.

Currently, the ATCM has among the items in its agenda the "Implications of Climate Change for the Antarctic Treaty Area Management", while the CEP has included climate change under item named *"Implications of Climate Change for the Environment a. Strategic approach b. Implementation and assessment of the climate change response work program".*

Considering recommendations from the Meeting of Experts, the CEP adopted the Climate Change Response Work Program in 2016, the purpose of which is to provide a mechanism for identifying and analyzing specific goals and actions. Through this effort, the CEP can support broader efforts made within the Antarctic Treaty System to build ecosystem resilience to the effects of climate change, and help clarify relevant implications for Antarctic governance and management. This program includes tasks and response measures for the issues related to climate change, which may be of interest for the CEP in order to move forward with Antarctic management within the context of a changing climate. Finally, and in order to promote efficient and timely implementation of the CEP Climate Change Response Work Program, in 2017 the CEP created the Subsidiary Group on Climate Change Response, the purpose of which is to promote the Response Plan coordination and communication among the Antarctic Treaty Members, its observers, and experts. This Group also suggests annual updates to the Response Plan, including management, research, or monitoring activities, and it writes progress annual reports.

Reviewing Tools in a Changing World

One of the most valuable tools in the Madrid Protocol was its Annex on Environmental Impact Assessment, which mandates that an analysis of environmental consequences must take place before any activity can proceed in the Antarctic continent.

In order to provide members a specific methodological tool for conducting environmental impact assessment in Antarctica, in 1999 the CEP created the first draft of the "Guidelines for Environmental

Impact Assessment in Antarctica" (Resolution 1 [1999] – ATCM XXIII – CEP II, Lima).

The goals in this first draft had their focus on different sides of an activity with natural values present locally or within its area of influence. For instance, in the case of Antarctic stations, Environmental Impact Assessments were focused on the identification of issues such as soil erosion, permafrost impacts due to construction, soil contamination due to waste and spillage disposal, and road compression, among others. In many cases, these effects were expected to be localized.

As of today, there were two updates made to these guidelines. The first one was made in 2005 (Resolution 4 [2005] – ATCM XXVIII – CEP VIII, Stockholm), when the Parties looked for guidelines that best addressed potential cumulative effects of one or more suppliers, whether private or state-run, that are conducting several activities in multiple areas.

As part of the process that started with the Meeting of Experts held in 2010, a more significant change in perception would appear in 2016 when the Parties agreed on the latest version (which is still in effect) Resolution 1 (2016) – ATCM XXXIX – CEP XIX, Santiago. An additional goal was added to the Guidelines, to help proponents consider the potential consequences of climate change in suggested activities and its associated environmental effects.

These guidelines indicate, to the extent possible, that the foreseen or potential consequences of climate change in the environment in the place where activities will be carried out must be taken into consideration for as long as such activities will occur, including the dismantling phase, if relevant. Effects identification must also consider climate change consequences, especially for any long-term activities.

These developments suggest that the Antarctic Treaty System is moving toward a broader definition of environmental protection in the Antarctic. Considering the negative consequences of an activity on the continent is no longer sufficient; rather global considerations for climate change must be considered when preserving the Antarctic ecosystem. An activity can nowadays trigger bigger or different environmental effects if the climate changeability is taken into account for the analysis.

In the same line, it is possible to analyze one of the issues considered in the Madrid Protocol's Annex on the conservation of flora or fauna, such as the introduction of non-native species. While one of the articles of the Madrid Protocol referred to prohibiting the introduction of non-native species on the ground, on ice shelves, or in the water within the Antarctic Treaty Areas, the main goal of this restriction was to limit the deliberate introduction of species, such as dogs used for sleds.

As time went by, several Parties to the Antarctic Treaty raised concerns about the damage that species unintentionally introduced could cause to the Antarctic continent, such as insects present in shipments sent to Antarctica or in seeds, spores, or small rhizomes present in the footwear, farm tools or ground vehicles wheels. The scientific project "Aliens in Antarctica" from the International Polar Year (2007-2008) provided robust quantitative evidence on unintentional transportation of species, through samples taken from shipments, clothing, and personal equipment for Antarctica, as well as from scientific and technical staff and visitors.

With this evidence at hand, the CEP created the Non-Native Species Manual, the first draft of which was adopted in 2011 (Resolution 6 [2011] – ATCM XXXIV – CEP XIV, Buenos Aires). The rationale behind this manual was not only to provide a better understanding of the type of species, but also to draw attention to the existence of the threat resulting from non-native species. As stated in the manual, "with rapid climate change occurring in some parts of Antarctica, increased numbers of introductions and enhanced success of colonization by non-native species are likely".

The robust scientific bibliography on this topic provided the basis for the Parties to reach an agreement that made it possible to increase measures to prevent species introductions that could not have succeeded decades ago but today would be able to find conditions suitable for settlement and colonization of ice-free areas, with the severe consequences that may result for the Antarctic ecosystem. Nowadays, with increasing air and naval activities carried out to Antarctica and also among sites within Antarctica, implementing these measures has become critical especially to avoid the introduction and distribution of species on the continent for Antarctic National Programs with important operations and also tour operators.

If we look further for examples, we can find that, even though the CEP did not adopt many tools for Antarctic waste management throughout the years, aside from tools already included in Annex III of the Madrid Protocol, it has provided analysis of climate change consequences pertaining to waste management.

In this sense, the CEP's Clean-Up Manual (Resolution 2 [2013] – ATCM XXXVI – CEP XVI, Brussels) says: "As noted by the 2010 Antarctic Treaty Meeting of Experts on Climate Change and Implications for Antarctic Management and Governance, climate changes could accelerate localized release of contamination from past waste disposal sites and abandoned work sites through increased melting". This Manual is nowadays a valuable tool for those in charge of clean-up of those sites that have historic waste to remediate their sites in a complete and organized manner and to prioritize the places in which they should act, considering that those sites clean-up may be hard, difficult, and sometimes even dangerous. In this sense, a Climate Change Response Program was also drafted, which encouraged National Programs to assess the sites where they carried out previous activities (not yet cleaned up or remediated) that are most likely to be affected by climate change, so as to give them a priority status. This is a good example of a scenario that we thought for years could have mostly local effects when in fact it could have a different, larger scope.

It is also interesting to highlight that the Committee has addressed other new or growing issues during the last years. Recently adopted Resolution 5 (2019) "Reducing Plastic Pollution in Antarctica and Southern Ocean" is pointed out here. Through this Resolution, the Parties expressed their concern about the growing level of macro and micro-plastics within the Antarctic Treaty Area. In this resolution, while acknowledging that the largest source of the plastic found in Antarctica comes from other places, it proposes some localized solutions to reduce plastic pollution in Antarctica by minimizing the use of certain products, such as cosmetic products with micro-plastics. Even though this regulation may be considered a small step, it allowed for plastic pollution to be incorporated into current debates. This could open the door for broader discussions and for new rules on this matter to be passed in the future. Adopting Resolution 4 (2018) – ATCM XLI – CEP XXI, Buenos Aires "Environmental Guidelines for Operation of Remotely Piloted Aircraft Systems (RPAS) in

Antarctica" constituted further evidence of the way in which the Antarctic Treaty, through the work of the CEP, has dealt with issues that may stem from new technologies.

Planning Life and Work in Today's Antarctica

Recognizing that for more than a century we have had scientific stations in Antarctica, permanent or semi-permanent, which have provided logistical support for life and activities in Antarctica, in the future they have to be planned considering current dynamics and problems.

The Climate Change Response Plan is clear in this sense: national operators must assess the climate change risks (for example, permafrost) as regards their infrastructure and their effects on the environment. Nowadays, current and future changes in permafrost that may seriously affect the establishment of an Antarctic station or the maintenance of a gravel road for airplanes landing must be considered in planning and maintaining installations. Planning, environmental impact assessment, and monitoring, control, and maintenance are essential to mitigate effects.

Current Perspective Challenges

Many of the environmental issues that must be addressed in the Antarctic continent have existed throughout the years. Fuel and waste management, and direct interference with fauna caused by anthropic activities still require attention and compliance with regulations in force.

Addressing the added element of building resilience to the global phenomenon of climate, however, is not an easy task. Mitigating the effects of climate change and creating resilience, while international agreements have failed to reduce greenhouse gas emissions does not fully address an increasingly serious problem. The Climate Change Response Program and the CEP Subsidiary Group are going through their first years of work. Parties will have to be seriously committed to have their implementation moved forward.

Despite the challenges it implies, moving from a local perspective to a new, broader one related to the effects of a global issue stands out as a positive change. This shows the Antarctic Treaty and the Committee on Environmental Protection's working capability and it implies a step forward to a more globally-focused perspective for its preservation.

The Antarctic continent is not static, and the consequences of our actions can shift along with environmental changes. Therefore, we must assess change and move jointly with it while acting dynamically. In this sense, having sufficient and up-to-date scientific information will be critical to make decisions. We must bear in mind that, in many cases, management timeframes do not match those of scientific research and, as has happened before, the challenge will be in deciding the criteria to be applied in regulating our actions and activities, considering that we will not always have all the information when a decision must be made.

In discussing these challenges, it will be essential that those who manage the Antarctic continent continuously ask for global commitment to have the continent preserved, since actions need to be taken from different fields of international bargaining –beyond the Antarctic Treaty scope

– so that we can keep on preserving Antarctica, with its unique ecosystems and its function as global climate regulator.

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The Committee for Environmental Protection and the important role of science in international efforts to protect the Antarctic environment

Ewan McIvor

Abstract

Science and environmental protection are intimately linked in the Antarctic, as reflected by the region's international designation as a natural reserve, devoted to peace and science. The objective of the Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol) is to comprehensively protect the Antarctic environment, including its globally-significant scientific values. The Environmental Protocol established the Committee for Environmental Protection (CEP) to support Antarctic nations to address ongoing, new and emerging environmental challenges, drawing on the best available scientific advice. The CEP requires a sound understanding of the state of the Antarctic environment, how it is changing and how it is likely to change in the future, the consequences of interactions between human activities in the Antarctic region and the environment, and also the environmental implications of pressures from outside the region. The Scientific Committee on Antarctic Research (SCAR) is a significant and valued contributor to that work, and along with other expert organisations plays an important role in ensuring the Committee's work is informed by the best available science. The CEP has outlined its priorities in a rolling five-year work plan that also identifies associated science, knowledge and information needs. Continued close collaboration between the CEP and the science community is vital, and there are various avenues for science to continue to inform international efforts to ensure the wise management and protection of Antarctica.

Key words

Antarctic, Environmental Protocol, CEP, policy, science.

Introduction

Science is often described as the currency of the Antarctic Treaty system[1], and it is undeniable that cooperation in the conduct and support of regionally- and globally-important science is the main glue that binds nations in their Antarctic endeavours. The considerable weight assigned to science as an indicator of meaningful Antarctic engagement is reflected in the requirement to carry out 'substantial scientific research' in Antarctica as a pre-requisite for attaining decision-making status in the primary governance forum, the Antarctic Treaty Consultative Meeting (ATCM)[2]. The standing and reputation of the nations active in Antarctica also rests, in no small part, on their commitment and actions with regard to protecting the environmental (including scientific) values of the region. Indeed, formally undertaking to comprehensively protect the Antarctic environment is a further pre-requisite for participating in decision-making[3].

These central tenets of the Antarctic Treaty system – to work together to expand scientific knowledge of the region and to safeguard its truly exceptional environmental values – are not pursued in isolation from each other. In practice, Antarctic science and environmental protection objectives are intimately and necessarily linked. Science informs and supports, environmental protection efforts, which in turn serve to maintain the scientific values of Antarctica. This mutually beneficial synergy is reflected at the very highest level, through the designation of Antarctica under international law – the Protocol on Environmental Protection to the Antarctic Treaty (hereafter the Environmental Protocol) – as a 'natural reserve, devoted to peace and science'[4].

When the Antarctic Treaty Parties negotiated the Environmental Protocol in the late 1980s and very early 1990s they captured the clear understanding, evident also in preceding environmental measures adopted through the ATCM such as the 1980 Convention on the Conservation of Antarctic Marine Living Resources, that science is fundamental for ensuring robust and lasting protection of Antarctica's environmental values, and that the unique opportunities Antarctica offers for science must also be protected. Accordingly, the Parties wrote into the body of the Environmental Protocol several obligations to promote their vision of an effective connection between science and environmental protection. These include requirements that policy for the comprehensive protection of the Antarctic environment and associated measures must draw upon 'the best scientific and technical advice available'[5], and must consider the advice of the peak international Antarctic science body, the Scientific Committee on Antarctic Research (SCAR)[6], and relevant other expert scientific organisations.

The Environmental Protocol established over-arching principles that further strengthen the connections between science and environmental protection. These include the requirements that protection of Antarctica's 'value as an area for conducting scientific research, in particular research essential to understanding the global environment' must be a fundamental consideration, and that all activities must be planned and conducted on the basis of 'information sufficient to allow prior assessments of, and informed judgments about, their possible impacts on the Antarctic environment and dependent and associated ecosystems and on the value of Antarctica for the conduct of scientific research'[7].

The Environmental Protocol also established the Committee for Environmental Protection (hereafter the CEP or Committee), a new international body to support the Parties and to serve as the primary interface between Antarctic environmental policy and science. The CEP plays a central and significant role in carrying forward the vision outlined above, and has now been operating for over 20 years. This paper reviews its roles, priorities and related science needs, and outlines some of the many ways in which science informs its ongoing efforts to support the wise management and protection of Antarctica.

Role of the Committee for Environmental Protection

The Environmental Protocol represented the Antarctic Treaty Parties' best efforts to ensure the robust and lasting protection of Antarctica, in light of the known and reasonably foreseeable environmental challenges at the time of its drafting. The objectives, principles and requirements established by the Environmental Protocol and its associated Annexes were framed accordingly and included, for example, requirements for prior environmental impact assessment of all proposed activities, for indefinitely prohibiting mining and mineral exploration, for preventing the introduction of non-native species, for managing past and contemporary waste, and for affording special protections to certain species and areas. However, the Parties recognised that their work would not be complete with the signing of Environmental Protocol, and that there would be a continuing need for expert advice on how to address ongoing, new and emerging environmental challenges. This was to be the role of the CEP, which would bring Antarctic nations together to discuss and agree on how best to advance their shared commitment to comprehensively protect the environment.

The CEP first met in 1998 in Tromsø, Norway, following the entry into force that year of the Environmental Protocol, and it generally meets annually in conjunction with the Antarctic Treaty Consultative Meeting (ATCM)[8]. Each Party to the Environmental Protocol is entitled to be a member of the Committee, and membership has grown from 27 in 1998 to 41 in 2020. The current CEP membership represents the majority of the 54 Antarctic Treaty Contracting Parties, and includes all those nations with active Antarctic programs. In recent years there have been coordinated efforts to encourage and support all remaining Antarctic Treaty Parties to also accede to the Environmental Protocol[9]. This recognises the value of expanding the community of nations that are formally committed to protecting the Antarctic environment, and of increasing the breadth of expertise and experience available within the CEP.

Sessions of the CEP also involve representatives of other international organisations with environmental, scientific and technical expertise relevant to the protection of Antarctica, which have 'observer' status in the Committee. While some of these observers are identified through a Decision of the ATCM[10], representatives of key scientific bodies, including the SCAR President and the Chair of the Scientific Committee for the Conservation of Antarctic Marine Living Resources (SC-CAMLR), are identified in the body of the Environmental Protocol itself as standing observers[11]. The current CEP Members and Observers are presented in Table 1.

The Committee's overall role is to provide advice and formulate recommendations to the Parties on implementing the Environmental Protocol[13]. Its work is broad-ranging, covering virtually all matters under the umbrella of environmental protection. Article 12 of the Environmental Protocol identifies

Members		
Argentina	Australia	Belarus
Belgium	Brazil	Bulgaria
Canada	Chile	China
Colombia	Czechia	Ecuador
Finland	France	Germany
Greece	India	Italy
Japan	Korea (RoK)	Malaysia
Monaco	Netherlands	New Zealand
Norway	Pakistan	Peru
Poland	Portugal	Romania
Russian Federation	South Africa	Spain
Sweden	Switzerland	Turkey
Ukraine	United Kingdom	United States
Uruguay	Venezuela	
Observers *Other Contracting Parties to the Antarctic Treaty*		
Austria	Cuba	Denmark
Estonia	Guatemala	Hungary
Iceland	Kazakhstan	Korea (DPRK)
Mongolia	Papua New Guinea	Slovakia
Slovenia		
Standing Observers		
Scientific Committee for the Conservation of Antarctic Marine Living Resources (SC-CAMLR)	Council of Managers of National Antarctic Programs (COMNAP)	Scientific Committee on Antarctic Research (SCAR)
Other scientific, environmental and technical organisations		
Antarctic and Southern Ocean Coalition (ASOC)	International Association of Antarctica Tour Operators (IAATO)	International Hydrographic Organization (IHO)
Intergovernmental Panel on Climate Change (IPCC)	International Union for the Conservation of Nature (IUCN)	United Nations Environment Programme (UNEP)
World Meteorological Organization (WMO)		

Table 1. *Members and Observers of the Committee for Environmental Protection (as at 12 October 2020)*[12]

the following particular matters the Committee is to consider:

- the effectiveness of measures taken pursuant to this Protocol
- the need to update, strengthen or otherwise improve such measures
- the need for additional measures, including the need for additional Annexes, where appropriate
- the application and implementation of the environmental impact assessment procedures set out in Article 8 and Annex I
- means of minimising or mitigating environmental impacts of activities in the Antarctic Treaty area;
- procedures for situations requiring urgent action, including response action in environmental emergencies
- the operation and further elaboration of the Antarctic Protected Area system
- inspection procedures, including formats for inspection reports and checklists for the conduct of inspections
- the collection, archiving, exchange and evaluation of information related to environmental protection;
- the state of the Antarctic environment
- the need for scientific research, including environmental monitoring, related to the implementation of this Protocol.

Drawing on the best available scientific advice and expertise of its membership and observers, the Committee supports the development and application of 'tools' for protecting the Antarctic environment, in the form of binding regulations and non-binding guidelines. A short publication prepared by the Committee in 2016, on 25 Years of the Protocol on Environmental Protection to the Antarctic Treaty[14] outlined some of the tools it had developed to that time, and the Secretariat of the Antarctic Treaty maintains a current list on its website[15]. Broadly speaking, these include:

- area-based tools: to prohibit, regulate or guide activities in particular areas, such as the designation and management of Antarctic Specially Protected Areas (ASPAs), Antarctic Specially Managed Areas (ASMAs) and Historic Sites and Monuments (HSMs)[16], site-specific Visitor Site Guidelines[17];
- value-based tools: to protect particular values wherever they occur, such as Specially Protected Species designations[18] or the Guidelines for handling of pre-1958 historic remains[19];
- activity-related tools: to regulate or guide the ways particular activities interact with the environment, such as the Clean-Up Manual[20] or the Environmental Guidelines for Operation of Remotely Piloted Aircraft Systems (RPAS) in Antarctica[21]; and
- generally applicable tools: that apply to all activities in all locations, such as the Guidelines for Environmental Impact Assessment in Antarctica[22] or the Non-Native Species Manual[23].

Such tools need to keep pace with changing circumstances, and indeed the situation in Antarctica has not remained static since the Environmental Protocol was adopted in 1991. Over the subsequent decades, the types and locations of human activities in the region have changed, with new stations and science support facilities established (e.g. Brooks et al., 2019) and a marked increase in the level and types of tourism activities and locations visited (e.g. IAATO, 2020 and New Zealand, 2012). Advances in technologies have allowed for new interactions with the environment, with both positive and negative implications. For example, remotely piloted aircraft systems, or drones, can now support research, monitoring and operational activities that might have previously required the use of large, noisy and more costly piloted aircraft, but also present new environmental challenges such as the potential for wildlife disturbance. The state of scientific knowledge has also improved and provided, for example, improved knowledge related to the impacts of activities (e.g. Coetzee and Chown, 2015), greater insights into terrestrial biogeography (e.g. Terauds and Lee, 2016), and a better – though still developing – understanding of largely 'external' pressures, particularly climate change (e.g. Turner et al., 2009). These and other such developments must be drawn into the mix to inform the Parties' actions and, accordingly, to shape the Committee's work.

CEP priorities and science needs

Reflecting its wide-ranging responsibilities, the Committee's agenda and activities cover a broad spectrum of environmental issues. To help focus the individual and collective efforts of Members and Observers towards the most important issues, since 2008 the Committee has maintained a rolling five-year work plan[24]. The issues and priorities identified in the work plan are revisited at each CEP meeting. Long-standing high priorities include:

- addressing the risks to biodiversity associated with non-native species, including transfer to Antarctica, transfer of species between locations, marine non-native species risks, and effective monitoring, control and eradication measures;
- further developing the Antarctic protected areas system by identifying and designating specially protected areas, in a systematic way, to help ensure the robust and lasting protection of the range of environmental, scientific and other values of Antarctica;
- supporting the Parties' desire to ensure the appropriate management of Antarctic tourism by better understanding how tourism interacts with the environment, and the potential consequences of those interactions; and
- understanding and addressing the implications of climate change in the Antarctic for the protection and management of the environment.

Some other issues that feature on the Committee's work plan include the repair or remediation of environmental damage, monitoring and state of the environment reporting, marine spatial protection and management, implementing and improving Antarctic environmental impact assessment provisions, enhancing biodiversity knowledge, protecting outstanding geological values, and managing historic heritage.

Because knowledge of Antarctica is incomplete, and the situation is not static, the Committee continually requires new and updated scientific information to keep pace with these and other challenges. It requires a sound understanding of the state of the Antarctic environment, how it is changing and how it is likely to change in the future, the consequences of interactions between human activities in the Antarctic region and the environment, and also the environmental implications of pressures from outside the region.

The Committee is an environmental advisory body, not strictly a scientific body, but its progress on these issues and priorities benefits greatly from the ready availability of scientific information that is:

- relevant: addressing the priority issues under consideration at the time, or drawing attention to emerging issues that may require consideration;

- high quality: adhering to the fundamental principles of scientific rigour and impartiality (Hughes et al., 2018) and presenting the state of knowledge, while also highlighting gaps in knowledge, uncertainties and differences of opinion in the scientific community; and
- accessible: synthesising the state of knowledge on an issue for a region or topic, avoiding overly technical language, describing the salient points arising from data rather than presenting raw data, and using figures and maps where helpful.

Without such 'policy-relevant' scientific information, the CEP would lack critical input for the policy-making process of understanding the nature of an issue, identifying the suite of options, deciding on a preferred approach, and evaluating the success or otherwise of the chosen course of action. In short, credible scientific information about the Antarctic environment, and the relationships between human activities and the environment, is a key requirement for the CEP to effectively fulfil its mandate to provide advice and recommendations to the Antarctic Treaty Parties.

Scientific information has contributed, and continues to contribute, to advancing the CEP's priorities, and there are many good examples of the transfer of science into environmental management and policy. For example, guiding principles[25] and practical measures[26] for preventing the introduction of non-native species into the Antarctic terrestrial environment have been directly informed by dedicated research to understand and quantify risks[27]. Spatial analyses such as the Environmental Domains Analysis of Antarctica[28], the Antarctic Conservation Biogeographic Regions[29], and the Assessment of Important Bird Areas[30] in Antarctica have been recognised as relevant and important bases for the further development of the Antarctic protected areas system.

Science is made available to inform the Committee's work in several ways. Foremost among these is via the direct involvement of SCAR, which advances its mission by providing 'independent and objective scientific advice and information to the Antarctic Treaty System and other bodies'[31]. The uptake of SCAR's advice by the Committee is enhanced by its efforts to integrate research undertaken by scientists from many countries (Hughes et al., 2018). The SCAR Standing Committee on the Antarctic Treaty System (SC-ATS)[32] is the coordinating point for delivering science from the wider SCAR community into the CEP, through papers to annual meetings, and through the involvement of SCAR representatives in the annual CEP meetings and intersessional processes. On the latter, for example, SCAR is an active participant in the work of the CEP Subsidiary Group on Climate Change Response (SGCCR) which, among other things, seeks to communicate the science needs identified in the Committee's Climate Change Response Work Program, and to feed the knowledge associated from related research back into the Committee to help implement identified management actions. Further, a joint SCAR-CEP workshop on Further Developing the Antarctic Protected Area System, held in 2019, provided a valuable forum for extended and productive discussions between SCAR and CEP representatives on this priority issue, including the identification of related challenges and science and policy actions[33].

Under the CEP's Rules of Procedure, SCAR is one of only three observer organisations (together with SC-CAMLR and COMNAP) that, like CEP Members, are able to submit Working Papers (i.e. papers for discussion and action). This 'observer' label is appropriate in the context of an international forum for decision-making by member States, but perhaps doesn't adequately reflect SCAR's significant role in advancing the objectives of the Environmental Protocol. It makes regular and highly-valued contributions[34] to the work of the Antarctic Treaty Parties and the CEP, and by volume of meeting papers ranks among the most prolific contributors. Some of these papers are co-authored with CEP Member Parties or other Observers[35], reflecting a considered partnership approach to the conduct and communication of Antarctic science, and also the multiple hats worn by some members of the Antarctic science community. Some SCAR papers respond to specific requests from the CEP or Parties for SCAR's advice on the current state of scientific knowledge on an issue. Examples include the regular updates to the 2009 SCAR Antarctic Climate Change Environment Report[36], assessments of the conservation status of Antarctic species[37], and various reports on scientific knowledge about the effect of noise on marine wildlife[38]. Yet other papers pro-actively draw the Committee's attention to emerging issues that may warrant Members' individual or collective attention[39].

Other observer organisations also contribute significantly to ensuring the Committee has available a sound scientific basis for its deliberations. The Antarctic and Southern Ocean Coalition (ASOC) has within its network experts on many environmental issues, and it regularly brings forward comprehensive reviews of research relevant to the Committee's work, such as on climate change[40]. Similarly, the International Association of Antarctica Tour Operators (IAATO) draws on the current state of scientific knowledge to underpin requirements and guidelines for its member activities, which in turn inform discussions in the CEP[41]. The World Meteorological Organization (WMO) provides information regarding its programs that can assist with understanding climate change and its implications for the Antarctic region[42], and also engages in the intersessional work of the SGCCR.

Of course the CEP Members themselves also contribute considerable scientific knowledge and expertise, drawing on their Antarctic science communities, their involvement in international programs, and the published scientific literature to inform their positions in debates at meetings and in intersessional processes. They actively share relevant research through meeting papers, sometimes simply bringing attention to newly published scientific literature of relevance to topics of interest[43], and at other times taking the further step of incorporating such research as a basis for proposed new tools[44].

As well as seeking scientific advice from partner bodies such as SCAR, the CEP often builds into its own detailed work programs actions to seek out new or updated scientific knowledge. The SGCCR mentioned above is a good example of this, but others include the Committee's detailed intersessional processes to undertake five-year reviews of the Non-Native Species Manual and Clean-Up Manual, both of which included in the early stages comprehensive reviews of new research relevant to the related environmental risks and management options.

The CEP does not itself have a mechanism or the administrative support to undertake science or even keep track of relevant scientific developments[45], so that responsibility has largely been borne by relatively well-resourced Members, and by SCAR. To complement those much-needed efforts, the Antarctic Environments Portal presents a further source of science-based information relevant to the interests of the CEP. Now managed by SCAR, the Portal was originally hosted and developed by New Zealand, in collaboration with SCAR and several other Antarctic Treaty Parties. The simple yet laudable aim of the Portal is to place up-to-date 'policy-ready' information about priority and emerging Antarctic environmental issues at the fingertips of anyone who needs it. The main target audience is CEP Members, Antarctic Treaty Parties and their national representatives, but the Portal also serves a variety of other stakeholders. For users, the Portal is a website (www.environments.aq) that presents succinct and science-based summaries of key issues, as well as an interactive map that can display and overlay a variety of environmental and activity layers. Behind the scenes, the information summaries are developed through a rigorous editorial processing involving both scientific peer-review and review to ensure an absence of bias or other issues that may might prove sensitive in the particular legal and political circumstances of Antarctica, and which might present impediments to uptake in the consensus-based setting of the Committee. The CEP and ATCM have commended the Portal as an important source of high quality, accurate, non-political and up-to-date scientific advice for use by Parties on a voluntary basis, and have requested SCAR to use the Portal, as appropriate, for providing state-of-knowledge reports on issues of policy and management relevance[46]. The Portal continues to be developed, and the CEP is regularly invited to review its Content Management Plan and make suggestions for new and revised information summaries.

Over the years, the CEP has regularly highlighted the importance of high quality science-based information to support and inform its work, and the importance of close engagement with the science community. The Committee has also regularly encouraged scientific activity to enhance the state of knowledge on which to base effective environmental protection measures. However, until recently, these identified 'science needs' were dispersed across various sources. The final reports of annual CEP meetings often contained a record of the Committee's agreement that further research was needed to better understand an issue, or to inform related environmental protection measures. Similarly, issue-specific work plans such as the Climate Change Response Work Program and guidance documents such as the Non-Native Species Manual and Clean-Up Manual identified priority areas for research. As a consequence, it was difficult even for experienced CEP representatives, let alone more recent participants, partner organisations or members of the science community, to gain a full picture of the types of science the Committee had already highlighted as important to inform its work.

Papers presented to the CEP meetings in 2017 and 2018 drew together 'science needs' previously identified by the Committee, in the broader context of considering ways to ensure the CEP could remain well placed to support the Parties' efforts to comprehensively protect the Antarctic environment[47]. In discussion, the Committee highlighted the importance of retaining close links between its work and science. Further, the Committee agreed that having a consolidated list of its identified science, knowledge and information needs would be useful as a communications tool for its engagement with the ATCM and other stakeholders, would help with promoting and supporting science to better understand and address the environmental challenges facing Antarctica, would help to ensure that it received relevant science input, and would support collaboration and prioritisation of related science[48]. The Committee decided to incorporate the science needs directly into its five-year work plan, to identify the links to priority issues and to ensure regular updates as needed. In the agreed format the five-year work plan now presents each issue, the relative priority assigned by the Committee (1-3 = higher to lower), associated actions, a program of tasks for the coming five-year period, and the related 'science knowledge and information needs' identified by the Committee. An example of this format is presented in Table 2.

From here, the Committee's science, knowledge and information needs will be reviewed and revised as appropriate, as part of the regular process during its annual meeting to update the five-year work plan. Publishing the science needs in conjunction with the policy needs should support broad engagement in efforts to better understand and address the environmental challenges facing Antarctica, including by guiding Members' respective national Antarctic science communities and national science processes, by identifying areas for collaboration between national science communities, and by supporting collaboration between the CEP and other organisations and programs involved in research and monitoring in the Antarctic region (e.g. SCAR, WMO, Southern Ocean Observing System). Some of the science needs currently presented in the five-year work plan are described in fairly general terms, so future updates would usefully consider whether they give scientific partners and stakeholders sufficient guidance to inform a response.

As a core component of the CEP five-year work plan, the incorporated science knowledge and information needs are now publicly available on the website of the Secretariat of the Antarctic

Priority 1 Issue: Introduction of non-native species

Actions

1.Continue developing practical guidelines & resources for all Antarctic operators.
2.Implement related actions identified in the Climate Change Response Work Programme
3.Consider the spatially explicit, activity-differentiated risk assessments to mitigate the risks posed by terrestrial non-native species.
4.Develop a surveillance strategy for areas at high risk of non-native species establishment.
5.Give additional attention to the risks posed by intra-Antarctic transfer of propagules.

Science, knowledge and information needs

•Identify terrestrial and marine regions and habitats at risk of introduction
•Identify native species at risk of relocation and vectors and pathways for intracontinental transfer
•Synthesise knowledge of Antarctic biodiversity, biogeography and bioregionalisation and undertake baseline studies to establish which native species are present
•Identify pathways for the introduction of marine species (including risks CEP Five-year Work Plan 2019 associated with wastewater discharge)
•Assess risks and pathways for introduction of microorganisms that might impact on existing microbial communities
•Monitor for non-native species in the terrestrial and marine environments (including microbial activity near sewage treatment plant discharges)
•Identify techniques to rapidly respond to non-native species introductions
•Identify pathways for introduction of non-native species without any direct human intervention

Priority 2 Issue: Repair or remediation of environmental damage

Actions

1. Respond to further request from the ATCM related to repair and remediation, as appropriate.
2. Monitor progress on the establishment of Antarctic-wide inventory of sites of past activity.
3. Consider guidelines for repair and remediation.
4. Members develop practical guidelines and supporting resources for inclusion in the Clean-up Manual.
5. Continue developing bioremediation and repair practices for inclusion in the Clean-up Manual.

Science, knowledge and information needs

- Research to inform the establishment of appropriate environmental quality targets for the repair or remediation of environmental damage in Antarctica
- Techniques to prevent mobilisation of contaminants such as melt water diversion and containment barriers
- Techniques for in situ and ex situ remediation of sites contaminated by fuel spills or other hazardous substances

Treaty[49]. However, the Committee has also agreed it would be beneficial to actively communicate its science needs directly to relevant groups, possibly using alternative formats tailored to the target audiences. SCAR has indicated that the science needs will be helpful for its consideration of new scientific research programmes[50]. For science needs related to climate change in particular, the Committee has noted that the SGCCR could play an important communication role[51].

The Committee has communicated this initial suite of science, knowledge and information needs to the ATCM, in keeping with its role under Article 12(k) of the Environmental Protocol to provide advice to the Antarctic Treaty Parties on the need for scientific research, including environmental monitoring. This advice has fed into ongoing priority discussions under the ATCM Multi-Year Strategic Work Plan related to Parties' science priorities, future Antarctic science challenges, and opportunities for enhanced international collaboration[52].

Concluding remarks

Almost 30 years after the adoption of the Environmental Protocol, there remains strong international commitment to protecting Antarctica, its environmental values and its value as a place for conducting globally-significant science. The Antarctic Treaty Parties recognise the key role that science and the CEP play in supporting those international efforts[53].

In the face of ongoing, new and emerging environmental challenges, the CEP wants and needs to draw on the best available science to inform its work. Doing so helps to ensure the CEP can provide the best possible support to the Parties, and also aids with the consideration and uptake of the CEP's advice and recommendations by the decision-making body, the ATCM.

It remains important for the CEP to clearly articulate policy priorities and questions that can guide research efforts. Building on the first steps taken with the CEP five-year work plan and linked science, knowledge and information needs will assist in that regard. Positive outcomes will also depend on continued action to encourage and support science that will contribute to understanding and addressing the environmental challenges facing Antarctica. The Committee and Parties will also need to be alert and responsive to new and emerging issues, including those that may become apparent through welcome contributions from the science community.

The existing actions and relationships described in this paper contribute to promoting an active and effective interface between Antarctic science and environmental protection, and it is clear that the Committee values the significant contributions made by SCAR and other sources of timely, relevant and high-quality scientific advice. This interface requires ongoing care and attention, and continued close engagement between the CEP and the science community will be essential. Encouragingly, experience suggests that the desire for such engagement is strong.

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Endnotes

1.The Antarctic Treaty system is the set of international agreements that collectively provide for the governance and management of the Antarctic region, taking into account its unique circumstances. Article 1(e) of the Protocol on Environmental Protection to the Antarctic Treaty defines Antarctic Treaty system as 'the Antarctic Treaty, the measures in effect under that Treaty, its associated separate international instruments in force and the measures in effect under those instruments'.

2. Antarctic Treaty, Article IX(2) establishes this requirement for acceding Parties to attain what is commonly referred to as Antarctic Treaty Consultative Party status. This provision does not apply to the 12 original signatories to the Antarctic Treaty, although it is arguable that their commitment had been demonstrated through their active participation in the 1957/58 International Geophysical Year, and in some cases their much earlier scientific efforts. There are currently 29 Consultative Parties and 25 Non-Consultative Parties – see https://ats.aq/devAS/Parties.

2. Environmental Protocol, Article 2 and Article 22.4.

3. Environmental Protocol, Article 2 states 'The Parties commit themselves to the comprehensive protection of the Antarctic environment and dependent and associated ecosystems and hereby designate Antarctica as a natural reserve, devoted to peace and science.'

4. Environmental Protocol, Article 10.1.

5. Environmental Protocol, Article 10.2, Article 11.4, Article 12.2.

6. Environmental Protocol, Article 3.

7. CEP Rules of Procedure, Rule 9. See https://documents.ats.aq/cephandbook/att469_e.pdf.

8. See ATCM Resolution 1 (2012) https://ats.aq/devAS/Meetings/Measure/515, the 2016 Santiago Declaration on the Twenty Fifth Anniversary of the signing of the Protocol on Environmental Protection to the Antarctic Treaty https://documents.ats.aq/ATCM39/ad/atcm39_ad003_e.pdf, and ATCM XLII / IP153 Strengthening Support for the Protocol on Environmental Protection to the Antarctic Treaty (Australia, France, Spain) https://documents.ats.aq/ATCM42/ip/ATCM42_ip153_e.doc.

9. See for example Decision 1 (2016) https://ats.aq/devAS/Meetings/Measure/631.

10. Environmental Protocol, Article 11.4.

11. See https://ats.aq/devAS/CEP/Authorities.

12. Environmental Protocol, Article 12.

13. See https://documents.ats.aq/atcm39/ww/atcm39_ww007_e.pdf.

14. See https://ats.aq/devAS/EP/GuidelinesAndProcedures.
15. See https://ats.aq/devph/en/apa-database.
16. See https://ats.aq/devAS/Ats/VisitorSiteGuidelines.
17. Article 3 of Annex III to the Environmental Protocol provides that the CEP shall review and provide advice on the criteria for proposing native mammals, birds, plants or invertebrates for designation as a 'Specially Protected Species', and on proposals for designation of Specially Protected Species. In developing its advice to the ATCM, the CEP is required to take into account any comments provided by SCAR and by other organisations as appropriate. The process is outlined in the Guidelines for CEP Consideration of Proposals for New and Revised Designations of Antarctic Specially Protected Species under Annex II of the Protocol https://documents.ats.aq/recatt/att381_e.pdf.
18. See https://documents.ats.aq/recatt/Att090_e.pdf.
19. See https://documents.ats.aq/recatt/Att667_e.pdf.
20. See https://documents.ats.aq/recatt/Att645_e.pdf.
21. See https://documents.ats.aq/recatt/Att605_e.pdf.
22. See https://documents.ats.aq/ATCM42/WW/ATCM42_WW008_e.pdf.
23. See https://ats.aq/e/committee.html.
24. See CEP Non-Native Species Manual https://documents.ats.aq/ATCM42/WW/ATCM42_WW008_e.pdf.
25. See SCAR/COMNAP Inter-continental Checklists For Supply chain managers of the National Antarctic Programmes for the reduction in risk of transfer of non-native species https://www.comnap.aq/wp-content/uploads/2019/11/Intercontinental-Checklists-2019.pdf.
26. See for example Chown et al., 2012.
27. The Environmental Domains Analysis is a classification of the Antarctic continent into 21 distinct Environments (also known as 'Environmental Domains') based on a suite of physical characteristics (climate, slope, land cover and geological data). See Morgan et al., 2007 and ATCM Resolution 3 (2008) https://ats.aq/devAS/Meetings/Measure/412.
28. The Antarctic Conservation Biogeographic Regions are 16 biologically distinct ice-free regions encompassing the
Antarctic continent and close-lying islands within the Antarctic Treaty area. See Terauds et al., 2012, Terauds & Lee, 2016 and ATCM Resolution 3 (2018) https://ats.aq/devAS/Meetings/Measure/661.
29. 204 bird breeding sites in Antarctica were identified as Important Bird Areas in Antarctica global criteria established by BirdLife International. See Harris et al., 2015 and ATCM Resolution 5 (2015) https://ats.aq/devAS/Meetings/Measure/616
30. See SCAR Strategic Plan 2017-2022 https://www.scar.org/library/scar-publications/strategic-plans/774-2017-strategic-plan/file.
31. See https://www.scar.org/policy/scats/.
32. See ATCM XLII/IP165 (2019) Co-conveners' report of the Joint SCAR / CEP Workshop on Further Developing the Antarctic Protected Area System. Prague, Czech Republic, 27-28 June 2019 https://documents.ats.aq/ATCM42/ip/ATCM42_ip165_e.doc.
33. See ATCM Resolution 7 (2019) on SCAR's Sixtieth Anniversary and the Role of SCAR in Providing Scientific Advice to Support the Work of the Antarctic Treaty System https://ats.aq/devAS/Meetings/Measure/707.
34. Recent examples include the ATCM XLII/WP050 (2019) Review and Update of the "Checklists for supply chain managers of National Antarctic Programs for the reduction in risk of transfer of non-native

species" https://documents.ats.aq/ATCM42/wp/ATCM42_wp050_e.doc prepared jointly by SCAR and COMNAP, ATCMXLII/IP024 (2019) Systematic Conservation Plan for the Antarctic Peninsula Project Updates https://documents.ats.aq/ATCM42/ip/ATCM42_ip024_e.doc prepared jointly by SCAR and IAATO, and ATCM XLII/IP042 (2019) Emperor penguins - vulnerable to projected rates of warming and sea ice loss; an international collaboration to inform species-related conservation decision-making and conservation planning https://documents.ats.aq/ATCM42/ip/ATCM42_ip042_e.doc prepared jointly by SCAR, United Kingdom, Australia, Finland, France, Germany, Norway, Monaco and ASOC.

35. ATCM XLIII/IP136 (2019) Antarctic Climate Change and the Environment – 2019 Update (SCAR) https://documents.ats.aq/ATCM42/ip/ATCM42_ip136_e.doc.

36. ATCM XXXI/WP10rev.1 (2008) Status of the Regional, Antarctic Population of the Southern Giant Petrel – Progress (SCAR) https://documents.ats.aq/ATCM31/wp/ATCM31_wp010_rev1_e.doc.

37. For example ATCM XLII/WP68 (2019) Anthropogenic Noise in the Southern Ocean: an Update (SCAR) https://documents.ats.aq/ATCM42/wp/ATCM42_wp068_e.doc.

38. For example ATCM XXXVIII/IP093 (2015) Monitoring biological invasion across the broader Antarctic: a baseline and indicator framework (SCAR) https://documents.ats.aq/ATCM38/ip/ATCM38_ip093_e.doc, or ATCM XXXV/WP6 (2012) Reducing the risk of inadvertent non-native species introductions associated with fresh fruit and vegetable importation to Antarctica (SCAR) https://documents.ats.aq/ATCM35/wp/ATCM35_wp006_e.doc.

39. See for example ATCM XL/IP147 (2017) Climate Change Report Card (ASOC) https://documents.ats.aq/ATCM40/ip/ATCM40_ip147_e.doc.

40. See for example ATCM XLII/IP099 (2019) Reducing Single-Use Plastic and Waste Generated by Polar Tourism (IAATO) https://documents.ats.aq/ATCM42/ip/ATCM42_ip099_e.doc.

41. Recent examples include ATCM XLII/IP094 (2019) The Year of Polar Prediction in the Southern Hemisphere: Consolidation Phase (WMO) https://documents.ats.aq/ATCM42/ip/ATCM42_ip094_e.doc and ATCM XLIII/IP164 (2019) Scoping Workshop: Towards Implementing an Antarctic Regional Climate Centre Network https://documents.ats.aq/ATCM42/ip/ATCM42_ip164_e.doc.

42. See for example ATCM XLII/WP1rev.1 (2019) The Antarctic Peninsula under a 1.5°C global warming scenario (United Kingdom) https://documents.ats.aq/ATCM42/wp/ATCM42_wp001_rev1_e.doc, ATCM XLII/IP12 (2019) Numerical evaluation of mobile sources impact at environmental impact assessment in the Antarctic (Belarus) https://documents.ats.aq/ATCM42/ip/ATCM42_ip012_e.doc and ATCM XLII/IP150 (2019) Eradication of a non-native grass Poa annua L. from ASPA No 128 Western Shore of Admiralty Bay, King George Island, South Shetland Islands – update 2018/2019 (Poland) https://documents.ats.aq/ATCM42/ip/ATCM42_ip150_e.doc.

43. See for example ATCM XXXI/WP27 (2008) Systematic Environmental Protection in Antarctica: Final report on Environmental Domains Analysis for the Antarctic continent as a dynamic model for a systematic environmental geographic framework for Annex V of the Protocol (New Zealand) https://documents.ats.aq/ATCM31/wp/ATCM31_wp027_e.doc.

44. Although the ATCM in 2018 expressed willingness to consider proposals for funding to assist the CEP to undertake priority work, on a case-by-case basis (ATCM XLI Final Report, para 131), which might usefully provide some scope for the CEP to develop or commission targeted science-based products.

45. ATCM Resolution 3 (2015) The Antarctic Environments Portal https://ats.aq/devAS/Meetings/Measure/614.

46. ATXM XL/WP034 (2017) Supporting the work of the Committee for Environmental Protection

(CEP): A paper by the CEP Chair https://documents.ats.aq/ATCM40/wp/ATCM40_wp034_e.doc and ATXM XLI/WP017 (2018) Supporting the work of the Committee for Environmental Protection (CEP): A paper by the CEP Chair https://documents.ats.aq/ATCM41/wp/ATCM41_wp017_e.doc.

47. CEP XX Final Report (2017), paras 22-27 https://documents.ats.aq/ATCM40/cr/ATCM40_cr001_e.pdf.

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An effort to make the impossible possible – managing Antarctica for climate change

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Abstract

Antarctica is set aside as a reference area for science and monitoring, as is clearly underlined in the Environmental Protocol. Anthropogenic climate change is already having an impact in Antarctica and will in the future likely to be the most important factor threatening the values held in this unique nature reserve. While climate change over the last 5-10 years has been a top priority issue in the work of the Committee for Environmental Protection, this has not always been the case. This article explores the evolution of CEP's climate change discussions over the years and how the Committee has worked to organize and prioritize its efforts in this regard. Through the Committee's continued efforts to develop climate change strategies and actions the Antarctic Treaty Parties will be better placed to maintain the values of the Antarctic nature reserve in the face of climate induced environmental change.

Key Words

Antarctic, Environmental Protocol, CEP, policy, climate change.

Introduction

The Parties to the Antarctic Treaty, through the adoption of the Protocol on Environmental Protection to the Antarctic Treaty (1991), the Environmental Protocol, set aside Antarctica as a nature reserve, and thereby committed themselves to comprehensive protection of the Antarctic environment, as well as dependent and associated ecosystems[1]. Antarctica as a nature reserve differs from the traditional concept of nature reserves[2] in many respects, as the emphasis is on protection of the whole suite of environmental values present in the entire area[3] rather than specific and/or rare values in a relatively limited geographic area. But as the case is for many nature reserves, also Antarctica is set aside as a reference area for research on and monitoring of processes of both regional and global importance, as is clearly underlined in the Environmental Protocol[4]. Whatever way one looks at it, it is clear that the protection objectives of the Environmental Protocol sets high aims for safeguarding Antarctica's unique environment into the future.

The Protocol holds a large collection of provisions that direct Parties in their effort to achieve this overarching protection objective. Key to this is the general environmental principle that all activities that are to take place in Antarctica have to be planned and conducted in such a manner that adverse effects on the environment are avoided[5]. This key requirement is supported by a large number of specific provisions that frames and guides all human activity in Antarctica for which advance notice is required in accordance with the Antarctic Treaty. Furthermore, the Environmental Protocol also stipulates a number of additional tools that the Parties can effectuate to strengthen protection where values may be at risk. The opportunity to designate specific areas as Specially Protected Areas[6] and species at risk as Specially Protected Species[7] are examples of such tools.

In adopting the Environmental Protocol, the Antarctic Treaty Parties also established an organizational structure to support their efforts in overseeing the implementation of this extensive legal framework. This was accomplished by including a provision establishing a Committee for Environmental Protection (commonly known as, and hereafter referred to as the CEP or the Committee), which would be mandated to provide advice and guidance to the Parties as how to maintain and reach the overarching goal of comprehensive protection[7]. In its advisory capacity the CEP also develops management tools for the consideration and adoption by the Treaty Parties, for example guidance for environmental impact assessments, conservation of flora and fauna, environmental monitoring, marine pollution, protected species, waste from past activities, historic sites and monuments, and more. The Committee guides and prioritizes its discussions on basis of a five-year work plan, in which it has identified high-priority environmental issues[9].

Climate change has over the last 5-10 years been a top priority issue in the CEP five-year work plan. While it is clear that climate change is caused and aggregated by human activities and actions that take place elsewhere than in Antarctica itself, there is a clear and general agreement that anthropogenic climate change is already having an impact in Antarctica and is in the future likely to by far be the most important factor influencing the Antarctic environment (see Box 1), and thereby threatening the values held in the unique nature reserve that Antarctica is. However, climate did not have such a prominent place in the agenda at the start of the Committee's work. This article explores the evolution of CEP's climate change discussions over the years, and how the Committee has dealt with the dilemma of having to manage for a major threat caused by actions and activities that lie outside the remit of the Committee's responsibilities.

BOX 1

The climate system and the way it is changing is complex and dynamic, and there are many knowledge gaps to be filled to achieve a full and comprehensive understanding of how the changes will influence the overall environment. However, below are briefly described some recent observations that may be relevant to highlight as potential signals of climate change induced changes to the environmental values of Antarctica.

The recent IPCC Special Report on Oceans and Cryosphere in a changing Climate (IPPC, 2019) summarizes that the Southern Ocean is warming and being disproportionately and increasingly important in global ocean heat increase. Ocean warming here as elsewhere has contributed to observed changes in biogeography of organisms ranging from phytoplankton to marine mammals, consequently changing community composition, and in some cases, altering interactions between organisms.

While many continental regions of Antarctica have not exhibited significant change over the past century, in some parts of the Antarctic Peninsula, the annual mean air temperatures rose significantly between 1950 and 2000, although noting a recent pause in this atmospheric warming. The terrestrial Antarctic biota is characterized by considerable physiological and ecological flexibility and can generally speaking be expected to show increases in productivity, population sizes and ranges of individual species, and community complexity, while the establishment of non-native organisms (exuberated by climate change) may present an even greater threat than climate change itself (see e.g. Convey and Peck, 2019).

Recent studies and observations relevant in context of impacts of climate change include[10]:

- Rapid changes in terrestrial vegetation in response to regional drying in the Windmill Islands, East Antarctica (Robinson et al. 2018).
- Two massive breeding failures in an Adélie penguin colony in Terre Adélie, East Antarctica, with no chicks surviving the 2013–14 and 2016–17 breeding seasons in years with crucial differences in the timing of sea-ice recession compared to other years (Ropert-Coudert et al. 2018).
- Indications that the main krill population centre between 20° and 80°W in the Southern Ocean experience a climate-related poleward contraction in its distribution over the last 90 years (Atkinson et al. 2019).
- Emperor penguins are shown to be highly sensitive to climate change, given their critical reliance on sea ice during breeding (e.g. Ainley et al., 2010; Jenouvrier et al., 2017).
- The risk of establishment of non-native species is likely to increase with climate warming. Most known Antarctic non-native species have been found within the Antarctic Peninsula

BOX 1

region. Non-native invertebrate species have already begun to increase their distribution within Antarctica (Newman et al. 2014).

•Ice-free areas in Antarctica could expand by over 17,000 km2 by the end of the century, close to a 25% increase, under the strongest IPCC forcing scenario (Lee et al., 2019). Most of this expansion would occur in the Antarctic Peninsula, where the availability and connectivity of biodiversity habitat would drastically change.

It is important to note that the implications of climate change for individual species over the short term can be both positive and negative, while the ecosystem balance would be expected to change in the longer term. Certain species and ecosystem components that define Antarctica as we know it today are under pressure, and as such threatens the aim of the Environmental Protocol in protecting Antarctica.

The journey toward the top of the priority list – path and decisive actions

When the Environmental Protocol came into force and the CEP had its first meeting in 1998, climate change had already started to become a clearly visible issue of global concern. IPCC had just released its second assessment report in 1995, and in 1997 the UNFCCC's Kyoto Protocol was adopted (coming into force in 2005). Nevertheless, despite the obvious key role climate has in shaping Antarctica, the CEP in its early years had very few dedicated discussions relating to climate change and its implication for the Antarctic environment, and judging by report language few connections were made between other conservation issues and the overarching climate change challenge in the setting of the Committee. In the first seven meetings the word "climate" is only found a handful times in total in the final reports from the Committee's meetings.

A small shift took place around 2005, after the release of IPCC's third assessment report in 2001 and the coming into force of the Kyoto Protocol in 2005, with an increasing focus on climate change challenges relating to a wide array of the agenda items discussed. At its meeting in Stockholm (Sweden) in 2005 the CEP had extensive discussions about its future work, including major issues facing the CEP currently and in the future. The records from these discussions show that "global environmental pressures, including climate change" was amongst those issues identified as needing further consideration[11]. The initial discussions in Stockholm were followed up by a dedicated CEP workshop on Antarctica's Future Environmental Challenges, held in conjunction with the Committee's meeting in Edinburgh (United Kingdom) in 2006, where climate change again was highlighted as an important external pressure for the Committee to consider in its future deliberations[12].

At the tenth meeting of the Committee in New Delhi (India) in 2007 climate change jumped right to the top of issues that the Committee dedicated its attention to. Two important steps were taken. Firstly, as a follow-up from the future challenge discussions that had taken place during the preceding CEP meeting, the Committee adopted its first (provisional) five-year workplan as a tool for it to prioritize topics it should focus its discussions and work on[13]. In this first workplan climate change was identified as an issue of high priority. Secondly, the Committee agreed to add climate change as a standing item on its agenda, albeit initially as a sub-item under its agenda item on Environmental Monitoring and Reporting[14].

These important steps forward did not happen in a vacuum, but rather in the context of a number of major relevant global climate events and initiatives. It was just a few years after the Arctic Council in the north had concluded its important and very politically speaking impactful work on assessing climate change and climate change impacts for the Arctic[15], it was the same year as IPCC released its fourth assessment report[16], and it was in the run-up of the massive international scientific initiative, the International Polar Year 2007-08 which aimed amongst other to improve the general understanding of the critical role of the polar regions in global (climate) processes.

Thus there was a clear backdrop to the heightened focus on climate change in the Committee. There was an obvious motivation for making climate change visible on the agenda with a widening recognition of the importance and significance of climate change in Antarctica and the implications for the CEP's environmental management responsibilities in the continent. Although the Committee did agree to add climate change to the agenda, the idea of focusing more on climate change in the CEP did not come without hesitation amongst some Members. And in the discussions it was clearly indicated by some Members that attention on the issue of climate change should be restricted to the Antarctic context and not duplicate efforts by other international organizations such as the IPCC and UNFCC. Nevertheless, climate change has since 2007 been an identified and prioritized topic for discussion at the Committee's meetings. This shift is also clearly reflected in a generally speaking increased number of relevant references to climate change in the final reports of the Committee's meetings. From 2011 climate change became a stand-alone item on the agenda - Climate Change Implications for the Environment.

Identifying key issues and organizing the discussions

The implications of climate change for the management of Antarctica are extensive and complex, and the CEP in many respects faced an enormous challenge in finding a direction and focus for its efforts. Two important initiatives were particularly important in assisting the Committee in shaping its direction.

Firstly, the Scientific Committee for Antarctic Research (SCAR) did a fundamentally important effort by collating and assessing all available scientific evidence on climate change and climate change impacts in the Antarctic through its Antarctic Climate Change and the Environment (ACCE) process, cumulating in an extensive report published in 2009 (Turner, J. et al.). This initiative was very much inspired by the work that had been undertaken by the Arctic Monitoring and Assessment Program (AMAP), a working group under the Arctic Council, a few years earlier in compiling and assessing the current Arctic climate and climate impact science in the Arctic Climate Impact Assessment (ACIA) report. The effort had proved to be substantial and groundbreaking for robust and evidence based discussions on climate change issues in the north, and SCAR noted that the ACCE "should be taken as a companion to the Arctic Climate Impact Assessment published in 2005"[17]. Through the ACCE report SCAR presented the current understanding of the physical and chemical climate system of the Antarctic region, the way it varies through time, and the profound influence of that variation on life on land and in the ocean around the continent. It also examined predictions of how the system would evolve over the next century under conditions of increasing concentrations of greenhouse gases and recovery of the ozone hole. A summary of ACCE was prepared and submitted to the CEP at its meeting in Baltimore (the United States) in 2009. The Committee welcomed this assessment as an important scientific foundation for its climate related discussions, and both strongly encouraged further research to close important knowledge gaps and welcomed regular updates of the report to ensure that it at all times would have the best available science as basis for its discussions.

Secondly, the Antarctic Treaty Parties, at their meeting in 2009 (Baltimore, United States), decided on basis of advice from the CEP to arrange a separate meeting of experts on the implication of climate change for management and governance of the Antarctic region[18]. This Antarctic Treaty Meeting of Experts (Climate ATME) was held in Norway in April 2010. The meeting was mandated to examine a number of topics relevant to the issue of climate change in Antarctica, in particular key scientific aspects of climate change and consequences of such change to the Antarctic terrestrial and marine environment; implications of climate change to management of Antarctic activities; the need for monitoring, scenario planning and risk assessments; and the outcomes of the Copenhagen negotiations relevant for the Antarctic. The Climate ATME was highly successful and broadly attended meeting. The participants agreed that Antarctic climate change and the implications for governance and management in Antarctica was both a relevant and important topic to discuss under the Antarctic Treaty system and emphasized the importance of continuing the discussions on climate change issues in Antarctica. They also particularly emphasized the importance of the ACCE as a fundamental source of scientific information and the importance that the findings and recommendations of the report will play in further consideration of climate change issues in the Antarctic. A full 22 the 30 recommendations that came out of the Climate ATME were directly relevant for the CEP's agenda and continued discussions and would in the years to come prove to provide invaluable guidance for the Committee.

The next major structural initiative taken by the CEP to tackle the complexity of the climate change discussions related to a key recommendation from the Climate ATME which had suggested that the CEP should consider developing a climate change response work program, incorporating for example management of non-native species, vulnerability of ASPAs in light of climate change and the suitability of existing management tools in a climate change context. In 2013, at its meeting in Brussels (Belgium) the Committee, in being presented with an update of the ACCE findings from 2009, noted the pace of change reported in the update and in this context recalled the Climate ATME recommendation regarding a response work program, and decided on this basis to initiate work in developing such a program[19]. Extensive discussions took place both during the meetings and through formal intersessional work, paving the way for the adoption of the Committee's first Climate Change Response Work Programme (CCRWP) at the Committee's meeting in Sofia (Bulgaria) in 2015. In adopting the CCRWP, the Committee noted that it identified actions consistent with its roles and functions, specifically focusing on addressing impacts of climate change in Antarctica and not duplicating the climate change mitigation activities which were appropriately the responsibility of other bodies. The Committee agreed to retain the CCRWP as a separate document, to be flexible and dynamic, and to be updated annually as required[20]. The Antarctic Treaty Parties, welcoming the work and advice of the CEP, adopted a Resolution that same year, encouraging the CEP to begin implementing the CCRWP as a matter of priority, and provide annual progress reports to the Antarctic Treaty Consultative Meeting on its implementation[21]. Box 2 provides a summary of the CCRWP as it was adopted in 2015. Currently the implementation and review of the Climate Change Response Work Programme is a standing subitem on the CEP's agenda item on climate change.

Box 2: CCRWP

The Committee for Environmental Protection's Climate Change Response Work Programme has been developed with the following vision as basis:

Taking into account the conclusions and recommendations from the ATME on Climate Change in 2010, the CCRWP provides a mechanism for identifying and revising goals and specific actions by the CEP to support efforts within the Antarctic Treaty System to prepare for, and build resilience to, the environmental impacts of a changing climate and the associated implications for the governance and management of Antarctica.

Within a number of specific climate change issue areas (first column in table) the CCRWP identifies gaps and needs (second column in table) and suggests prioritized actions and tasks for the CEPs further work.

Climate related issue	Gaps/needs
Enhanced potential for non-native species (NNS) introduction establishment	•Framework for surveillance for non-native species establishments in marine, terrestrial and freshwater environment •Response strategy for suspected NNS introductions •Assessment of whether existing regimes for preventing NNS introductions and transfer are sufficient. Analyze management tools applied in other areas. •Improved understanding of risks associated with relocation of native terrestrial species •Assessment and mapping of Antarctic habitats at risk of invasion •Assessment of risks of introducing non-native marine species •Techniques for eradication and control •Ongoing surveillance programme to identify status of NNS in light of climate change
Change to the terrestrial(incl. aquatic) biotic and abiotic environment due to climate change	•Understanding how terrestrial and freshwater biota will respond to a changing climate and the impacts of these changes •Understanding as to how the abiotic terrestrial environment will change and the impacts of these changes

Box 2: CCRWP

Climate related issue	Gaps/needs
Change to marine near-shore abiotic and biotic environment (excluding OA)	•Understanding and have the ability to predict near-shore marine changes and impacts of the change •Have a broader understanding of what monitoring data will be required to assess climate driven changes to the marine environment
Ecosystem change due to ocean acidification	•Understanding of the impact of OA to marine biota and ecosystems
Climate change impact to the built (human) environment resulting in impacts on natural and heritage values	•Understanding how the abiotic terrestrial environment will change and how this might impact result in impacts on environmental or heritage values •Understanding of effects of climate change on contaminated sites and implications for species/ecosystems (eg. whether climate change will increase mobilization and exposure of species/ecosystems to contaminants and understanding how species/ecosystems will respond to exposure to such contaminants) •Understanding what conservation/remedial interventions might be applicable to counteract these impacts
Marine and terrestrial species at risk due to climate change	•Understand population status, trends, vulnerability and distribution of key Antarctic species •Improved understanding of effect on climate on species at risk, including critical thresholds that would give irreversible impacts •Framework for monitoring to ensure the effects on key species are identified •Understand relationship between species and climate change impacts in important locations/areas
Marine, terrestrial and freshwater habitats at risk due to climate change	•Understand habitat status, trends, vulnerability and distribution •Improved understanding of the effects of climate change on habitat, eg. sea ice extent and duration, snow cover, ground moisture, microclimate, changing melt flows and consequences to lake systems •Improved understanding of potential expansion of human presence in Antarctica as a result of changes resulting from climate change through e.g. changes in sea ice distribution; collapse of ice shelves; expansion of ice free area).

Recognizing that a work program rarely implements itself, but needs oversight and coordination, the CEP immediately initiated a discussion to identify the best mechanisms for managing and supporting implementation of the CCRWP. This culminated cumulated in the CEP agreeing at its meeting in 2017 (Beijing, China) to establish a Subsidiary Group on Climate Change Response (SGCCR) charged to facilitating the coordination and communication and updating of the CCRWP[22]. Today the SGCCR is starting to find its place as a permanent subsidiary group of the CEP, balancing the structural charge of coordinating and communicating the CCRWP actions and proactively moving CCRWP actions forward. It should be expected that the SGCCR will start to visibly shape the climate agenda of the CEP in the years to come.

Connecting with CCAMLR on the issue of climate change

Climate change in Antarctica has both terrestrial and marine implications, which interlink and intertwine. As a consequence, climate change is clearly an overlapping area of interest and concern between the CEP and its sister body the Scientific Committee under the Convention for the Conservation of Marine Living Resources (SC-CCAMLR), where both are bound to consider implications of climate change in this area in their efforts to provide advice for sustainable management to the Antarctic Treaty Consultative Parties and the CCAMLR Members respectively. This was clearly recognized at a (first) joint workshop between the two committees, held in Baltimore in 2009, where climate change was identified as an area where the development of joint approaches and understanding would be particularly pertinent[23]. A second joint workshop, held in Punta Arenas (Chile) in 2016, focused on this topic in particular, aiming to identify the effects of climate change that were considered most likely to impact the conservation of the Antarctic, and to identify existing and potential sources of research and monitoring data relevant to the two bodies[24]. This workshop was particularly valuable in further enhancing the cooperation and information sharing between the two committees, enabling a joint understanding of the evidence base relating to climate change in the area of joint concern, and thereby paving the way for compatible approaches in supporting policy making in a changing Antarctic and Southern Ocean into the future.

What climate issues have been in focus?

It could be said that the CEP in principle has two general tracks to follow with regard to the specific discussions relating to climate change as basis for any advice to the Antarctic Treaty Parties on the effectiveness of current measures and need for additional measures to protect Antarctica (as mandated through Article 12 of the Environmental Protocol).

One track relates to any influence Antarctic activities may have on the overall climate change which in turn impacts the Antarctic environment. Article 3 (2)(i) of the Environmental Protocol requires activities to be planned and conducted so as to avoid adverse on climate and weather patterns. The other track is more convoluted, considering existing and potential new measures that would contribute to mitigate the negative impacts of climate change on the Antarctic environment, and thereby maintain the values of the nature reserve envisioned by the Environmental Protocol. This track has by far been the main focus of the CEP climate discussions, reflecting the relative importance between these two climate pressures issues in the Antarctic context. The following will briefly touch on some of the issues that the CEP has had its attention on with respect to these two tracks.

Protecting Antarctica from anthropogenic climate change

The CEP is charged with advising on effectiveness of current measures and need for additional measures for the Parties' efforts to protect Antarctica[25], which without doubt should be understood to include consideration of measures that aim to mitigate negative impacts of anthropogenic climate change.

Understanding how and where climate change impacts the Antarctic environment is a fundamental basis and starting point for assessing effectiveness of existing measures and considering new measures. Understanding how and where climate change impacts the Antarctic environment is also an extremely complex charge, where there will always be a lack of knowledge while at the same time new knowledge is produced and made available constantly.

The Environmental Protocol specifies that the CEP, in carrying out its functions, should consult with the Scientific Committee on Antarctic Research (SCAR)[26], and SCAR does indeed provide significant scientific support for the CEP. Some key examples include:

- SCAR's compilation of current state of knowledge through the ACCE report was an enormous step forward and a key contribution to the CEP's climate change toolbox. The Committee very quickly requested that SCAR to provide annual/regular updates on this report, to allow the Committee's members to have the best available scientific understanding as basis for their deliberation. The regular updates are not represented as a synthesis report, but as a perspective on recent scientific advances.

- Since 2003 the Antarctic Treaty Consultative Meetings have included a SCAR lecture, in which SCAR has highlighted for the Antarctic Treaty Parties and the CEP Members science issues with policy implications. A number of these lectures have directly or indirectly provided insight into climate change issues relevant for Antarctic governance, and is an important supplement in the evidence base toolbox available to the CEP in its climate discussions. In 2017 the SCAR Science Lecture focused on what the United Nations Paris Climate Agreement means for Antarctica, followed up in 2019 on what the Paris Climate Agreement means for Antarctic and Southern Ocean Environmental Protection, the latter outlining the implications of the 2015 Paris Climate Agreement for biodiversity and its protection in the broader Antarctic region, and for biodiversity conservation globally. The Committee noted that this lecture in particular lecture was impactful, widely attended, and provided useful and detailed context for its discussions[27].

- SCAR plays an active role towards the CCRWP, both through mapping SCAR members' activities against gaps and needs identified in the work program and by participating actively in the SGCCR providing invaluable guidance in the group's efforts to track science developments relevant for management purposes and thus updating of the CCRWP.

Another tool which is available for the CEP for the purpose of having access to the evidence base is the Antarctic Environments Portal, which aims to be an important link between Antarctic science and Antarctic policy, by allowing easy access to reliable, science-based information on a range of issues relevant to the management of the Antarctic environment[28].The Portal contains a number of relevant information summaries on the topic of climate change and climate change implications.

Generally speaking discussions relating to climate change impacts have been topic based, rather than taking on the full scale complexity of climate change impacts in one go. The Climate ATME gave a rare opportunity for spending time discussing the science underpinning impact knowledge. In 2019, at its meeting in Prague, the Committee had an unusual extensive and comprehensive climate change impact discussion relating to the Antarctic Peninsula under a 1.5°C global warming scenario, where it underlined the importance of it remaining informed about climate change and to take a leadership role in considering the implications of a climate change for the Antarctic environment. The Committee noted that it would be important to take the anticipated changes into account as it continued to develop its management tools and guidance material and emphasized the importance of considering regional variations in climate change, both for management actions and for research and long-term monitoring, and highlighted the need for a better understanding of the impacts of the combined pressures of human activities and climate change in Antarctica[29]. Although the CEP itself does not discuss and provide advice related to implementation and commitments to global climate agreements, discussions and advice that clearly show the implications of potential future climate scenarios could be said to provide an important impetuous to the Parties to participate in such discussions.

Since climate change gained a strong foothold in the CEP agenda the Committee has to a large degree approached the question of climate change impacts topic by topic, or maybe rather management tool by management tool. This has likely been a sensible approach, and the only way to gain any headway with the complexity of the topic. While early discussions in this regard were more by chance, topic directed recommendations from Climate ATME contributed to formalize and structure such topical discussions, as did the CCRWP. The topics that have been under most scrutiny in context of climate change impacts are non-native species, Antarctic protected areas and protected area systems, protected species and EIA-processes.

The Committee has had numerous discussions relating to area protection in light of climate change, which have contributed to develop the overall thinking and the particularities of this particular management tool. At their meeting in Brasilia (Brazil) in 2014 the Committee discussed experiences from the Arctic in applying a particular management tool and noted that protecting areas which are resilient to climate change may ultimately assist in the longer-term protection of biodiversity[30]. Although the discussion itself did not lead to concrete decisions, it nevertheless contributed to heighten awareness of the utility of protected area tool as an active response to climate change in order to pursue the protection goals of the Environmental Protocol. The SCAR/CEP Workshop on Further Developing the Antarctic Protected Area System held prior to the Committee's meeting in Prague (Czech Republic) in 2019 also discussed the importance of climate change in the further development of the Antarctic protected area system, including considering climate change pressures in identifying sites for protection, addressing the synergistic pressures of climate change and other pressures, and considering the potential of protecting "climate refugia"[31].

Likewise, in 2016, the Committee adopted a revised version of its guidelines for the Environmental Impact Assessment (EIA) process, where amongst other the issue of climate change was incorporated as a new element. The updating of the guidelines in this regard was a direct response to the Climate ATME recommendation which called for a review of existing management tools to assess their continuing suitability in a climate change context, identifying the relevance of updating the EIA guidelines particularly with regard to planned long-term activities. The updated guidelines thus, include a number of reference to climate change as an impact factor, and calls for those planning activities in Antarctica to give consideration to anticipated / potential environmental consequences of climate changes in the location of the proposed activity, and over the timeframe of the proposed activity, including the decommissioning phase where relevant. While such guidelines only provide guidance to a proponent of Antarctic activities, they are nevertheless provide the proponent with a reminder of the seriousness of the issue and the fact that it may influence the planning of activities.

If a scientific assessment determines that a species is at significant risk of extinction the CEP can recommend Specially Protected Species designation to the ATCM[32] and develop an Action Plan for the species. The Committee has so far not designated any species as Specially Protected Species. However, research has shown that climate change is contributing to putting certain species at risk (see eg. Morley et al., 2019; Thratan et al., 2020. While the CEP so far has not developed sufficient information on the conservation status of Antarctic species to support SPS designation on this basis, there are currently indications that proposals relating to designating species as SPS due to climate risk may be expected shortly. At its meeting in 2019 the Committee discussed the dependence and vulnerability of emperor penguins to climate change and noted the need for further research and collaboration on the subject. There were clear indications in the material put forward that this was to be seen as initial steps in a designation assessment process[33].

Avoiding adverse impact on climate and weather patterns from Antarctic activities

There have been few in-depth discussions in the CEP relating to how Antarctic activities contribute to climate change, and when the topic has been brought to the table it has mostly been dismissed, both with the argument from some Members that the contribution of Antarctic emissions to global emissions are negligible and cautioning that the CEP should not duplicate efforts of other organizations in this regard. While some Members have stressed the symbolic effect that the opportunity provided for Antarctica to set an example to the rest of the world in actively reducing greenhouse gas emissions, these discussions have generally speaking not led to any clear and specific actions. For example, a suggestion brought to the table by the United Kingdom at CEP XI (Kiev, Ukraine) to standardize emission calculations in Comprehensive Environmental Evaluations (CEEs) met opposition, where for some Members expressed concern that the CEP should not be duplicating efforts of other organizations, particularly with respect to CO2, while other Members expressed caution over attempting to set standards for calculating emissions, with many countries bound by their own domestic standards[34].

Although the CEP discussions relating to greenhouse gas emissions and reduction of carbon footprint in Antarctica often has been stifled as it has touched upon sensitive policy and political agendas, where the "difficult" Members have varied through time, the Committee has nevertheless in many instances throughout the years discussed and promoted green technology as an important effort to reduce environmental impacts and risks in Antarctica, but which has been recognized to also contribute to reduced emission in Antarctica. While the Committee at its first meeting (1998) considered that it might be better that energy sources and alternative energy issue should considered first in the operations discussion of the ATCM itself, as these were issues that had operational implication[35], in following up one of the recommendation from the Climate ATME the Committee nevertheless acknowledged and encouraged continuing efforts in developing and exchanging experience of energy efficiency and alternative energy practices so as to promote reduction of the carbon footprint of activities in Antarctica and cut fossil fuel use from stations, vessels, ground transportation and aircraft[36].

Two issues relevant in the context of climate change, and which are of global concern - Black Carbon and Ocean Acidification – have only been superficially considered thus far, but have been identified by the Committee as issues that need attention in future discussions[37].

The science needs

Very often CEP discussions relating to climate change issues one way or the other conclude that further knowledge is required and there is a need for more research. The Committee itself is not in a position to do or initiate science, but it does highlight its needs for the science community to pick up on[38]. Both the CEP five-year workplan and the CCRWP contains an overview of general science needs, and are used for communicating these needs. The Committee's current science needs relating to climate change is extensive and ranges from the general need to improve our understanding of current and future change in terrestrial, aquatic, near-shore and marine biotic and biotic environment due to climate change to more specific needs such as identifying areas that may be resilient to climate change and impacts of climate change on key Antarctic species[39].

Concluding remarks

This article has explored when and how the issue of climate change has made its way into the CEP agenda, and what the outcomes have been so far. Largely reflecting the increased global awareness of the problem, the issue has moved its way from barely being visible in the discussions to weaving into almost all of the topical discussions that take place in the Committee. Although the climate challenges are as extensive if not more as before, there is good cause to applaud the Committee's efforts to organize and tackle the complexity of the issue, and there is good reason to believe that through the Committee's continued efforts to develop climate change strategies and actions the Antarctic Treaty Parties will be better placed to maintain the values of the Antarctic nature reserve, as envisioned by the Environmental Protocol.

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Endnotes

1. Environmental Protocol, Article 2.

2. A nature reserve is generally speaking understood to be an area of land protected in order to keep safe the animals and plants that live there, often because they are rare. Nature reserves are often relatively small. IUCN defines the protected area category "strict nature reserve" as an area strictly set aside to protect biodiversity or geological/geomorphological features, where human visitation, use and impacts are strictly

controlled and limited. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.
3. The Antarctic continent itself is approx. 14 million square kilometres (the size of the United States and Mexico combined), while the surrounding Southern Ocean adds on another 20 million square kilometres or so.
4. For example the fifth operative paragraph of the Preamble to the Protocol confirms Parties acknowledgement of "the unique opportunities Antarctica offers for scientific monitoring of and research on processes of global as well as regional importance"
5. Article 3 of the Environmental Protocol sets out the underlying environmental principle of the protection regime as follows: "The protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area."
6. Environmental Protocol, Annex V, Article 3
7. Environmental Protocol, Annex II, Article 3 (4)
8. Environmental Protocol Article 11 establishes the Committee for Environmental Protection and entitles all Parties to be members, while Article 12 establishes the Committee's functions.
9. The CEP adopted the first version of a five-year workplan (provisionally) at CEP X in New Delhi (cf. CEP X Final Report (2007), paras 7-17).
10. These examples draw on information found in CEP XXII IP 136, containing SCAR's annual update on its Antarctic Climate Change and the Environment report, as well as CEP XXII IP 42 on implications of 1.5 degree warming in the Antarctic Peninsula and the Antarctic Environments Portal (www.environments.aq).
11. CEP VIII Final report (2005), paras 11-32 and Annex 6.
12. See CEP IX WP 42 and IP 113 reporting from the workshop on Antarctica's Future Environmental Challenges.
13. CEP X Final Report (2007), paras 7-17.
14. CEP X Final report (2007), paras 269-275.
15. ACIA, 2005. Arctic Climate Impact Assessment
16. IPCC, 2007: Climate Change 2007
17. See the preface of the ACCE Report (Turner et al., 2009).
18. ATCM XXXII Decision 1 (2009) Meeting of Experts on Climate Change
19. CEP XVII Final Report (2013), paras 62-67.
20. CEP XIX Final Report (2015), paras 73-80 and Appendix 2.
21. ATCM XXXIX Resolution 4 (2015) Committee for Environmental Protection Climate Change Response Work Programme.
22. CEP XX Final Report (2017) paras 67-79. The establishment of SGCCR was confirmed by the Antarctic Treaty Parties through ATCM XL Decision 1 (2017) Subsidiary Group of the Committee for Environmental Protection on Climate Change Response (SGCCR).
23. CEP XII Final Report (2009), paras 261-268.
24. CEP XIX Final Report (2016), paras 43-56.
25. Environmental Protocol, Article 12 (1).
26. Environmental Protocol, Article 12 (2).

27. CEP XXII Final Report (2019), para 37.
28. The Antarctic Environments Portal is described in more detail in McIvor (2020) in this volume of JAA.
29. CEP XXII Final Report (2019), paras 38-42.
30. CEP XVII Final Report (2014), para. 56-58.
31. CEP XXII Final Report (2019), paras 172-180.
32. Environmental Protocol, Annex II, Article 3 (4).
33. CEP XXII Final Report (2019), paras 198-200.
34. CEP XI Final Report (2008), paras 135-143.
35. CEP I Final Report (1998), para 8.
36. CEP XIII Final Report (2010), para 370.
37. Ocean Acidification is identified as a separate climate change issue in the CCRWP (https://documents.ats.aq/ATCM39/att/atcm39_att072_e.doc)
38. See McIvor (2020) in this volume of JAA for a more in-depth-discussion of CEP and science needs.
39. See the CEP 5 Year Work Plan for the specific list of needs (https://documents.ats.aq/atcm42/ww/atcm42_ww005_e.pdf)

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SUSTAINABLE TOURISM IN NATURAL PROTECTED AREAS AS A BENCHMARK FOR ANTARCTIC TOURISM.

Alvaro Soutullo and Mariana Ríos

ABSTRACT

Antarctic tourism is increasing every summer, reaching 74,401 tourists in the 2019/20 season, a 32% increase since the previous season. The Consultative Parties to the Antarctic Treaty have discussed this issue since the 1960s. The adoption of the Madrid Protocol constituted a major step in regulating Antarctic tourism. Yet, the substantial increase of tourism since the adoption of the Protocol has raised concerns, highlighting the need of rethinking how tourism is managed, and eventually regulated. There have been suggestions of addressing the lessons learnt from tourism in other natural protected areas (NPA), to inform decisions on how to better manage tourism in Antarctica. This document aims to summarize some of the lessons and recommendations derived from that vast experience, to inform current debates on Antarctic tourism. We highlight 9 key concepts that we understand are particularly relevant in the context of current debates on Antarctic tourism.These are largely derived from a recent rsummary on Tourism and Visitor Management in Protected Areas, edited by IUCN. Many of the challenges, concepts, and tools that tourism in NPA faces and uses are being considered in the current debate on Antarctic tourism. Yet, a more systematic and comprehensive approach to the analysis of these issues is still missing. We believe a thorough analysis of this experience in NPA will shed valuable insights to the debate on how to improve Antarctic tourism management. Finally, based on the successful experience of CCAMLR, we suggest it might be time to explore further the idea of developing a convention on Antarctic tourism to regulate the activity.

KEY WORDS

Tourism, natural protected areas, visitor management.

Growing challenges of tourism in Antarctica

Until the 1980s numbers of tourists visiting the Antarctic during summer did not usually exceed 1000 persons per season. Since the end of the 1980s, numbers of tourists visiting the Antarctic have grown substantially (Liggett et al., 2011; Verbitsky, 2013). Most tourism (in terms of overall visitor numbers) remains 'traditional' ship-based tourism, with visitors being transported to a number of different coastal locations, where shore-based activities are undertaken for a short period of time before returning to the ship. In parallel to growing ship-based tourism, land-based tourism and other nongovernmental activities have also grown, facilitated by air access to Antarctica on a commercial basis since the late 1980s (Liggett et al., 2011; Verbitsky, 2013). Similar to land-based tourism, fly-sail-operations also have substantially increased. Currently, almost 20% of tourists visiting the Antarctic participate in fly-sail operations (ATCM XLII IP26). The growth in these different categories of Antarctic tourism has resulted in a total number of 74,401 tourists in the 2019/20 season, a 32% increase since the previous season (Carey, 2020). Most landings concentrate at a few specific locations along the Antarctic Peninsula's southwest coast.

The Consultative Parties to the Antarctic Treaty have discussed the issue of tourism since the 1960s. The adoption of the Madrid Protocol constituted a major step in regulating Antarctic tourism. Yet, the substantial increase of tourism since the adoption of the Protocol has raised concerns. The ATCM has regularly reaffirmed their responsibility for managing Antarctic tourism in line with the objectives, principles and values of the Antarctic Treaty System, and has annually discussed trends in Antarctic tourism and related concerns. Over more than 25 years, issues that have been discussed include (Liggett et al., 2011; ATCM XLII IP26): Cumulative impacts, environmental impact assessment, post-visit reporting, and monitoring effects of touristic activities; site specific guidelines, visitation of new sites, and establishment of 'Areas of Special Tourist Interest'; educational value of tourism and relationship between tourism and science; port-state control of touristic activities, establishment of an international observation scheme, and added value of an accreditation scheme for tourism; property rights issues and tourism through third state-operations; introduction and spread of diseases and non-native species; cooperation among competent authorities and adopting a strategic approach to Antarctic tourism management; and adoption of a separate annex on tourism in the Madrid Protocol.

The growing trend in the number of visitors in the Antarctic continues, highlighting the need of structural, institutional and legislative changes to successfully manage this activity (Liggett et al., 2011). COVID pandemic has forced a pause in tourism and, as Carey (2020) states, it is a good opportunity for rethinking how tourism is managed and most remarkably, how it is regulated, shifting from a reactive approach to a proactive one.

Antarctic tourism as a singular case of tourism in Natural Protected Areas

The Environmental Protocol to the Antarctic Treaty designates Antarctica as a natural reserve devoted to peace and science. On several occasions, there have been suggestions of addressing the lessons learnt from tourism in other natural protected areas (NPA), to inform decisions on how to better manage tourism in Antarctica (ATCM XLII IP 128). Tourism has been managed in natural protected areas all over the world for more than one hundred years (Ceballos-Lascuráin, 1996). This document aims to summarise some of the lessons and recommendations derived from that vast experience, to inform current debates on Antarctic tourism. There is a range of experiences of tourism in NPA in conditions that closely resemble some of those found in Antarctica, including remoteness (e.g., the Gates of the Arctic National Park and Preserve), polar conditions (e.g., the Quttinirpaaq National Park), and co-management by several countries (e.g., the Kavango-Zambezi Transfrontier Conservation Area). We highlight 9 key concepts that we understand are particularly relevant in the context of current debates. These are largely derived from a recent revision on Tourism and Visitor Management in Protected Areas, edited by IUCN (Leung et al., 2018).

1) Tourism in natural protected areas has committed a range of mistakes that has deteriorated a number of protected areas all over the world, sometimes beyond reasonable restoration capacity. It seems key to understand those experiences to avoid making the same mistakes in Antarctica.

2) A basic principle of tourism in NPAs is that for tourism to be sustainable it must, first and foremost, contribute to the conservation of nature in the long term, not for a while or sporadically, and ensure that conservation is not compromised by poorly managed visitor use. We understand the same principle applies to Antarctica, and that the analysis of the possible benefits and negative impacts of tourism in Antarctica has to explicitly consider this concept, as stated by the General Principles of Antarctic Tourism (ATCM XXXII R7): "All tourism activities undertaken in Antarctica will be conducted in accordance with the Antarctic Treaty, its Protocol on Environmental Protection, and relevant ATCM Measures and Resolutions. Tourism should not be allowed to contribute to the long-term degradation of the Antarctic environment and its dependent and associated ecosystems, or the intrinsic natural wilderness and historical values of Antarctica. In the absence of adequate information about potential impacts, decisions on tourism should be based on a pragmatic and precautionary approach that also incorporates an evaluation of risks. Scientific research should be accorded priority in relation to all tourism activities in Antarctica. Antarctic Treaty Parties should implement all existing instruments relating to tourism and non-Governmental activities in Antarctica and aim to ensure, as far as practicable, that they continue to proactively develop regulations relating to tourism activities that should provide for a consistent framework for the management of tourism. All operators conducting tourism activities in Antarctica should be encouraged to cooperate with each other and with the Antarctic Treaty Parties to coordinate tourism activities and share best practices on environmental and safety management issues. All tourism organisations should be encouraged to provide a focus on the enrichment and education of visitors about the Antarctic environment and its protection."

3) A key question for successful sustainable tourism in NPA is how to distribute benefits among all stakeholders involved. We understand the same applies to Antarctica, with the needs of National Antarctic Programmes and the personnel they deploy to Antarctica, having to be explicitly considered when designing (and authorizing) touristic activities. Furthermore, as with other commercial activities, some of the revenues generated by tourism should be directed to support the work of AT Parties in Antarctica. This might include contributing to challenges in the vicinity of sites visited by operators (e.g., to implement actions to minimize the impacts

of tourism or enable monitoring the activity), but also, a more generic support to the work of National Antarctic Programmes. Key components of successful revenue-sharing systems in NPAs include: (1) clearly identified and communicated economic benefits, (2) benefits proportional to the impacts generated by the activity, (3) stakeholders involved in the design of the distribution system, and the decision on how the revenues are used, (4) sufficient regulatory and institutional support to develop clear objectives, aims, goals and responsibilities (Spenceley et al., 2017).

4) Project-scale Environmental Impact Assessments (EIA) have a limited capacity to avoid the broader or cumulative negative impacts of tourism in NPAs. The same is to be expected in Antarctica. Strategic Environmental Assessments (SEA) can be used to assess the overall impacts of all tourism developments and activities, and then be used (for example) as a preparatory planning tool for specific activities in specific sites. While EIA can be used to assess the effects of individual projects, policies related to multiple projects that may have cumulative and synergistic effects, require the more strategic approach of SEA (Carvalho-Lemos et al., 2012). This poses challenges to the way Parties to the Treaty evaluate and share information (Marsden, 2011; Roura & Hemmings, 2011). For example, it requires unified criteria for EIAs, communicating planned activities with sufficient time and in formats that allow other Parties to assess the cumulative impacts of several tourism activities carried out simultaneously by different operators, and the additional pressures that tourism adds to those resulting from other planned activities (Kriwoken & Rootes, 2000).

5) Sustainable tourism in NPAs follows a number of principles that are expected to apply to Antarctic tourism as well:

a)Proper management depends on the objectives and values of the NPA.

b)Proactive tourism and visitor management planning considering NPA objective and values improves efficiency in implementing actions.

c)Changes in the type of activities and the expected experience of visitors are desired.

d)Impacts on natural values and social conditions are inevitable consequences of human use

e)Management should be aimed at influencing human behaviour by minimising tourism-induced change.

f)Impacts can be influenced by many factors, so limiting the amount of use is only one of many management options.

g)Monitoring is essential for successful management.

h)The decision-making process should separate technical description from value judgements (e.g., separate ‘existing conditions’ from ‘preferred conditions’).

i)Affected groups should be invited to participate, as consensus and partnership are essential for successful implementation.

j)Communication is key to increase awareness and for public understanding of the reasons underlying management decisions.

6) There are numerous tools for the application of the principles of tourism and visitor management in NPAs that should also be included in the Antarctic tourism planning, assessment and management toolbox. For example, the analysis of the Recreation Opportunity Spectrum, the analysis of Carrying Capacity, and the establishment of Limits of Acceptable Change

(McCool el al., 2007).

7) There are essentially 4 types of tourism management strategies in NPA:

a) Increasing the supply of tourism opportunities,
b) Reducing demand for problematic uses,
c) Increasing the durability of resources,
d) Limiting problematic uses (Manning et al., 2017).

The first two strategies manipulate supply and demand, either by increasing the supply of tourism opportunities to accommodate more use and/or spread it more evenly, or by reducing the demand for problematic uses by modifying their character, so its impacts are lessened. The other two strategies treat supply and demand as fixed. They focus on reducing the impacts of use by modifying visitor behaviour, or enhancing the durability of sensitive features, or by simply prohibiting problematic uses.

A range of tactics exist to put forward these strategies. Zoning is one of the most commonly used, and is an essential component in all tourism and visitor management processes. Rationing tourism and recreation opportunities is another option. Enforcement is required to support the rules and regulations behind limiting visitor use. Various enforcement tactics can be used. 'Soft' enforcement includes management measures that encourage people to follow the rules. Codes of practice can be useful, with tour operators and concessionaires being central to the success of such measures. In cases where soft enforcement is not effective, 'hard' law enforcement may be needed.

It seems reasonable to consider these 4 strategies when discussing how to better manage tourism in Antarctica. Although the current discussion is considering tactics that fall within these 4 major strategies (spatial planning approaches -Antarctic Specially Protected Areas versus. Areas of Special Tourist Interest-, accreditation schemes, prohibition of certain types of activities, controls at ports of departure, observers schemes, visitor site guidelines, or restrictions in the number of tourists landing at the same time), a comprehensive and systematic analysis of all the options available in the NPA toolbox, is still lacking.

8) A central component of successful tourism management in NPAs is Adaptive Management. An essential component of any tourism strategy in NPA is a commitment to permanent monitoring that identifies present conditions, assesses the effectiveness of management actions, and provides a basis for undertaking appropriate restoration and adaptation actions, including necessary adjustments to management plans. The current approach to Antarctic tourism is much more static and with very limited emphasis on monitoring and incorporation of lessons. There is a need for a shift in the way tourist activities are planned and assessed in Antarctica (Roura & Hemmings, 2011; Verbitsky, 2013). From a reactive approach based on EIAs, to a more flexible approach based on monitoring and evidence-based adaptive management (e.g., Salafsky et al., 2019). There are already some promising experiences applying this approach in Antarctica, as the one promoted by Caijao et al. (2020) in Barrientos Island.

9) Monitoring programs in NPA address three distinct aspects of tourism activity:

a) Monitoring visitors' impact,
b) Monitoring visitors' experience,
c) Monitoring management effectiveness.

The same seems also appropriate for systematically monitoring tourism in Antarctica. Also on this issue there is extensive experience on the implementation of monitoring schemes of impacts of tourism in protected areas that might be suitable for Antarctic conditions (e.g., McCrone, 2001).

A way forward?

Many of the challenges, concepts, and tools that tourism in NPA faces and uses are being considered in the current debate on Antarctic tourism. Although tourism has been one of the most analysed and discussed issues in the ATCM/CEP agenda, a more systematic and comprehensive approach to the analysis of these issues is still missing. We believe a thorough analysis of the experience in NPAs will shed valuable insights to the debate on how to improve Antarctic tourism management and regulation within the ATA.

All over the world sustainable tourism has proved to be a powerful tool to promote natural areas conservation, as well as awareness of their value for human well-being. We firmly believe the same applies to Antarctica. Yet, for that to actually occur, it is of utmost relevance that the mistakes made in many NPAs are avoided.

In order to achieve sustainability, Antarctic tourism should expand its current planning, assessment and management toolbox, to incorporate the range of tools developed for natural areas elsewhere. To avoid some of the most pervasive impacts of tourism on natural areas, AT Parties need to move from a reactive approach based on EIA, to a more strategic approach, based on SEA and adaptive management. Timely monitoring and proper assessment of cumulative impacts is key. This requires substantial improvements in the way information is collected and shared among Parties, as well as unified criteria to assess the impact of touristic activities. There is also a need to discuss how the benefits of Antarctic tourism are shared among the different stakeholders involved. Much of the management approach proposed here to ensure the sustainable development of tourism in Antarctica, has been successfully implemented by CCAMLR for over 30 years, to ensure sustainable exploitation of living marine resources in the Southern Ocean (Kock, 2000; Croxall & Nicol, 2004; Brooks et al., 2016).

Over time the AT Parties have considered an array of regulatory options for tourism and non-governmental activities in Antarctica, including an additional tourism annex to the Protocol, as well as a proposal for the development of a new Antarctic Treaty instrument (ATCM XXV IP83). While the debate on how to better manage Antarctic tourism seems stagnated, there is a rising number of voices warning about the potential consequences of maintaining business as usual (e.g., Liggett et al., 2011; Verbitsky, 2013; Carey et al., 2020). Based on the successful experience of CCAMLR, a convention on Antarctic tourism might be an appealing alternative to explore further (ATCM XLII IP26).

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Management and bioremediation of hydrocarbon-polluted soils in Antarctica.

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Abstract

Until a few years ago, the Antarctic continent was considered a pristine place. However, human activity there changed that condition, being hydrocarbon pollution a concerning and attention-drawing issue. Soils around scientific stations show different levels of pollution caused by oil-derived fuels, such as gasoil. Bioremediation is a tested, effective technique to remove contaminating hydrocarbon from the soil. Biostimulated biopiles is the most effective, tested strategy for Antarctic soils that makes use of the microorganisms' catabolic potential; ecopiles, in turn, seem to be a better alternative that brings more complex biological systems into the process, such as vascular plants, in order to obtain higher removal levels. Finally, a reflection is made that appropriate, specific logistics are needed to reduce execution times of these innovative bioremediation treatments.

Key words

Bioremediation, Antarctic soils, Hydrocarbon-degrading bacteria, Biopiles.

Introduction

Antarctica is the only continent on the planet for which a documented, agreed intention exists to have it fully preserved from anthropogenic damage. To that end, signatory countries of the Antarctic Treaty (Antarctic Treaty, 1959) also undersigned the Protocol on Environment Protection, also known as the Madrid Protocol (Secretariat of the Antarctic Treaty, 1991). Despite that intention and the actions consequently implemented, Antarctica was not fully free from the damaging effects of human activity. Natural phenomena, such as ocean and air mass movements as well as migrating fauna take contaminating agents with them from different parts of the world to the area located below parallel 60°S. Also, the number of permanent and temporary scientific stations (COMNAP, 2017) and the logistics supporting them and touristic navigation (as well as fishing navigation) introduce contaminating compounds to the Antarctic environment which last in time and have an impact on the ecosystem (Bargagli, 2008; Aronson et al., 2011). In this way, heavy metals (Bargagli et al., 1998; Espejo et al., 2014; Chu et al., 2019), hydrocarbons (Jackie M. Aislabie et al., 2004; Saul et al., 2005; Curtosi et al., 2007; Kukučka et al., 2010; Mac Cormack et al., 2011) and plastics (do Sul et al., 2011; Lacerda et al., 2019) are usually reported as contaminating compounds in the Antarctic environment, which alerts humanity about an impact that human activity has in that region.

The demanding weather conditions existing in the Antarctic Continent for the thermal homeostasis needed by the human being, as well as facilities technology, require a constant and reliable energy supply. Renewable energy sources, such as hydrogen, solar energy, and wind energy have been considered and, in some cases, used for specific stations (Marschoff, 1998; Henryson and Svensson, 2004; Tin et al., 2010) which is a big step forward. Notwithstanding this, as of today, it has not been possible to fully replace electricity and heat produced with fossil fuels, especially gasoil, particularly due to two of their benefits: effectiveness and reliability. Thermal electric power is produced by using internal combustion engines and induction generators. From a mechanical perspective, this is a simple, well-known, and easy to maintain technology. (Diesel Technology Forum, 2013; Fairfax et al., 2020). Fossil fuels in general and gasoil, in particular, have a high energy density, which implies a large advantage affecting the cost of energy production (Layton, 2008). Also, diesel engines' service life is large (30,000 hours approximately at a first deep revision, depending on the model and quality); given their cost, it is possible to have back-up units in the event any of them fails or needs maintenance. Fossil fuels do not rely on weather conditions to produce energy and so their production can be constant, stable, and continued. However, this power matrix, which depends on fossil fuels, requires back-up logistical support involving large costs related mostly to transportation which, in some cases amount to three times purchase value (Olivier et al., 2008). Annual gasoil consumption is calculated to be millions of liters for the Antarctic continent. McMurdo station, for instance, has gasoil needs of about 5 million liters, while smaller bases take about 300,000 liters per year (Tin et al., 2010). Among Argentine bases, Marambio has gasoil requirements of about one million liters per year, while Carlini uses close to 300,000 liters.

Oil hydrocarbon is the polluting agent most commonly reported in Antarctica and raises concerns for all national programs developing activities there. Despite thermal electric energy being reliable, gasoil use, transportation, and storage imply a permanent risk of introducing hydrocarbon to the environment, both into the bases and into the marine routes that lead to them. Events such as Bahía Paraíso in 1989 (Kennicutt et al., 1991, 1992), Patriarche in 2001 or Explorer in 2007, among many others (Ruoppolo et al., 2013) show that the risk is real and that the consequences it may have in ecosystems are, in some cases, severe.

There are containment measures and intervention tools when oil spills in the sea. Barriers and pumps allow to confine the problem and to remove most of the spilled substance before it reaches the coast and affects the fauna. The possibility also exists to add dispersants to work in the hydrocarbon by breaking the hydrophobic film, thus reducing its detrimental effects and allowing erosion through biotic and abiotic mechanisms. Nevertheless, these operations are only possible if weather and navigation conditions allow them.

When spills occur in soils, applicable containment strategies are different. Many of the Antarctic bases are in coastal areas. This means that not contained spillage could drain or leach to the coast, which would affect the fauna of that coastal area; it could also end up in the sea where the damages are more difficult to mitigate if there are not sufficient means. For that reason, if there was a spillage affecting primarily soil, it would be convenient to keep it at a surface level, making it relatively simple to treat it; in the case of sea or sediments, treatment becomes more complex and recovery, in many cases, is impossible. In those instances, using absorbing materials and building containment barriers are an appropriate option.

Liquid containment and recovery representsthe first phase of the technical and operating action that can be taken when hydrocarbon leakages occur. In order to keep the Antarctic environment as free of contamination as possible, all contaminating agents dumped in it have to be removed. When the issue regards soils, there are two ways in which it can be solved. One possibility is to excavate the polluted soil to take it out of the Antarctic continent for treatment and later restoration to its original place, best case scenario, or for final disposition in a different place. While this possibility might seem a solution, it is extreme both as regards costs and as regards complex logistics associated. Moreover, removing soil implies severe environmental effects and changes to the natural conditions created through biotic and abiotic pedogenesis that takes hundreds or thousands of years (Beyer et al., 1995, 2000; Blume et al., 2002; Ugolini and Bockheim, 2008). If the intention is to restore the soil to its original place, once again, transportation costs must be considered together with the fact that such soil has been exposed to no-antarctic temperature, air, flora, and microflora. For those reasons, without regard to treatments that could significantly change the material composition, the soil being restored following treatment outside Antarctica would be a very different version of the original soil. In sum, except for very sophisticated treatments, restoration does not seem to be a plausible option for a continent such as the Antarctic. As an alternative, contaminated soil treatment can be considered without it being removed (in situ) or with removal but without transportation (on-site). The most commonly mentioned physicochemical methods are thermal desorption, wash, and chemical rusting. These methods have the advantage of being relatively quick which, allows to solve the contamination issue within days. However, they have two big disadvantages that become even bigger when the matrix to be remediated is in Antarctica or comes from there. One disadvantage is that they are expensive and the transportation cost of the required machines and/or of the soil if treatment cannot be given in Antarctica, has to be considered. The other disadvantage is that the soil characteristics are completely changed and even native microbial communities living in it can be cleared away. For instance, a thermal treatment that reaches 100°C to 300°C in their mild version and 300°C to 550°C in their strong version destroy or change both mineral and organic soil fractions, getting away from the ideal result of restoring the soil's original conditions (Vidonish et al., 2016). Rusting methods imply adding a mixture of chemical reactive to the soil to attack the organic components in it. The most commonly mentioned reactive are those based on the Fenton reaction that uses a combination of hydrogen peroxide (H2O2) and iron (Fe2+ or Fe3+) or those whose main reactive is peroxydisulfate (S2O82-) (Palmroth, 2006; Palmroth et al., 2006; Yang et al., 2020). The main issue of these methods is the lack of specificity of the rusting reaction, which decomposes all organic matter, regardless of whether it is a contaminating agent or a natural component of the soil being treated. This makes the resulting material very different from the original soil. Washing implies partially or fully removing contaminating agents using a mix of water and surfactants that work in touch with the soil to be treated and must act using mechanical agitation (Kostecki et al., 2004; Fernández Rodríguez et al., 2014). These processes also lack specificity since they equally remove contaminating and organic matter, as well as mineral compounds soluble in water. Besides, they create a new contaminated matrix (in this case, washing water) that will need appropriate treatment. Washing, as opposed to other physicochemical methods, is not fatal or toxic for native microbial communities. For that reason, it could be combined with a biological method.

In this scenario, using biological tools (mainly bacteria, fungus, and plants) capable of decomposing or reducing the levels of hydrocarbon while preserving the original characteristics of the soil is essential for remediation. Using living creatures or biological systems (if we consider enzymes) is known as bioremediation and is one of the most important disciplines of biotechnology applied to environmental care (Vallero, 2010).

The set of methods that constitute bioremediation show several advantages since they are considerably cheaper than other techniques based on physical or chemical principles (besides the fact that they can be added to those techniques); they are easy to carry out and allow to be applied "in-situ". As they are based on biological activity, they can be affected or modulated by environmental factors, the low temperature being of particular relevance, as it lowers the speed of biochemical reactions. For that reason, biological processes to remove contaminating agents can take longer, especially in such extreme places as Antarctica. Despite this, the cost/benefit ratio and the fact that it is an environment-friendly technique to recover environmental liabilities, make it a very feasible technique to apply in the white continent.

Among the measures and suggestions arising from the Protocol on Environmental Protection for Antarctica, the prohibition to introduce alien species to the continent is particularly relevant. This measure aims to preserve biodiversity by avoiding (or at least restricting) potentially invasive species from entering into the continent as they may change the compositions of some native communities. This is why any bioremediation process must be designed, planned, and implemented using native microorganisms only. This creates the need to obtain and develop appropriate native biological tools to remove contaminating agents from the Antarctic environment.

Some different approaches or strategies that can be applied to remove contaminating agents through methods based on biological systems, and they're also are many variants and combinations of them. They imply exploiting the potential of native microbial communities living in the contaminated soil fostering their development and catabolic activity. This is achieved by providing nutrients (oxygen, nitrogen, and phosphorus) in an adequate and sufficient amount so that microorganisms can use the contaminating molecules as a substrate. This strategy is based on the existence of enough microbial cellules in the soil to be treated that can decompose contaminating agents. This restriction is not common in soils since the diversity of microorganisms living there shows a very versatile range of metabolic pathways, particularly in cases of chronic pollution. In the case this does not occur, the alternative is bioaugmentation, which implies adding microorganisms capable of decomposing the contaminating agents. Other than these strategies, using plants to improve the effectiveness of bioremediation is also relevant. These processes that imply using vegetal species are commonly known as phytoremediation.

Bioremediation is possible in Antarctica and there are many examples of the application of this technology to treat contaminated soils beyond parallel 60°.

Bioremediation strategies Applied in Antarctica for hydrocarbon contaminated soils

Among remediation strategies, biostimulation reports show better results and effectiveness in removing oil-derived hydrocarbon from soils. As mentioned in the paragraph above, biostimulation consists of optimizing the factors that may be restrictive for microbial development, such as nutrient concentrations (nitrogen and phosphorus mainly), soil content of water (humidity), oxygen availability, and temperature. Among these factors, there is evidence that balancing the Carbon:Nitrogen:Phosphorus (C:N:P) ratio is key to obtain effective processes, even in Antarctic soils (Martínez Álvarez et al., 2015).

In the case of bioaugmentation, the microorganisms to inoculate must be able to partially or fully decompose the contaminating agents present in the soil. This is usually applied when the soil does not have microorganisms that can help with remediation or when the remediation speed is too low. Many times, the usefulness and effectiveness of this strategy is controversial since the introduced microorganisms are not able to attach themselves to the soil (they compete with the microorganisms already living in that soil, much better adapted to that environment). However, this technique can be implemented together with the adaptation of factors (biostimulation + bioaugmentation), improving the removal levels obtained. One variation of bioaugmentation is the inoculation of bacteria that can produce surfactants. Surfactants are, essentially, detergent that increases the availability of hydrocarbon for the bacteria by creating a type of emulsion fostering organic compounds degradation (Mac Cormack and Fraile, 1997). As mentioned above, the Madrid Protocol (1991) must be considered for the Antarctic continent since it prevents species from around the world from being introduced to the continent. Therefore, the use of native microorganisms from the white continent is essential to implement this strategy.

In applying one of these strategies to contaminated soil in the Antarctic continent, it is not only the scientific factor that must be considered but also the way to transfer the expertise acquired in a laboratory to a real, specific scenario. This is an essential technology leap to achieve specific treatment for the Antarctic ecosystem: soil recovery in cases of contamination. It is always difficult to complete the transfer from laboratory to field because there are many uncontrollable factors, but it is particularly complex in Antarctica due to its extreme weather conditions.

An option that has shown good results for soil bioremediation in extreme environments is the use of biopiles (McWatters et al., 2016; Martínez Álvarez et al., 2017). The use of biopiles is an "on-site" treatment in which contaminated soil is dug and set in piles in a specific treatment area (usually, close to the original place), that must be isolated from surrounding soil so as to prevent the contaminating compound from leaching. These piles also favor microbial biodegradation through aeration (either mixing or forced), by adding nutrients (biostimulation), or by adjusting humidity. Moreover, these piles are usually covered, which favor an increased soil temperature and help maintain humidity at a relatively stable level. It also prevents nutrients and hydrocarbons from being leached or washed. These are very desirable features for treatment in Antarctic bases, since, otherwise, low temperatures, snow coats, and humidity change could significantly reduce the effectiveness of these processes.

Processes like these have been implemented in the Arctic (Mohn et al., 2001; Gomez and Sartaj, 2013) and have been also developed in Antarctic bases in the last few years. Argentina and Australia, in particular, (both signatory members of the Antarctic Treaty) have implemented these strategies in their bases in cases of Antarctic gasoil contamination (Table 1). Carlini (Arg.), Davis (Aus.) and Casey (Aus.) are some of the scientific bases in which soil bioremediation processes have been successfully applied (in some cases recovering over 10,000kgs of contaminated soil), proving that both countries are leaders in research and expertise transfer to avoid, contain, reduce, and remediate human impact in the white continent.

A still untapped alternative: phytoremediation and use of ecopiles

The Antarctic Peninsula is a very different region from the rest of the continent due to its unique weather, vegetation, and fauna. While it has bleak weather for most organisms, two domestic vascular plants can be found on this continent: Deschampsia antarctica and Colobanthus quitensis. They mainly grow in ice-free coastal areas (maritime Antarctica), which represents about 2% of the continent's Surface; that is where most anthropic activities occur.

This biological resource allows for new potential biotechnologies to be explored in the field of bioremediation by applying processes that involve contaminated soil, these plant species, and their associated microorganisms. All these processes are collectively called phytoremediation. Phytoremediation accelerates the deterioration of the contaminating agent in the soil as a result of the increase in the number of microorganisms living in the root zone layer, called rhizosphere, and of their increased catabolic activity. This type of process, therefore, exploits the synergic interaction between plants and microorganisms to fully eliminate or to reduce harmful effects in the environment of contaminating compounds.

Phytoremediation has some advantages over other bioremediation processes. We have already mentioned some general advantages, but some others are worth mentioning: it is compatible with other remediation technologies. That is to say, they can be implemented together or in tandem with bioaugmentation or biostimulation or even with some physicochemical methods, to name but a few. It is easy to maintain and, therefore, easy to put into practice. If we think of the Antarctic continent, maintenance work is even smaller since all vegetal species are well adapted to the weather and there are no other species that may act as a weed; neither are there any important pathogens that may compete for substrate or nutrients. Introducing vegetal species in soils that lack them (either because of their high contamination or because they never had any vegetation), improves said soil properties, as the root system adds increased aeration, changed structure, and increased microbiological activity, among other things.

Both D. antárctica and C. quitensis thrive mainly in ice-free coastal areas and, in some adequate areas, large green carpets grow. D. antarctica belongs to the family of Poaeceae, composed of 30 to 40 species (annual and perennial) distributed in both hemispheres. In November, seeds blossom and shrubs from the previous year recover. These plants can also have vegetal growth by expanding their shrubs. Their spread capability is astonishing. Reports have been made that an individual of this species can thrive and reestablish after having been taken to a different place (Parnikoza et al., 2009). This allows them to grow new shrubs when some individuals are carried by the wind or moved by birds. In addition, studies made with other species of Deschampsia showed that this family has tolerance to certain levels of hydrocarbon (Macoustra et al., 2015). This turns D. antarctica into an adequate biotechnological tool to remediate hydrocarbon-contaminated soils. This is because seedlings grown under controlled conditions or taken from heavily populated places can be transplanted to the soil to be remediated and it can settle there, providing all the benefits associated to the existence of a plant when removing contaminating agents. A report has also been made that inoculating D. antarctica with bacteria resistant to low temperature and high salinity improves the plant responses to stress caused by extreme environments (Gallardo-Cerda et al., 2018). These results suggest that the search for microorganisms resistant to the Antarctic environmental conditions and capable of fostering vegetal growth will increase the prospects of successful implantation and, consequently, of the remediation system.

Recent surveys found D. antarctica shrubs attached to chronically contaminated soils with Antarctic gasoil in Argentine base Carlini. During Summer Antarctic Campaign (SAC) 2019-2020 some soils were found to have hydrocarbon concentrations of about 1,000 mg Kg-1. This, along with the background detailed above, poses D. antarctica as a potential candidate to be used for a hydrocarbon phytoremediation system for Antarctic soils, since it is a requirement to have a plant species that can tolerate hydrocarbon concentrations in the soil to be remediated.

To design a phytoremediation process, having a plant species that can resist the contaminating compound is just the beginning. To develop a successful phytoremediation strategy, it is essential to know the maximum amount of contaminating compounds that the system can take, to have microorganisms that can deteriorate hydrocarbon and that are able to settle in the soil and the root system, once attached to the plant species. Finally, an application design is also necessary that considers the soil volume and handling, as well as the weather features.

The environmental microbiology group from AAI is currently working on all these points mentioned above to develop a specific phytoremediation strategy known as ecopile (Image 2). An ecopile implies isolating the contaminated soil by using a membrane. That membrane receives aeration to favor microbial aerobic processes while individuals of the inoculated plant species are introduced in its upper part, as they were inoculated with degrading microorganisms that foster plant growth. Also, nutrients are added to the soil to spur growth and microorganism's metabolic activities and to favor plant development (Germaine et al., 2015). This way, ecopile is a design that combines biostimulation and microorganism-assisted phytoremediation, an improved technical feature of phytoremediation.

Logistics related to Antarctica soils remediation

Reducing the impact of hydrocarbon contamination in Antarctica depends both on technological developments that try to respond to the need for remediation methods and on associated logistical processes.

For climatic reasons mainly, bioremediation treatments as well as resupply tasks are performed in summer. It is in summer, when soils have little or no snow on them when large fuel movements are made to storage. If spillage occurred while performing these tasks, it would be relatively easy to contain it and remove it for treatment. During the rest of the year, human errors in handling fuel transfer are more frequent mainly because of demanding temperature conditions both for materials and for people. For this reason, it is necessary and convenient to have processes to collect, stockpile, and dispose of contaminated soils until they are treated. Heavy or semi-heavy machines enable the creation of containment slopes as well as contaminated material removal. Also, when there are geomembranes available that allow early implementation of the treatment when the time has not passed since contamination occurred, particles from the soil absorb less hydrocarbon and, therefore, the hydrocarbon is more bioavailable than it is when present in elder soil.

A point that is worth bearing in mind is that designing and implementing rational bioremediation treatment requires knowledge of the hydrocarbon concentration in the affected soil. To that end, it is convenient to have specialized equipment at the base (gas chromatography or Fourier-transformed infrared spectroscopy) as well as trained staff to make a robust, significant sampling of the soil to be treated and to analytically determine its hydrocarbon content. In this way, the period between the moment when contamination occurred and when bioremediation treatment commenced can be significantly reduced, with all the benefits that imply.

Conclusion

For countries committed to environmental quality in Antarctica, it is essential to have technologies and specific processes for treatment and recovery of contaminated soils. In that sense, biostimulated biopiles have proved to be an adequate strategy for the Antarctic summer conditions by offering a contained system that avoids leachate and also protecting microbial plants that can deteriorate hydrocarbon. Ecopiles appear as an improved possibility with bigger removal effectiveness. Both types of treatment respect the prohibition to introduce alien species and focus their potential on microorganisms activity (bacteria and fungus) and macroorganisms activity (D. antárctica).

It seems convenient for bases to have a spillage response process and an effective bioremediation protocol to reduce hydrocarbon impact in the Antarctic environment,

Base	Country	Configuration	Bioremediation Strategy	Soil amount(kg)
Carlini	Argentina	Biopiles	Biostimulation	860
Carlini	Argentina	Biopiles	Biostimulation	860
Carlini	Argentina	Biopiles	Biostimulation	14,000
Casey	Australia	Biopiles	Natural alleviation + Biostimulation	1,700,000

Base	Initial contaminating agent concentration(ppm)	Process Efectiveness(%)	Reference
Carlini	2,180	75.79	Martinez Alvarez et al 2017
Carlini	6,098	55.04	Martinez Alvarez et al 2020
Carlini	3,735	Not published	Not published
Casey	3,531	74.31	Mc Watters et al 2016

Table 1. *Examples of bioremediation treatment in hydrocarbon-contaminated soils in a biopile system in Antarctic bases*

Image 1. *Gasoil storage tanks in Argentine base Marambio exposed to winter environmental conditions.*

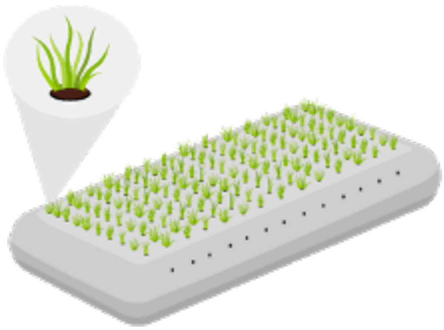

Image 2. *Conceptual design of an ecopile. The soil to be treated is set in a water-proof membrane. Its lateral measures are to be defined based on the amount of soil and its depth is approximately 30 cm. Holes are made on the upper part to introduce the D. antarctica and the sides are drilled from end to end to set tubes that allow passive aeration for the soil.*

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