Antarctica’s Protected Areas Are Inadequate, Unrepresentative, and at Risk

Justine D. Shaw1,2*, Aleks Terauds2, Martin J. Riddle2, Hugh P. Possingham1, Steven L. Chown3

1 School of Biological Sciences, The University of Queensland, St. Lucia, Queensland, Australia, 2 Terrestrial and Nearshore Ecosystems, Australian Antarctic Division, Department of the Environment, Kingston, Tasmania, Australia, 3 School of Biological Sciences, Monash University, Clayton, Victoria, Australia

Abstract: Antarctica is widely regarded as one of the planet’s last true wildernesses, insulated from threat by its remoteness and declaration as a natural reserve dedicated to peace and science. However, rapidly growing human activity is accelerating threats to biodiversity. We determined how well the existing protected-area system represents terrestrial biodiversity and assessed the risk to protected areas from biological invasions, the region’s most significant conservation threat. We found that Antarctica is one of the planet’s least protected regions, with only 1.5% of its ice-free area formally designated as specially protected areas. Five of the distinct ice-free ecoregions have no specially designated areas for the protection of biodiversity. Every one of the 55 designated areas that protect Antarctica’s biodiversity lies closer to sites of high human activity than expected by chance, and seven lie in high-risk areas for biological invasions. By any measure, including Aichi Target 11 under the Convention on Biological Diversity, Antarctic biodiversity is poorly protected by reserves, and those reserves are threatened.

Why Protect Terrestrial Antarctica?

The majority of Antarctica’s biodiversity is concentrated in ice-free areas. While there is life outside of these areas [8,9], biodiversity and human activity are much higher within them. For these reasons, we focus on the protection of ice-free environments. Threats to the ecological integrity of Antarctica are accelerating because of a growing variety of activities, be they tourism- or science-related, have increased considerably over the last 20 years and are predicted to continue to do so [20].

Protected areas are generally effective in reducing threats to biodiversity and regarded as the cornerstone of conservation [21]. Their efficacy is enhanced substantially when they are representative of the biodiversity of a region [22]. This is recognised by the Strategic Plan for Biodiversity 2011–2020, which has set 17% of terrestrial land area protected as the most recent target (Aichi Target 11) [23]. The Madrid Protocol likewise recognizes the significance of representative protected areas, calling...
for ASPAs to be identified “within a systematic environmental-geographic framework” and include “representative examples of major...ecosystems” [24].

Given that conservation threats to terrestrial Antarctica are growing, that protected areas are a cornerstone of conservation, and that a network of specially protected areas is already considered a key tool in the conservation management of Antarctica, we assess the effectiveness of this network in a contemporary global context. How representative is this network and, compared with other areas of Antarctica, how high are the risks to the network of nonindigenous species invasion, which at present pose the greatest conservation threat to the region [2,25]? Our assessment was conducted in three steps. We quantified the proportion of ice-free land that is protected, as this is where the majority of Antarctic biodiversity occurs; examined its representativeness using recently developed protected-area assessment metrics [26]; and quantified the level of threat these protected areas face from biological invasion using information from a recent, spatially explicit risk assessment (see Methods S1 for details of data sources and analytical methods) [25].

**Antarctic Protection Relative to Other Continents**

Antarctica’s ice-free area is 46,253 km², of which only 1.5% is formally designated as a protected area for the purposes of terrestrial biodiversity conservation (688 km²). Fifty-five ASPAs have been designated in ice-free areas for their biodiversity values (Figure 1; Tables S1, S2), while a further 10 ASPAs (not considered here) conserve other values, such as historic sites or geologically important features, that are of concern to the ATS [5]. The mean protected area of each Antarctic Conservation Biogeographic Region (ACBR), the equivalent of ecoregions elsewhere (Figure 1) [27], is 1.1%, and no ACBR has 10% or more of its area designated as protected area (range: 0% to 6%; Table S3). In a global context, on a country-comparison basis, Antarctica lies in the lowest quartile for total percentage protection (Figure 2A), mean protected area of each ecoregion, and number of ecoregions with 10% of protection (Figure S1). By any measure, including recently agreed-upon Aichi Target 11, this level of protection is inadequate. While Antarctica ranks in the second-highest quartile for protection equality (Figure 2B) (i.e., the adapted Gini coefficient of Barr et al. [26]), detailed examination of ecoregional protection reveals a less optimistic situation. Five of the fifteen Antarctic ecoregions are not represented in the current portfolio of ASPAs designated for the protection of biodiversity (Figure 1) and two contain most of the protected areas (17 and 10, respectively), representing 74% (503 km²) of all ice-free ASPAs designated for the protection of biodiversity. Combining total percentage protection with a protection equality metric, as previously recommended but not implemented globally [26], provides an integrated protection metric by which Antarctica is ranked in the lowest quartile of countries large enough to assess, placed 69th (out of 84), between Mali and Kazakhstan (Figure 2C).

**Protected Areas at Risk of Invasion**

In terms of risk, the mean distances of ASPAs to tourist landing sites and scientific activity (i.e., established scientific facilities) are 289 km (range: 0 km to 2406 km) and 64 km (range: 0 km to 832 km), respectively, significantly closer than expected for the same number of randomly selected ice-free sites (Figure 3). Seven of the 55 ASPAs, all of which are on the Antarctic Peninsula, are at high risk of nonindigenous species establishment (risk exceeds 50%, according to Chown et al. [25]), overlapping with high-risk areas for nonindigenous
Overall, the mean risk index of establishment of nonindigenous species for ASPAs is 12% (standard error ±5%), significantly higher (by 24 times) than the mean risk for a randomly selected set of ice-free locations (0.5% ±0.1%, χ² = 86.1, p<0.0001). Aichi Target 11 of the Strategic Plan for Biodiversity 2011–2020 [23] aims for “at least 17% of terrestrial and inland water areas” to be protected to ensure conservation of biodiversity. Globally, 13% of terrestrial areas are protected [31]. By comparison, only 1.5% of ice-free terrestrial Antarctica (0.005% of the total continental area) is formally protected for the purposes of biodiversity conservation. Aichi Target 11 also calls for the global protected-area network to be ecologically representative. Again, Antarctica fails to meet this benchmark.

In addition to representing the biodiversity of a given region, protected areas should also safeguard biodiversity from threatening processes [32]. In Antarctica, however, protected areas are significantly closer to sites of human activity than would be expected by chance. This is partly a product of the history of protected-area designation. Such proximity elevates threat, given that human population density adjacent to protected areas is the most significant predictor of their invasive species richness, both in the broader Antarctic region [33] and elsewhere [34]. Moreover, two of the ASPAs at high risk of invasion already support nonindigenous species [14,35].

The Way Forward

Antarctic terrestrial biodiversity is concentrated in the continent’s relatively small and fragmented ice-free areas. Increasing human activity and risk to biodiversity is also concentrated in these areas, and the total area accorded the additional protection conferred by ASPA status is small. Of the 73 ASPAs, only 55 (688 km²) occur in ice-free areas and have recognised terrestrial biodiversity values. In consequence, while there is a widespread general perception that Antarctica is well conserved, in practice conservation of terrestrial biodiversity from a continent-wide perspective is poorly served by the protected-area system. Therefore, what is required now is a systematic network designed to best

A Natural Reserve, Devoted to Peace and Science?

In a global context, the designation of Antarctica as “a natural reserve, devoted to peace and science” under the ATS is unique; no other continent has a similar level of apparent protection [6]. This situation may be at least partly responsible for Antarctica’s repeated exclusion from global assessments of protected-area effectiveness [26,28,29]. However, its apparent protection status reflects management intent, not management outcome [30]. Although the Antarctic environment is less utilised and populated than others, activities permitted on the continent (e.g., road and building construction, vehicle traffic, waste disposal) are having substantial impacts on biodiversity [12,18,19].
conserve the biodiversity of Antarctica as a whole. Once a protected area is designated and human activity restricted, management efforts are relatively minimal compared to protected-area management requirements globally [36]. Parties to the Convention on Biological Diversity (CBD) have agreed to improve global protection of biodiversity by encouraging nations to meet the Aichi Targets by 2020. Although Antarctica is excluded from the provisions of the CBD, we believe that the Aichi Targets should be met for the region. For a continent that is so little impacted by human activity compared with the rest of the planet, achieving an objective that has already been attained by several nations should be straightforward for those who manage the region under the Antarctic Treaty System.

Acknowledgments

We are grateful for constructive comments from P. Convey (British Antarctic Survey), R. Fuller (University of Queensland), and M. A. McGeoch (Monash University). Data utilised in these analyses are contained in the Supporting Information, or the sources referenced therein.

Supporting Information

Figure S1 Two measures of protected-area coverage of 83 countries and Antarctica. (A) Mean percentage protection of ecoregions and (B) percentage of ecoregions with at least 10% protection. We divided the scores of all countries into quartiles for each measure and assigned colours to each quartile: green = highest quartile, yellow = second highest quartile, orange = second lowest quartile, and red = lowest quartile.

Figure S2 Continent-wide risk of establishment of nonindigenous species and high-risk ASPAs. (See Chown et al. [25] for details of risk index). Inset shows location of ASPAs overlaid on risk index cells with values >0 for the Antarctic Peninsula region.

Table S1 Designation of ASPAs and their invasion risk. Designations from Antarctic Protected Areas Database, Secretariat of the Antarctic Treaty, http://www.ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=69&lang=e. (DOCX)

Table S2 Ice-free ASPAs that have designations related to the protection of terrestrial biodiversity. (DOCX)

Table S3 Overlap of ice-free, biodiversity-designated ASPAs and ACBRs. (DOCX)

Methods S1 Supporting methods. (DOCX)
References

1. Cressey D (2012) Antarctic seas in the balance. Nature 490: 524.
2. Chown SL, Lee JE, Hughes KA, Barnes J, Barrett PJ, et al. (2012) Challenges to the Future Conservation of the Antarctic. Science 337: 158–159.
3. Sanderson EW, Jauhi M, Levy MA, Redford KH, Wannebo AV, et al. (2002) The human footprint and the last of the wild. BioSci 52: 891–904.
4. Berkman PA, Lang MA, Walton DWH, Young PJ, et al. (2013) The biodiversity and biogeochernistry of cryoconite holes from McMurdo Dry Valley glaciers, Antarctica. Arct Antarct Alp Res 36: 84–91.
5. Frenot Y, Chown SL, Whinam J, Selkirk PM, Porazinska DL, Fountain AG, Nylen TH, Virginia RA, Wall DH (2007) The biodiversity and the last of the wild. BioSci 52: 891–904.
6. Sanderson EW, Jaiteh M, Levy MA, Redford KH, Boitani L, Cowling RM, Dublin HT, Mace GM, Parrish J, et al. (2009) Greater focus needed on alien plant impacts in protected areas. Conserv Letters. E-pub ahead of print. doi:10.1111/j.1755-263X.2009.00057.x
7. Porazinska DL, Fountain AG, Nylen TH, Virginia RA, Wall DH (2007) The biodiversity and biogeochernistry of cryoconite holes from McMurdo Dry Valley glaciers, Antarctica. Arct Antarct Alp Res 36: 84–91.
8. Cressey D (2012) Antarctic seas in the balance. Nature 490: 524.
9. Porazinska DL, Fountain AG, Nylen TH, Virginia RA, Wall DH (2007) The biodiversity and biogeochernistry of cryoconite holes from McMurdo Dry Valley glaciers, Antarctica. Arct Antarct Alp Res 36: 84–91.
10. Molina-Montenegro MA, Carrasco-Urra F, Rodrigo C, Convey P, Valladares F, et al. (2012) Occurrence of the non-native annual bluegrass on the Antarctic mainland and its negative effects on native plants. Conserv Biol 26: 1–7.
11. Hughes KA, Worland MR, Thorne MAS, Convey P (2013) The non-native chironomid E. mutula in Antarctica: erosion of the barriers to invasion. Biol Inv 15: 269–281.
12. Campbell BB, Claridge GGC, Balla MR (1998) Short- and long-term impacts of human disturbances on snow-free surfaces in Antarctica. Polar Rec 34: 13–24.
13. Kerry KR, Riddle M (2009) Health of Antarctic wildlife: a challenge for science and policy. London: Springer. 407 p.
14. Tin T, Fleming ZL, Hughes KA, Aydley DG, Convey P, et al. (2009) Impacts of local human activities on the Antarctic environment. Antarctic Sci 21: 3–33.
15. Tin T, Larmers M, Liggert D, Maher PT, Hughes KA (2014) Setting the scene: human activities, environmental impacts and governance arrangements in Antarctica. In: Tin T, Liggert D, Maher PT, Larmers M, editors. Antarctic futures: human engagement with the Antarctic environment. Dordrecht: Springer. pp. 1–24.
16. Rodrigues ASL, Andelman SJ, Bakaar MI, Botani L, Brooks TM, et al. (2004) Effectiveness of the global protected area network in representing species diversity. Nature 428: 640–643.
17. Moilanen A, Wilson KA, Possingham HP, editors. (2009) Spatial Conservation Prioritization. Quantitative Methods and Computational Tools. Oxford: Oxford University Press. 304 p.
18. UNEP (2010) Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting, X/2. The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets. United National Environment Programme Convention on Biological Diversity. UNEP/CD/COP/DEC/X/2, Nagoya. Available: http://www.cbd.int/sp/targets/. Accessed 14 May 2014.
19. Boitani L, Cowling RM, Dublin HT, Mace GM, Parrish J, et al. (2009) Change the IUCN Protected Area categories to reflect biodiversity outcomes. PLoS Biol 6: e24707. doi:10.1371/journal.pbio.0060066
20. Terauds A, Chown SL, Morgan F, Peat HJ, Watts D, et al. (2012) Conservation biogeography of the Antarctic. Divers Distrib 18: 726–741.
21. Jenkins CN, Joppa L (2009) Expansion of the global terrestrial protected area system. Biol Conserv 142: 2166–2174.
22. Hulme PE, Pysek P, Pergl J, Jaroslí V, Schaffner U, et al. (2013) Greater focus needed on alien plant impacts in protected areas. Conserv Letters. E-pub ahead of print. doi:10.1111/j.1755-263X.2012.00186.x
23. UNEP (2010) Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting, X/2. The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets. United National Environment Programme Convention on Biological Diversity. UNEP/CD/COP/DEC/X/2, Nagoya. Available: http://www.cbd.int/sp/targets/. Accessed 14 May 2014.
24. Anon. (1991) Annex V to the Protocol on Environmental Protection to the Antarctic Treaty. Antarctic Treaty Consultative Meeting XVI, 7–18 Oct 1991, Bonn, Germany. Available: http://www.ats.aq/documents/recatt/Att006_e.pdf. Accessed 14 May 2014.
25. Chown SL, Huiskes AHI, Gremmen NJM, Lee JE, Terauds A, et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc Natl Acad Sci U S A 109: 4938–4943.
26. Barr LM, Pressey RL, Fuller RA, Segnan DB, McDonald-Madden E, et al. (2012) A new way to measure the world’s protected area coverage. PLoS ONE 6: e24707. doi:10.1371/journal.pone.0024707
27. UNEP (2010) Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting, X/2. The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets. United National Environment Programme Convention on Biological Diversity. UNEP/CD/COP/DEC/X/2, Nagoya. Available: http://www.cbd.int/sp/targets/. Accessed 14 May 2014.
28. UNEP (2010) Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting, X/2. The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets. United National Environment Programme Convention on Biological Diversity. UNEP/CD/COP/DEC/X/2, Nagoya. Available: http://www.cbd.int/sp/targets/. Accessed 14 May 2014.
29. Anon. (1991) Annex V to the Protocol on Environmental Protection to the Antarctic Treaty. Antarctic Treaty Consultative Meeting XVI, 7–18 Oct 1991, Bonn, Germany. Available: http://www.ats.aq/documents/recatt/Att006_e.pdf. Accessed 14 May 2014.
30. Chown SL, Huiskes AHI, Gremmen NJM, Lee JE, Terauds A, et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc Natl Acad Sci U S A 109: 4938–4943.
31. Chown SL, Huiskes AHI, Gremmen NJM, Lee JE, Terauds A, et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc Natl Acad Sci U S A 109: 4938–4943.
32. Chown SL, Huiskes AHI, Gremmen NJM, Lee JE, Terauds A, et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc Natl Acad Sci U S A 109: 4938–4943.
33. Chown SL, Huiskes AHI, Gremmen NJM, Lee JE, Terauds A, et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc Natl Acad Sci U S A 109: 4938–4943.
34. Chown SL, Huiskes AHI, Gremmen NJM, Lee JE, Terauds A, et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc Natl Acad Sci U S A 109: 4938–4943.
35. Chown SL, Huiskes AHI, Gremmen NJM, Lee JE, Terauds A, et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc Natl Acad Sci U S A 109: 4938–4943.
36. Chown SL, Huiskes AHI, Gremmen NJM, Lee JE, Terauds A, et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc Natl Acad Sci U S A 109: 4938–4943.