

REVIEW

Expanding the Protected Area Network in Antarctica is Urgent and Readily Achievable

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Abstract

The terrestrial protected areas of Antarctica are generally small, unrepresentative of the continent's biodiversity, and at risk from a range of pressures. While some consider the whole Antarctic region as a protected area, we demonstrate that the evidence does not support this view. The Protocol on Environmental Protection to the Antarctic Treaty recognizes that a systematic environmental-geographical framework provides a quantitative approach to inform expansion of the current Antarctic Specially Protected Area (ASPAs) network. We review the progress thus far and challenges facing the establishment of protected areas in terrestrial Antarctica when adopting best practice approaches, an assessment that is lacking for the region to date. Encouragingly, because of the historical investment in Antarctic biodiversity science, and the existence and implementation of defined processes to identify and designate ASPAs, the opportunity exists to rapidly expand the current ASPA network. However, challenges remain. Foremost among these is the adoption of a comprehensive systematic conservation plan by stakeholders. We outline a strategy for the Antarctic Treaty Parties to provide the equitable, effective, transparent, and scientifically founded expansion of protected areas that Antarctica urgently requires. We also highlight where opportunities for colearning may lie in conservation planning and policy development in the Antarctic and other commons or commons-like areas.

Introduction

The once widely held notion that terrestrial Antarctica is relatively free from major human influence is no longer tenable. Antarctic terrestrial environments and their biodiversity are under growing pressure from global change drivers (Turner *et al.* 2009; Convey 2011; Chown *et al.* 2012a; Convey *et al.* 2014), and localized pressures such as human disturbance to wildlife, the introduction of alien species, and pollution (Frenot *et al.* 2005; Tin *et al.* 2009; Hughes *et al.* 2011, 2015a; Chown *et al.* 2012b; Coetzee & Chown 2016). In consequence, improvement of the conservation of Antarctic environments and their constituent biodiversity is being much emphasized (e.g., Tin *et al.* 2014; Hughes *et al.* 2015b).

As is the case globally (Watson *et al.* 2014), protected area establishment has been recognized as an important conservation strategy in the Antarctic (Bonner & Smith 1985; Smith *et al.* 1992), geopolitically defined by the Antarctic Treaty as the land and ocean areas south of 60°S. Nonetheless, the efficacy of Antarctic area protection has received much criticism (e.g., Brooks *et al.* 2016). Few marine protected areas have been established and the Convention on Conservation of Antarctic Marine Living Resources is struggling to do so, with the recent notable exception of the newly proclaimed Ross Sea Marine Protected Area taking effect in December 2017. (See Commission for the Conservation of Antarctic Marine Living Resources announcement: tinyurl.com/nnzeqmt.) By contrast, protected area establishment is more

common for the terrestrial Antarctic, yet this protected area network is unrepresentative of the continent's biodiversity, faces threats from several external drivers, and falls short of global aspirations (Hughes & Convey 2010; Shaw *et al.* 2014; Hughes *et al.* 2016).

Critiques of the performance of the Antarctic terrestrial ASPA network are frequently met with the response that this protected area system is qualitatively different from those found elsewhere. Article 2 of the Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol 1991, hereafter the Environmental Protocol) designates Antarctica in its entirety as a "*natural reserve, devoted to peace and science.*" Thus, Antarctica as a whole is often considered to be protected (Bastmeijer & Van Hengel 2009; see also Ban Ki-moon's address on the 50th Anniversary of the signing of the Antarctic Treaty, reprinted in Berkman *et al.* 2011). The Environmental Protocol's designation avoids defining what activities should be considered to fall within the ambit of peace and science (though mineral resource activities are prohibited by Article 7 of the Environmental Protocol, while Article I of the Antarctic Treaty prohibits activities of a military nature and Article V prohibits nuclear testing and the disposal of nuclear waste). In consequence, activities with potentially significant conservation impacts can clearly still be undertaken, such as fishing, tourism, and station operations (Peter *et al.* 2013; Tin *et al.* 2014; Brooks *et al.* 2016; Coetzee & Chown 2016; Hughes *et al.* 2016).

Given these divergent perspectives, which may strongly color decision making for the region (see, e.g., the contrasting views of Chown *et al.* 2012a and Haward *et al.* 2012), and growing human use of the Antarctic (Tin *et al.* 2014), we first examine the idea that terrestrial Antarctica, as a whole, is equivalent to a protected area under recognized International Union for Conservation of Nature (IUCN) definitions (see Bastmeijer & Van Hengel 2009). Based on global criteria, we dispute this notion. We then consider briefly the evidence demonstrating inefficacy of the current ASPA network for conserving biodiversity. Finally, we set out for terrestrial Antarctica where progress has been made in each of the stages of formal systematic conservation planning (SCP; Margules & Pressey 2000; Pressey & Bottrill 2009), and where work needs to be done. We show that all the foundations required for addressing protected area (PA) deficiency on the continent are in place, and that comprehensive protection could be readily achieved. We also highlight where opportunities for colearning may lie among those involved in conservation planning and policy in the Antarctic and those doing so in other commons or commons-like situations.

The current status of Antarctica as a protected area

The Antarctic Treaty Parties (hereafter "the Parties") have long been concerned with the conservation of what they continue to call "fauna and flora." The Antarctic Treaty database lists 37 measures on fauna and flora (ATCM 2016a), commencing in 1961, and extending to 2013. Significant among the early measures were the "Agreed Measures for the Conservation of Antarctic Fauna and Flora" (AM 1964), which specifically provided the means to designate areas of outstanding scientific interest as "*Specially Protected Areas,*" given their merits for scientific research, rather than for conservation value per se.

Perhaps of more significance is Recommendation VII-2, made by the Parties at their seventh meeting (ATCM 1972). The Parties recommended that Specially Protected Areas include representative examples of major land and freshwater ecological systems; areas with unique complexes of species; areas which are the type locality or only known habitat of any plant or invertebrate species; areas that contain especially interesting breeding colonies of birds or mammals; and areas which should be kept inviolate so that in the future, they may be used for purposes of comparison with localities that have been disturbed by human activity. (See Bonner & Smith 1985; Hughes *et al.* 2013 for overviews of the early and later development of the Antarctic protected area system).

The Environmental Protocol rationalized and consolidated protected area establishment and management by including an explicit mechanism for area protection through its Annex V, which came into force in 2002. Specifically, Article 3 of Annex V, using language echoing Recommendation VII-2, provides the basis for the designation of "Antarctic Specially Protected Areas" (ASPAs) within a systematic environmental-geographical framework. The purpose of ASPAs is set out in Article 3(1) of the Environmental Protocol, as: "*Any area, including any marine area, may be designated as an Antarctic Specially Protected Area to protect outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or ongoing or planned scientific research*"; especially those that are "*representative examples of major terrestrial, including glacial and aquatic, ecosystems and marine ecosystems*" (Article 3(2b)). While sites may be designated under the Environmental Protocol to conserve a range of other values (i.e., geological formations, historic sites or monuments, and Antarctic specially managed areas), ASPAs are considered here to be those under the highest level of environmental protection specifically in terms of biodiversity protection (Hughes *et al.* 2013). The Committee on Environmental Protection (CEP; established to provide advice and formulate recommendations to the Antarctic

Treaty Parties in connection with the implementation of the Environmental Protocol) makes recommendations to the Antarctic Treaty Parties for the establishment of and management plans for ASPAs. The consideration of protected area management plans is a key standing item on the agenda of the CEP. Historically, the Antarctic Treaty Parties themselves have identified the need to designate additional specially protected areas, demonstrating concerns about activities that may compromise the conservation values of Antarctica (ATCM 2015, 2016a).

The IUCN's definition of a PA is "A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley 2008). Since the Antarctic Treaty is a legal, longstanding, and active framework within a defined spatial area (Saul & Stephens 2015), some authors have considered Antarctica in its entirety as a PA under this well-accepted IUCN definition (Bastmeijer & Van Hengel 2009).

Terrestrial Antarctica, as defined by the Antarctic Treaty, cannot, however, be considered a reserve, or more strictly, a PA under the IUCN definition for three operational reasons:

- (1) The IUCN itself does not recognize the entire area of Antarctica, as defined by the Antarctic Treaty, as a PA, and only recognizes ASPAs as PAs in their international database on the world's PAs (WCPA 2014).
- (2) An explicit assumption when designating PAs is that they will be managed as such, to achieve the goals for which they were established (Leverington *et al.* 2010). While a management plan is legally required by Annex V for every ASPA (Perterra & Hughes 2013), no overarching management plan exists to manage the Antarctic Treaty Area as a PA.
- (3) The Committee for Environmental Protection recognizes in Annex V of the Protocol that additional ASPAs are needed, and so implicitly at least does not recognize the entire area of Antarctica as a PA, nor does it manage it as such.

In his introductory address to the first Antarctic Protected Areas Workshop, Holdgate (1998) also made it clear that at that time the IUCN did not recognize the whole of Antarctica as a "...lawful 'Protected area'..." though he argued that it should. Thus, it is clear that, in the past and today, the current ASPA network is the only set of areas that can be considered equivalent to protected areas as recognized by the IUCN, and more generally, elsewhere. So, how effective (*sensu lato*, see Kukkala & Moilanen 2013) is this network at representing the continent's biodiversity?

Effectiveness of the current ASPA network

Fifty-five of the existing 73 ASPAs have been specifically designated for their biodiversity values (Shaw *et al.* 2014). The remaining 18 have been designated to conserve other values such as historic sites or geological features (Shaw *et al.* 2014). Three recent works have comprehensively assessed the effectiveness of the former ASPAs from a terrestrial perspective (Hughes & Convey 2010; Shaw *et al.* 2014; Hughes *et al.* 2016), while others have considered the lack of marine protected areas in the region (Douglass *et al.* 2014) or protection as a whole (Chown *et al.* 2015). Our concern here is solely with the terrestrial environment.

The overwhelming message of these assessments is that, at present, the ASPA network fails to capture the biodiversity features of the continent even at the broadest spatial scale, and that the network is largely not resilient to threats from local or global changes. Many ASPAs are designated in ice-free areas, where the majority of the continent's biodiversity resides. At current continent-wide best-resolution estimates, Antarctica's ice-free area is between 21,745 km² (Burton-Johnson *et al.* 2016) and 45,886 km² (Terauds & Lee 2016). Only approximately 745 km² (1.6–3.4%) of that area is formally protected by ASPA designation for biodiversity conservation (Terauds & Lee 2016). At the broadest scales, the ASPA network fails to include five of the continent's current 16 Antarctic Conservation Biogeographic Regions (ACBRs—equivalent to ecoregions globally—Terauds *et al.* 2012), and no ACBR has more than 10% ASPA coverage. The current network is at high risk of nonindigenous species establishment, and located closer to sites of tourist landing and scientific activity than expected when compared to the same number of randomly selected ice-free sites (Shaw *et al.* 2014). Standard biological principles have also not been considered during its designation, such as dispersal and connectivity, which may elevate risk from threats such as invasive species (Hughes & Convey 2010). By contrast with the global trend of an expansion in the PA network, the frequency of designation of ASPAs has also declined over the past 30 years (Hughes *et al.* 2013). The reasons for this decline are unclear, but do indicate that recent demonstrations of the network's inadequacy have not yet affected policy.

Refining the taxonomic scope of the assessment to the macroscopic terrestrial flora reveals a similar picture (Hughes *et al.* 2016). The 33 ASPAs that contain terrestrial macroscopic vegetation fail to represent vegetation present in six ACBRs, with a further six having <0.4% of their area within an ASPA designated for the protection of botanical values. Across the continent, protected

vegetation cover amounts to 16.1 km², with more than 50% of that in a single ASPA, and over 96% of it contained in just two of the 15 ACBRs that were considered by Hughes *et al.* (2016). Concerns about the efficacy of protection for the microbiota, uniquely important in an Antarctic terrestrial context, have also been raised (Hughes *et al.* 2015b).

By these metrics, terrestrial Antarctica falls short of the Convention on Biological Diversity's Aichi Target 11 for area-based conservation (see Chown *et al.* 2015). Perhaps of more concern, the inadequate state of the Antarctic protected areas network has been raised frequently over the past two decades. For example, Holdgate (1998) concluded on the basis of a broad analysis that: "Antarctica emerges as the worst protected of the Earth's continents." Others have expressed similar views about the efficacy of Antarctic area protection and the Environmental Protocol more generally (e.g., Redgwell 1994; Koivuurova 2005; Hughes *et al.* 2013; Shaw *et al.* 2014; ATCM 2016b; Hughes *et al.* 2016).

Expanding terrestrial protected areas in Antarctica

How will the expansion of the current ASPA network better conserve the continent's biodiversity? The establishment and maintenance of protected areas is the world's foremost strategy for conserving biodiversity (Watson *et al.* 2014). Globally, PA efficacy is variable, although on average the approach conserves more biodiversity than nonprotected areas (Gaston *et al.* 2008; Coetzee *et al.* 2014; Gray *et al.* 2016). In Antarctica specifically, area protection in terrestrial systems can reduce habitat alteration (Peter *et al.* 2013), including by human trampling (Perterra *et al.* 2013), eliminate exposure to local pollution (see review in Szopińska *et al.* 2016), lower the risk of intraregional transfer of nonindigenous species (Hughes & Convey 2010), and reduce the disturbance to important wildlife colonies (Harris *et al.* 2015; Coetzee & Chown 2016). Protected area benefits to marine Antarctic systems have been discussed widely, and especially from the perspective of lowering pressure from fishing (e.g., Brooks *et al.* 2016). Designation of protected areas, such as ASPAs, does not, of course, ensure compliance with their management objectives (Leverington *et al.* 2010), emphasizing the need for PAs to be managed in accordance with their objectives, a situation that applies as much to ASPAs as it does to PAs elsewhere (e.g., Hughes *et al.* 2013; Peter *et al.* 2013; Tin *et al.* 2014).

Nonetheless, systematic conservation planning is considered the de facto standard to expand protected area networks, and to ensure objective, transparent, and ef-

ficient conservation actions when establishing effective and representative reserve designs (Margules & Pressey 2000; Pressey *et al.* 2007; Moilanen *et al.* 2009; Pressey & Bottrill 2009). Moreover, the SCP approach fully incorporates Environmental Protocol Annex V Article 3(2)'s requirement that the "Parties shall seek to identify, within a systematic environmental-geographical framework, and to include in the series of Antarctic Specially Protected Areas" several conservation goals (see the Protocol Annex V Article 3(2)). Designating a representative set of ASPAs through expansion of the existing network would provide an immediate means to reduce pressures stemming from increasing science and tourism activities (discussed in Shaw *et al.* 2014; Tin *et al.* 2014), and ensure ongoing biodiversity conservation over the long term in the face of an increasingly unpredictable global socio-political environment (Dodds *et al.* 2017), including one faced by resource shortages (see discussion in Chown *et al.* 2012a). Moreover, adopting an SCP approach to expanding the protected area network would help guarantee that all activities in the region could be effectively integrated in the face of rapidly changing environmental circumstances (reviewed by Turner *et al.* 2009; Tin *et al.* 2014; Dodds *et al.* 2017).

The modern SCP approach follows 10 stages (Table 1; adapted from Pressey & Bottrill 2009). Several of these stages have already been partially or fully completed for the terrestrial Antarctic, thus setting the stage for the immediate and effective expansion of the ASPA network. To further facilitate the required actions, we set out what has been done, and what is still required to expand the current ASPA network:

- (1) *Scoping and the planning process.* The geopolitical boundaries of the region have been established by the Antarctic Treaty (see Saul & Stephens 2015), and Consultative Parties (those that contribute to decision making under the Antarctic Treaty System) have confirmed their commitment to the protection of Antarctica's fauna and flora through adoption of the Environmental Protocol (although only eight of the 24 Non-Consultative Parties have done so [i.e., those that do not contribute to decision making under the Antarctic Treaty System]). The ASPA framework, set out in Annex V to the Environmental Protocol, also demonstrates that the identification and designation of PAs are among the primary mechanisms through which Parties aim to achieve conservation objectives in Antarctica.
- (2) *Stakeholder involvement.* The Antarctic Treaty System (i.e., the Antarctic Treaty and associated agreements, see Berkman *et al.* 2011) brings together both national stakeholders (the Treaty Parties) and others

Table 1 Key steps in a Systematic Conservation Plan (adapted from Pressey & Bottrill 2009), with their current status for terrestrial Antarctica

Nr	Stage	Description	Completed in Antarctica?
1	Scoping and the planning process	Decisions on the boundaries of region and skills/techniques required	Yes
2	Stakeholder involvement	Stakeholders are those who will influence or be affected by conservation actions, or be responsible for implementing them. Stakeholders may be involved in different ways and different stages of the planning process	Ongoing
3	Describing the context for conservation areas	The political, economic, and social context for the planning requires description, including the types of threat to natural features that can be mitigated by the planning	Ongoing
4	Identifying conservation goals	Goals are qualitative agreements on the broad vision for the conservation of a region	Yes
5	Data collection and creation	Spatially explicit data on biodiversity (both focal groups and ecological processes), socioeconomic, political, and threatening processes collated to map constraints and opportunities for conservation actions	Partly
6	Reviewing current achievement of objectives	Assessments of the adequacy of existing approaches and management to achieve conservation objectives	Yes
7	Setting conservation objectives/targets	Interpretation of goals to define quantitative conservation objectives (targets) for the region	Partly
8	Selecting additional conservation areas	With stakeholders, decisions are required about the location and configuration of additional conservation areas based upon goals, and factoring constraints	No
9	Applying conservation actions to selected areas	Institutional arrangements, legal enforcement, and technical analyses are required to ensure designated conservation actions	Partly
10	Maintaining and monitoring conservation areas	Long-term monitoring and the implementation of effective management of individual areas is required to promote the persistence of values for which they were designated, as well as maintaining their objectives	Partly

such as representatives of economic activity (e.g., the International Association of Antarctica Tour Operators) and NGO representatives of particular activities (e.g., the Scientific Committee on Antarctic Research) and civil society (the Antarctic and Southern Ocean Coalition, Berkman *et al.* 2011; Dodds & Nuttall 2015). A formal process exists for the views of stakeholders to be raised and addressed at the Antarctic Treaty Consultative Meetings (Berkman *et al.* 2011). The continued involvement of these stakeholder groups in the development of the SCP should be considered critical to its success.

- (3) *Context*. The “context” of an SCP framework refers to the political, economic, social, and environmental contexts or template of the planning region, and

how these shape constraints or opportunities for conservation. The context includes which threats to biodiversity can be dealt with spatially (i.e., by establishing ASPAs) or that require other actions (i.e., diplomacy with nations who may oppose creation of a specific ASPA). The political, economic, social, and environmental contexts of the terrestrial Antarctic are relatively well known, though they are changing quickly (Berkman *et al.* 2011; Tin *et al.* 2014; Dodds & Nuttall 2015). It is this change which provides much of the impetus for further protected area designation (Shaw *et al.* 2014), thus continual assessment thereof is a key to the SCP process for terrestrial Antarctica.

The context of the international and collective management of Antarctica also presents challenges and

opportunities for implementation of a systematic conservation plan there. These challenges exist elsewhere also, and joint consideration of the Antarctic context and other similar situations offers opportunities for colearning. For example, transboundary PAs (those crossing borders) have fostered political goodwill and co-operation between nations elsewhere in the world (Sandwith *et al.* 2001), and so may help serve as an example as to how ASPA network expansion in Antarctica could mutually benefit all states, despite concerns to the contrary (Lukin 2014). Similarly, successes in negotiating protected areas in the Antarctic can help nations understand how seemingly irreconcilable national differences in approach or policy may be overcome (see discussion in Brooks 2013; Brooks *et al.* 2016). Evidence-based lessons from the Arctic and Antarctic may also be compared to provide insights into how environmental conservation may be improved in either region. While the geopolitical and environmental circumstances differ substantially between the polar regions (Koivurova 2005), recent analyses have shown that much colearning can be derived from examining the way in which conservation and regulation has proceeded in each area (Bennett *et al.* 2015; Koivurova *et al.* 2015). For example, the ongoing learning and adaptive governance characteristic of Arctic environmental management is a valuable lesson for the Antarctic Treaty, while the ways in which the Antarctic Treaty Parties have effectively begun to manage threats from invasive alien species are a lesson to be learned by those responsible for the Arctic (Bennett *et al.* 2015). In particular, establishing a robust and systematic network of protected areas is critical for conservation success in both the Arctic and Antarctic (Bennett *et al.* 2015). Thus, sharing and incorporating lessons learned in efforts to do so in both regions will improve biodiversity conservation in each, and in so doing help address global targets to reduce threats to life on the planet.

(4) *Identifying conservation goals.* In the broadest sense, a shared vision for Antarctic conservation has been expressed by Parties acceding to the Environmental Protocol, in that they "...commit themselves to the comprehensive protection of the Antarctic environment and dependent and associated ecosystems..." (Environmental Protocol 1991, Article 2). The use of an ASPA approach has also been identified as a primary mechanism in the Protocol to achieve conservation outcomes, ideally following a "systematic environmental-geographical framework, [to identify] Antarctic Specially Protected Areas." Many of the values that should be included in such a framework have also been identified (Annex V, Article 3).

(5) *Data collection, creation, and collation.* Because of the history of science in Antarctica, and ongoing investment in scientific research (Kennicutt *et al.* 2015), much is known about Antarctica's biodiversity and its spatial structure (Convey *et al.* 2014). Some information is not yet comprehensive, or nonexistent, and so requires development for incorporation into SCP. (For an overview of available data, see Supplementary Material Table S1.) While ice-free regions typically contain higher overall biodiversity values, ice-covered regions are also important for microbial diversity (Cavicchioli 2015) and algae (Broady 1996). However, there are deficiencies of data for microbial systems, which are important and spatially diverse in Antarctica, but unrepresented in the PA network (Hughes *et al.* 2015b), especially those that are associated with or occur below ice (Cavicchioli 2015).

In general, pressures on the continent's biodiversity are well known, mapped, and can be readily incorporated into an SCP. For example, nonindigenous species already established in Antarctica have the potential for causing significant impacts on biodiversity and ecosystems (reviewed in Frenot *et al.* 2005; Hughes *et al.* 2015a; McGeoch *et al.* 2015). Human activities have also led to habitat destruction, disturbance of species, and increase localized pollution (Tin *et al.* 2009; Peter *et al.* 2013). A recent meta-analysis has demonstrated that the impacts of human disturbance to wildlife in the region are variable, but that the impacts in some regions and species may be extreme, and thus it remains a cause for concern especially given expanding human activity in terms of tourism, research, and station operations (Lynch *et al.* 2010; Peter *et al.* 2013; Coetzee & Chown 2016). The potential impacts of climate change on biodiversity are not yet generally apparent on the continent, but they are anticipated to be severe, particularly for species such as penguins (e.g., Lynch *et al.* 2012).

By expanding the current ASPA network, Parties will be able to better direct and restrict the extent of human scientific and tourism and other economic activity and its impacts (e.g., Tin *et al.* 2014; Coetzee & Chown 2016). By implementing existing management plans in current ASPAs, and those for new ASPAs, the impacts of local disturbance and pollution can be mitigated. Likewise, nonindigenous species movement can be reduced by restricting human vectors of spread (Chown *et al.* 2012b; Hughes *et al.* 2015a; McGeoch *et al.* 2015), as can the risk from interregional transfer of species (Hughes & Convey 2010).

Less well known is how such pressures may change in coming years. For example, understanding the impacts of

climate change introduces substantial challenges to effectively expand the ASPA network, although assessments have started to evaluate the risk of nonindigenous species establishment under climate change (see Chown *et al.* 2012b; McGeoch *et al.* 2015). Similarly, the future expansion of potentially negative threats in an Antarctic context, such as those from invasive species spread, tourism, extractive use, or station operations, needs to be incorporated into the SCP (see Pressey *et al.* 2007; Moilanen *et al.* 2009; Pressey & Bottrill 2009; Lynch *et al.* 2010; Chown *et al.* 2012a; Dodds *et al.* 2017). As advocated globally for protected areas (Hannah *et al.* 2007), a representative network of ASPAs can potentially aid in reducing the impacts of changing environmental circumstances by providing a diverse range of opportunities for species to respond (e.g., Hannah *et al.* 2007, Moilanen *et al.* 2009; Chown *et al.* 2012b; Groves *et al.* 2012; Hughes *et al.* 2012). How interactions among changing climates and human activities are likely play out in an Antarctic context is far from certain, making a precautionary approach through area protection an important one to be considered.

- (6) *Review current progress.* As conservation actions have already been applied in terms of the current ASPA network, quantifying the extent to which they achieve current objectives is required. Such assessments have been undertaken in the past (e.g., Smith *et al.* 1992; Njåstad 1998), complemented and extended by recent, more spatially explicit, assessments of the effectiveness of the ASPA network, as set out above. They have demonstrated that considerable expansion of the current network is required if it is to achieve effective conservation of all of the elements of terrestrial Antarctic biodiversity, even at the ecoregion (equivalent to the ACBRs) scale.
- (7) *Set conservation objectives.* Setting clear conservation objectives is a critical component of the SCP process (Margules & Pressey 2000; Kukkala & Moilanen 2013). In part, the Environmental Protocol Annex V, Article 3 does so explicitly. The evidence to do so is also expanding, dating from the Scientific Committee on Antarctic Research's matrix-based approach (SCAR 1977), to continued improvements on the ACBRs (Terauds *et al.* 2012; Terauds & Lee 2016). In addition, Important Bird Areas (Harris *et al.* 2015) have been identified to form the basis for setting aside areas with important assemblages of species, including major colonies of breeding native birds or mammals (Article 3(2c)), an approach that is supported by the Antarctic Treaty Parties (ATCM 2015). Although at a coarse spatial resolution, recent assessments have also set objectives based on the ACBRs (Shaw *et al.* 2014; Hughes *et al.* 2016). The Committee for Environmental Protection, in consultation with the full range of stakeholders, is yet to use this information to identify an explicit set of objectives to be met by a given target date.
- (8) *Select additional conservation areas.* Once quantitative targets for the expansion of the ASPA network are set across stakeholder groups, complete datasets on the biodiversity features and pressures to it can be used to inform the evidence-based designation of new ASPAs. Various software platforms exist that are specifically tailored to aid in systematic reserve design. The most widely used systematic reserve planning software platforms are currently MARXAN and Zonation, which are both freely available (<http://www.uq.edu.au/marxan/>, Moilanen *et al.* 2009; <http://cbig.it.helsinki.fi/software/zonation/>). These approaches are yet to be applied to the Antarctic continent as a whole.
- (9) *Apply conservation actions.* From a policy perspective, the institutional arrangements, responsible Parties, and methodology for designating new ASPAs are well established in the Environmental Protocol and a clear path exists for the designation of new ASPAs and agreement of their management plans by the Antarctic Treaty Consultative Parties (see Berkman *et al.* 2011). This means that the framework, broadly agreed upon by stakeholders as the primary implementation method, is already in place to implement the recommendations of the SCP once it is completed. A major challenge with an SCP is to ensure that recommendations of the plan are actually implemented by stakeholders (Knight *et al.* 2008), and systematically applied as outlined here. While the existence of the ASPA designation framework under the Environmental Protocol does not guarantee the implementation of any SCP, the process provides the impetus to streamline and implement the designation of new PAs.
- (10) *Maintain and monitor conservation areas.* The final step in a comprehensive SCP approach is to ensure the conservation of the biodiversity features for which particular ASPAs were designated (Gaston *et al.* 2008). The nations that are Consultative Parties to the Antarctic Treaty, and will ultimately have responsibility for designating new ASPAs, have to develop protocols to address the specific management objectives of designated ASPAs, and monitor their objectives to ensure that management actions are effective (Leverington *et al.* 2010). To ensure the conservation efficacy of both existing and newly designated ASPAs, it is critical that impact evaluations be built into their management plans, and

that such data be collected under a range of scenarios, so for instance, areas with ASPAs designation and for those without (see Mascia *et al.* 2014). Because much of the global protected area estate is already established, testing the conservation efficacy of protected areas is not straightforward (see Coetzee *et al.* 2014; Ferraro & Pressey 2015; Gray *et al.* 2016). The Antarctic situation thus may serve as globally relevant arena to test the efficacy of PA designation on biodiversity, as it is one of the very few regions in the world where robust, quantitative, pre-, and postestablishment assessments of PAs can still be performed. Recent assessments have made clear that much needs to be done to ensure the adequate management even of the existing ASPA network (Hughes & Convey 2010; Tin *et al.* 2014). Concerns about the difficulty of some actions, such as appropriate monitoring, are partly assuaged by the increasing application of remote surveillance techniques (e.g., Lynch & Schwaller 2014; Chown *et al.* 2015; Hughes *et al.* 2016), but at present remote sensing cannot fully replace the need for baseline surveying and monitoring of many of the primary components of Antarctic terrestrial ecosystems (Kennicutt *et al.* 2015). Nonetheless, some protected area designations (such as for "inviolate areas," or areas free from any human activity) specifically preclude site visits.

Conclusion

Protected areas are an important conservation measure for the terrestrial Antarctic, as recognized early on (Smith *et al.* 1992) and explicitly by the Environmental Protocol. We have demonstrated that the ASPA system is not yet sufficiently well developed to safeguard the continent's biodiversity, and a clear set of objectives in this regard is yet to be explicitly agreed by stakeholders. Doing so would seem much more straightforward than for Antarctic marine areas, where some agreement has only just been reached after considerable delays driven by interests in commercial resource extraction (see discussion in Brooks *et al.* 2016; Jacquet *et al.* 2016), which largely are absent from terrestrial areas.

Best international practice, and notably Systematic Conservation Planning, provides a means to remedy this situation. Moreover, much of what is required to undertake SCP in the terrestrial Antarctic is already in place, acknowledging both that information on some aspects of biodiversity is still insufficient, and that all conservation planning assumes and recognizes that some refinement will be required based on changing conditions, grow-

ing information, and new discoveries. Largely, what is now required, therefore, is the political will to expand the current ASPA network to ensure an efficacious and resilient system of areas to protect the continent's terrestrial biodiversity. The Antarctic Treaty System has, in the past, demonstrated such will (reviewed in Berkman *et al.* 2011). Now is a time to do so again, so giving effect to the Treaty Parties' Santiago Declaration in 2016 to continue to prioritize the conservation of Antarctica (<http://bit.ly/1UBlbE6>).

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Supplementary Table S1 available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

Supplementary Table S1 Major existing, and status of potential, biodiversity datasets across the Antarctic region.

References

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