



## Review

# Protection of Antarctic soil environments: A review of the current issues and future challenges for the Environmental Protocol



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## ABSTRACT

2016 marked the 25th anniversary of the Protocol on Environmental Protection to the Antarctic Treaty. Terrestrial ice-free areas constitute approximately 0.18% of Antarctica, but represent the most biologically active, historically rich, and environmentally sensitive sites. Antarctic soils are easily disturbed and environmental legacies of human activities are scattered across the continent; many are remnants of the 1950s–1980s when environmental protection was less comprehensive than today. Adoption of the Environmental Protocol in 1991 represented an important and proactive shift in Antarctic governance, securing environmental protection as a fundamental tenet of the Treaty System. Twenty five years on standards of environmental management have greatly improved, yet environmental pressures are compounding. Shortcomings in the implementation of the Environmental Protocol exist due to disparities in cultural values, operational realities, and inconsistent environmental impact assessments among governments and National Antarctic Programs. Non-native species management remains underdeveloped; and there is inadequate representation of all biogeographic regions within the Protected Area system; therefore jeopardizing conservation of Antarctic biodiversity and the integrity of the soil environment. Fundamental improvements are required to address the current shortcomings and ensure effective environmental protection for the next 25 years, including: (1) increased multinational and multidisciplinary collaboration to answer targeted research questions addressing contemporary management challenges, (2) effective communication of science to policy makers and environmental managers to inform decision-making, and (3) making the mandate of long-term monitoring of the terrestrial environment a high priority for all governments signatory to the Antarctic Treaty.

## 1. Introduction

The Antarctic continent is an internationally managed natural reserve devoted to peace and science, designated as such by the Antarctic Treaty (1959). Human activities in Antarctica have shifted focus considerably over the last 200 years, from resource exploitation (sealing and whaling) to exploration, to science and tourism in recent times. Since the International Geophysical Year (1957/58) scientific research programmes have expanded (approx. 5000 people working in Antarctica annually) (COMNAP, 2012a), and tourism increased to more than 39,000 tourist visitors in the 2015/16 season (IAATO, 2016). Like elsewhere in the world, as our activities increased and diversified, humans began to alter and degrade the landscape.

The Antarctic Treaty (1959) did not provide prescriptive advice on environmental protection and consequently Treaty Parties set about to agreeing to an additional suite of international instruments to address environmental issues not covered in the Treaty. Tin and others (2014) provide an excellent summary of the history of the Antarctic Treaty

System (including all legal instruments designed for the protection of the Antarctic environment). 2016 marked the 25th anniversary of the adoption of the Protocol on Environmental Protection to the Antarctic Treaty (hereafter the Environmental Protocol). This synthesis paper seeks to review the last 25 years of improvement in environmental management of the Antarctic soil environment. The soil environment was chosen to constrain the scope of the synthesis and undoubtedly other elements of the terrestrial environment (e.g. freshwater bodies, intertidal zones etc.) could equally well be included. This paper presents some of the major scientific research and policy contributions that have enhanced the environmental protection of the soil environment. It considers: (1) the attributes of Antarctic soils that promote either resilience or vulnerability to degradation; (2) the provisions within the Environmental Protocol relating to the soil environment, giving examples of management changes following adoption of the Environmental Protocol; (3) outlines the major shortcomings in the implementation of the Environmental Protocol; and (4) gives some of the possible solutions to address the current shortcomings to ensure

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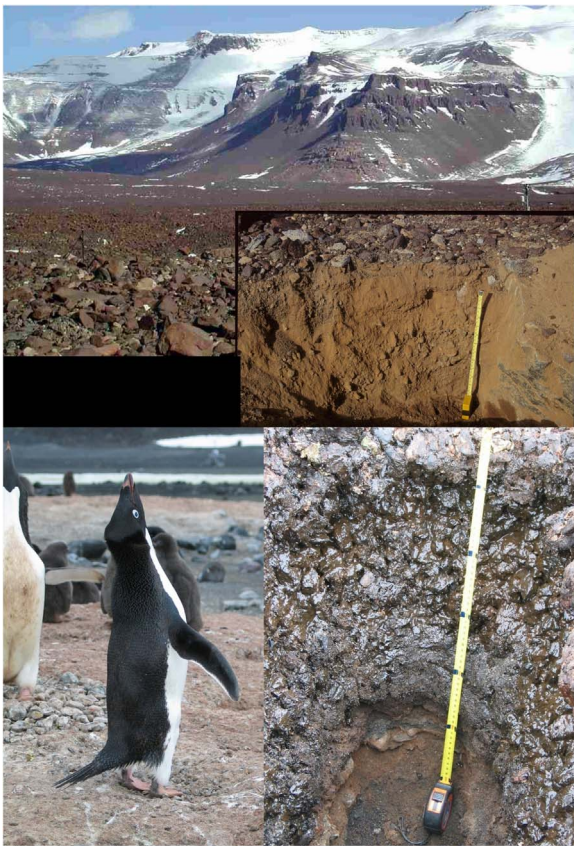


Fig. 1. Example of an arid McMurdo Dry Valley soil and landscape (top); Maritime Antarctic penguin-influenced soil and landscape (bottom). Photos from Megan Balks.

effective environmental protection for the next 25 years.

## 2. Antarctic soil environments

For a soil scientist, Antarctica provides a unique environment for studying soil formation and soil processes. Antarctic soils are among the oldest, coldest, and driest soils on Earth and have some unusual pedological features (Campbell and Claridge, 1987). In most parts of Antarctica, soil formation is extremely slow due to the frigid climate and lack of moisture, and it can take up to a millennia for 1 cm of soil to form (Campbell and Claridge, 1987). Slow pedogenesis and extremes in climate give rise to soil features such as varnished desert pavements, cavernous weathering, ventifacts, surface salt crusts and thick salt horizons at depth (Fig. 1). Maritime Antarctic soils tend to have increased soil moisture contents compared with soils of other climatic zones in Antarctica, such as the volcanic soils of Ross Island and the arid McMurdo Dry Valleys. Maritime Antarctic soils tend to be more weathered and developed, and the active layer (thawed soil layer above the permafrost) tends to be deeper and vegetation more abundant in response to higher temperatures and greater water availability (Campbell and Claridge, 1987; Bockheim, 1997) (Fig. 1). Antarctic ice-free soil environments account for just 0.18% of the continental area (Burton-Johnson et al., 2016), yet are the sites where the majority of human activity has historically occurred (Fig. 2).

The first crumbly, root-less, seemingly void of life Antarctic “soil” sample accompanied Shackleton back during his 1907–1909 voyage (Jensen, 1916), yet it was not until close to the end of the twentieth century that scientists removed the quotation marks and finally agreed Antarctic soil is truly a soil. It was not until 1997 that Antarctic soils were recognised in a Soil Order (Gelisols) in the United States Soil Taxonomy. Bockheim (2015a) gives a detailed account of the early history of Antarctic soil science. The first soil map was produced by

McCraw (1967) for the Taylor Valley in South Victoria Land. Later workers mapped soil spatial distribution in selected areas, and in a few instances noted the vulnerability and recoverability of soil to varying scales of human activities. Our understanding of Antarctic soils is limited in some remote regions by the lack of soil survey data. Even in areas close to research stations, such as the Vestfold Hills in East Antarctica, there are limited studies documenting the distribution and characterisation of nearby soils and sediment (Mergelov, 2014).

Detailed accounts of the history of human activity in Antarctica and resulting impacts on the soil environment are given in Campbell and Claridge (1987), Tin and others (2009) and O'Neill and others (2015) and references therein. The impacts from camping activities of scientists and movement of tourists has been well documented (Campbell et al., 1993; Tejedo et al., 2012, 2014; O'Neill et al., 2013, 2015; Balks and O'Neill, 2016). Localised studies on the recoverability of soil substrates following pedestrian traffic have revealed one set of guidelines does not necessarily fit all, where some maritime Antarctic sites are more resilient and readily recoverable due to the warmer, higher rainfall environments; other maritime sites where extensive moss and lichen communities are present, are highly vulnerable to damage. Arid sites on softer soil substrates in the Ross Sea region, such as in the McMurdo Dry Valleys, are vulnerable to disturbance with some visible impacts lasting many 10 s to 100 s of years, whereas at other sites visible disturbance from less severe activities such as camping are undetectable within a few seasons.

## 3. The environmental protocol

The Environmental Protocol (ATCP, 1991), signed in 1991, was the first step toward a comprehensive statement of environmental principles governing the conduct of Treaty Nations activities in Antarctica. The Environmental Protocol was intended to strengthen the Antarctic Treaty and built on and incorporated many existing SCAR (Scientific Committee for Antarctic Research, established in 1958 to advance Antarctic Research and provide independent and objective scientific advice and information to the Antarctic Treaty System) and Antarctic Treaty measures and recommendations on conservation (such as the 1964 Agreed Measures for the Conservation of Antarctic Flora and Fauna), waste management and marine pollution. By signing the Parties committed themselves to “...protection of the Antarctic environment and its dependant and associated ecosystems, including its wilderness and aesthetic values...” (Article 2 and Article 3(1)). It is the responsibility of the signatory governments to design their own internal institutional structures (appropriate national laws, regulations, administrative actions and enforcement measures) to comply with the Environmental Protocol’s requirements (Article 13). Although the Environmental Protocol did not come into force until 14 January 1998, some signatory governments through their National Antarctic Programmes (NAP: “the entity with national responsibility for managing the support of scientific research in the Antarctic Treaty Area on behalf of its government and in the spirit of the Antarctic Treaty”, COMNAP, 2008a), adopted the principles of the Environmental Protocol shortly after signing (Klein et al., 2008). Broadly, the Environmental Protocol currently comprises six annexes dealing with (I) Environmental Impact Assessment (EIA), (II) Conservation of Antarctic Flora and Fauna, (III) Waste Disposal and Waste Management, (IV) Prevention of Marine Pollution, and (V) Management of Protected Areas (see <http://www.ats.aq/e/ep.htm> for links to individual annexes). Annex VI on *Liability Arising from Environmental Emergencies* was adopted by the 28th Antarctic Consultative Treaty Meeting (ATCM) in Stockholm (2005) and will enter into force once approved by all Antarctic Treaty Consultative Parties.

Under Article 11 of the Environmental Protocol the Committee for Environmental Protection (CEP) was established as an expert advisory body to provide advice to the Antarctic Treaty Consultative Parties “in connection with the implementation of” the Environmental Protocol (Article 12). The remit of the CEP includes providing advice on the need

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