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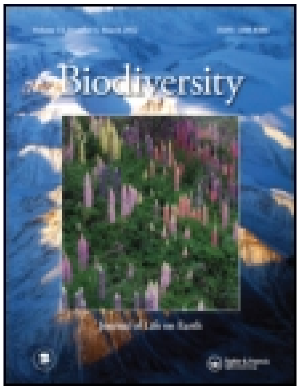

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KEYNOTE PAPER

The impacts of climate change on circumpolar biodiversity

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Some of the most rapidly changing ecosystems on our planet are located in the polar regions (IPCC 2007; Turner et al. 2009; SWIPA 2011). In some areas of the Arctic and Antarctic, atmospheric temperatures are rising at rates more than double the global average. In addition, there are other direct human impacts on polar regions such as pollution, exploitation and development. Polar ecosystems and the biodiversity they support are already responding to this change and it is expected that even more profound impacts will occur this century. Compounding the risk to polar biodiversity is the fact that many polar ecosystems have limited functional redundancy; in the event of the loss of a single keystone species, they may potentially be exposed to cascading effects and complete ecosystem restructuring (Post et al. 2009). Rapid climate change affecting the polar regions will also have profound physical and ecological consequences for the rest of the planet since the ice-covered Arctic Ocean, the Antarctic continent, and the globally significant Antarctic Circumpolar Current (ACC) serve a key role in regulating the Earth's climate and ocean systems.

This special issue is intended to provide an overview of circumpolar change that crosses disciplines, systems, taxonomic groups and regions, and integrates papers that address a range of topics including: the monitoring of freshwater, marine, and terrestrial organisms in both the northern and southern polar regions, the role of protected areas in monitoring change in a warming world, polar resource management and development, impacts on northern indigenous peoples, case studies of the biodiversity of selected polar organisms, impacts of sea ice loss on terrestrial and marine organisms and ecosystems, interconnections with lower latitudes, and the influence of historical processes that have impacted polar diversity. This keynote paper is intended to provide background and insight into the issue by comparing and contrasting the Arctic and Antarctic regions in terms of their physical environment, human influences, indications of climate change and impacts on their biodiversity.

Keywords: Antarctic; Arctic; global linkages; global and regional change; governance; historical processes; human impacts

Introduction – geography, climate and change in the polar regions

For many living organisms the polar regions support some of the most challenging habitats on our planet. Consequently, species that have evolved and adapted to polar extremes often exhibit unusual life forms, as well as unique behavioural and physiological processes. Though they have some features in common, the Arctic and Antarctic regions are also strikingly different in many ways. Their geography provides a clear contrast: the Arctic consists of the northern fringes and associated archipelagos of large continental landmasses surrounding the Arctic Ocean; the expansive, elevated Antarctic continent on the other hand lies over the South Pole and is surrounded and isolated by the wide expanse of the cold Southern Ocean (Figure 1). This difference drives important climatic contrasts between the two regions; the large and mostly ice-free Arctic landmasses absorb solar energy, particularly during the summer months, while the high albedo of the ice-covered Antarctic reflects it, with the result that in summer the Antarctic experiences significantly lower temperatures than the Arctic. The Arctic is much more connected to temperate regions through the continental shelves in the Arctic Ocean and the associated land masses. This physical

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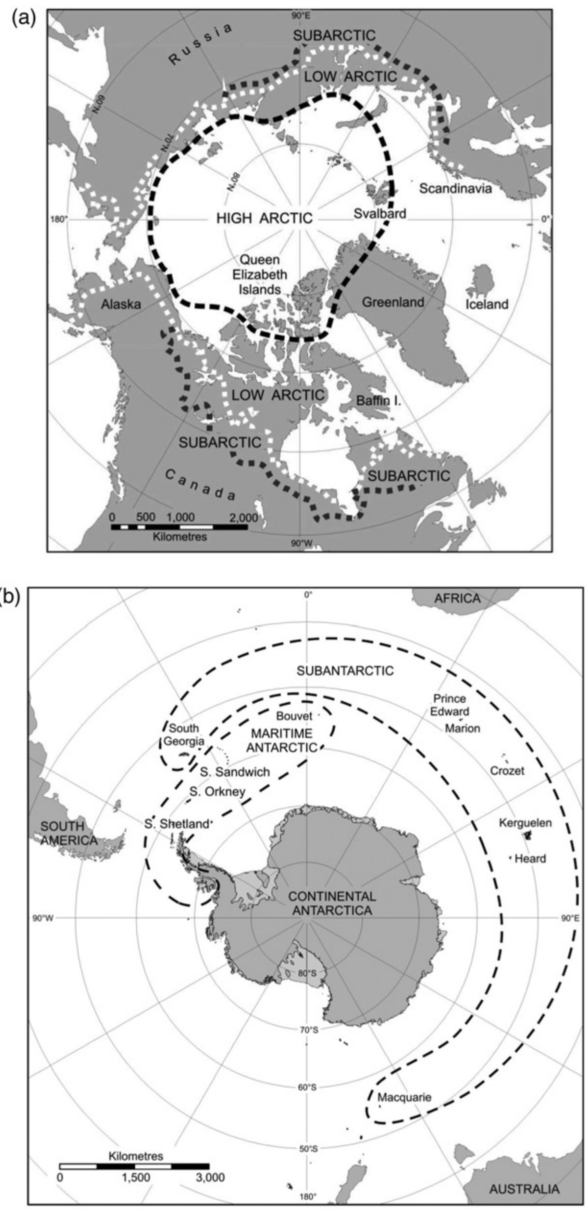

Figure 1. Geographical contrasts in the two polar regions: (a) the Arctic comprises the northern fringes of continental land masses surrounding a relatively small polar ocean; (b) the Antarctic consists of a large isolated and ice-covered continent, surrounded and isolated by the Southern Ocean (from Convey (2010), with permission).

connectivity supports substantial ecosystem connectivity through migrating organisms and under changing climates is expected to facilitate the northward movement of species and ultimately the colonisation of Arctic ecosystems by sub-Arctic and temperate invaders, in a manner that is not possible in the Antarctic. The Arctic Ocean is also strongly influenced both by freshwater and sediment input from the great northern rivers, as well as the direct impacts of centres of human population and industry. None of these features have parallels in the Antarctic.

The Arctic land masses reached their present positions about 10–15 million years ago (mya), while the Antarctic has been situated at a high southern latitude for much longer, and has moved relatively little, even in comparison with its position at the early stages of breakup of the supercontinent Gondwana over 100 mya. It has been suggested that large-scale glaciations began 6–10 mya in the Arctic, much later than in Antarctica (Eastman 1997; DeConto and Pollard 2003; Turner et al. 2009), but some recent evidence suggests a 'bipolar symmetry' in cooling (Moran et al. 2006; Krylov et al. 2008), with Arctic cooling initiating much earlier. In the south, the opening of the Drake Passage (23.5–41 mya), between the tip of South America and the Antarctic Peninsula, permitted formation of the oceanic ACC as well as unobstructed atmospheric circulation around the Antarctic continent, resulting in oceanographic and atmospheric isolation (Clarke, Barnes, and Hodgson 2005; Barnes et al. 2006). The Drake Passage opening was also partially responsible for accelerating the cooling of both the land and Southern Ocean waters that led to continental-scale ice sheet formation 25–30 mya. Parallel features and isolation do not exist in the Arctic, which has therefore faced less stringent evolutionary pressures. In this sense, the Arctic provides an intellectual or research connection between the more extreme, and in some respects structurally simpler, Antarctic oceanic and terrestrial systems and the more complex temperate and tropical systems (di Prisco and Verde 2006).

Organisms that live permanently in the polar regions face extreme environmental conditions including chronic low temperatures, high winds and solar radiation, freezing and/or desiccation stress, environmental variability on both short and long time-scales, and extreme and acute events. Strong seasonality is inherent, as beyond the polar circles the sun remains below the horizon for days to months in winter, and above it in summer. The terrestrial habitats of the higher latitudes of the Arctic and Antarctic are further characterised by the combination of long winters and extremely low air temperatures, typically −40 to −60°C or even lower, although such extremes are not reached at lower latitudes or in habitats protected by winter snow cover. In summer, at microhabitat scale, temperatures can be well above the ambient air temperature, even reaching +20 to 30°C for short periods when the standard meteorological air temperature remains below zero.

In the terrestrial ecosystems of the polar regions, the combination of low winter temperatures, the length of the winter season, and high summer microhabitat variability are responsible for both an extreme and highly variable environment. Arctic terrestrial ecosystems are characterised by high numbers and a large biomass of migratory vertebrates, taking advantage of brief but intense peaks of production, and providing an important connection with global biodiversity. There is no analogous migratory component within Antarctic or sub-Antarctic terrestrial ecosystems. In contrast to the extreme temperature variability on land, the Antarctic marine environment (and to a lesser extent that of the Arctic) is amongst the most thermally stable on Earth, in some locations varying as little as 0.2°C over the annual cycle. The extreme seasonality in light regime at high latitudes leads to intense pulses of biological production in the short polar summers both on land and in the sea, this being particularly apparent in the short phytoplankton blooms that form the basis of Arctic and Southern Ocean marine food webs.

Polar ecosystems face a range of physical environmental challenges in addition to temperature. Environmental conditions on land, particularly in the Antarctic, are often at one extreme of the spectrum seen on Earth (Peck, Convey, and Barnes 2006; Chown and Convey 2007). Many researchers consider the lack of liquid water to be the most important constraint for biological systems here (Kennedy 1993; Block 1996; Hodkinson et al. 1999). Indeed, a large proportion of the Antarctic continent is a frigid desert, with very low levels of precipitation combined with low relative humidity (Sømme 1995). In both polar regions there have been considerable changes in exposure to short wavelength and damaging ultra-violet-B radiation in recent decades following anthropogenic ozone depletion (Rozema 1999).

The rate and magnitude of the changes being seen in the polar regions, in combination with the structural simplicity of some of the component ecosystems, has led to the biota and ecosystems of these regions being proposed as sensitive biological indicators of the consequences of environmental change (e.g. Freckman and Virginia 1997; Walther et al. 2002; Convey, Scott, and Fraser 2003; Callaghan et al. 2004a,b; Chapin et al. 2005). The 'polar amplification' of global change trends is exemplified by compelling observations of glacier retreat, sea-ice thinning and permafrost degradation, amongst others. Indeed, Arctic summer sea ice is predicted to disappear completely in only a few decades (Moline et al. 2008), and 2012 has already recorded yet another record minimum sea-ice extent. For polar species and communities, failure to adapt to changes exceeding internal flexibility limits, or through appropriate behavioural responses, will result in extinction. Globally, the vulnerability of species to the considerable and largely anthropogenic contemporary climate changes, further exacerbated by other, cumulative anthropogenic pressures (e.g. over-harvesting, habitat loss, land use change and degradation due to development) raises the possibility that human influence may cause a major 'mass extinction' event in the near future (Hoffmann and Sgrò 2011).

Biodiversity at the poles

There are contrasting patterns of biodiversity in the Arctic and Antarctic in terms of species diversity, both on land and in the sea. Although large and globally significant populations of seabirds and marine mammals breed on the fringes of the Antarctic continent, macroscopic terrestrial diversity is low and comprised almost entirely of invertebrates and cryptogams (Convey 2007a). There are no native terrestrial vertebrates in the Antarctic, contrasting markedly with the large migratory populations of birds and mammals that exploit high Arctic summer productivity on land, as well as a smaller number of year-round residents. While the same invertebrate groups are important components of terrestrial diversity in both polar regions, in the High Arctic, diversity within these groups is generally much higher than seen in any part of the Antarctic (Jensen and Christensen 2003; Coulson and Resfeth 2004; Convey 2007b). The Antarctic vascular plant flora includes only two native species on the continent, ca. 70 when including the sub-Antarctic islands (Green and Walton 1975; Convey 2007a), whereas about 1000 species and subspecies are regarded as part of the regular Arctic flora (Elven et al. 2011). This contrast in diversity cannot be accounted for merely by looking at the difference in area of un-glaciated land in the two regions. Although the contrast is less pronounced between Arctic and Antarctic bryophyte and lichen floras it is still substantial. For this reason, the relative importance of primary producers other than plants, i.e. cyanobacteria and green algae, is probably greater for maintaining terrestrial food webs in the Antarctic than the Arctic. However, the reverse pattern is apparent in the sea. Isolation of the Antarctic continent and continental shelf during the final stages of breakup of the supercontinent Gondwana, followed by formation of the ACC and cooling of the continent and Southern Ocean through multiple glacial cycles has led to considerable evolutionary radiation in the marine environment (Griffiths, Barnes, and Linse 2009; Convey et al. 2012). Today, Antarctic benthic marine diversity and biomass is second only to that of coral reefs. The Arctic Ocean in contrast has experienced greater extinction and subsequent re-colonisation of marine habitats during glacial cycles, resulting overall in lower diversity in some groups than typifies the Antarctic (Verde et al. 2012). However, the Arctic also has a much more complex oceanographic system than does the Antarctic and in other groups, such as fish, there is higher diversity as well as representation of more than one higher taxonomic level. Both regions support large breeding populations of marine mammals and birds during their respective summers.

There are historical, physical and biological differences between the two modern habitats, and the modern polar faunas differ in age, endemism and physiological tolerance to various environmental parameters (Verde et al. 2012). With this background, combined with contemporary changes, comparative work at the poles is a source of invaluable information on the evolution of adaptations developed in response to imposed stresses and how polar biodiversity may respond to these challenges in the future.

Biological responses to change

With climate change so much in the current public eye as well as being central to governmental and scientific research priorities, the polar regions provide an opportunity for understanding and informing what has happened, is happening and will happen to our planet both in terms of climate and biodiversity. Given the rates of environmental change being experienced in parts of the polar regions, considerable research effort has been devoted to identifying biological responses to these changes, and how these might inform understanding of the consequences of change to be expected at lower latitudes currently facing slower rates of change (e.g. Walther et al. 2002; Callaghan et al. 2004a,b; Bergstrom, Convey, and Huiskes 2006). The evolution of polar organisms has taken millions of years to build adaptations suitable for survival and reproduction under extreme environmental conditions. When disturbances to these conditions occur, evaluating the response of adapted organisms will yield important indications of general trends in other organisms and the resilience of ecosystems to change. Hence, insights on the ability of organisms and communities to cope with the current rapid changes, which in many cases are simpler and more clearly understood in polar systems, are likely to provide fundamental information for understanding predicted changes and responses at lower latitudes and in less extreme environments (di Prisco et al. 2012).

In some instances, the constituent members of some polar ecosystems are likely to benefit, initially at least, from the current environmental changes. This is the case in systems such as the Antarctic terrestrial environment (Convey 2011), where the end result of local environmental changes is to provide greater energy input, warming and/or duration of liquid water availability, and there is an expectation, generally supported by the results of environmental manipulation experiments (Bokhorst et al. 2011) of increased production, biomass, population size, community complexity and colonisation. In the Arctic, there is evidence based on experiments (Elmendorf et al. 2012a) and long-term monitoring (Callaghan et al. 2011; Elmendorf et al. 2012b) that overall plant abundance will generally increase and that it has already increased in response to a warmer climate, although there is a strong regional variation (Elmendorf et al. 2012a,b). Furthermore, recent studies on High Arctic plant communities, as highlighted in this issue, show markedly different responses to change, often with contrasting results. Although these studies report significant change in the composition of some Arctic plant communities on a decadal scale, especially under moist conditions, overall species diversity is not strongly affected. However, at lower Arctic latitudes, the expected and observed northwards progression of tree and shrub lines will ultimately pose a threat to obligate species and communities of the more extreme conditions of the High Arctic (Walther et al. 2002). Alsos et al. (2012) modelled consequences of future climate change on geographic range and genetic diversity in 27 northern vascular plant species and predicted that two thirds will lose close to half of their range by 2080 under at least one emission scenario and circulation model, and one third will lose up to 50% of their genetic diversity, depending on the emission scenario chosen.

Patterns of response on land in the Arctic are often more complex than in the Antarctic due to the fact that the range of biological communities and components included is far greater. In the High Arctic, where terrestrial invertebrate and plant communities are broadly similar to those of the Antarctic continent, similar responses to warming and wetting would be expected. Increases in primary biological productivity are already being seen in the marine ecosystems of the Arctic and are strongly correlated to areas of sea-ice loss (Frey, Arrigo, and Gradinger 2011), with analogous changes reported at the margins of the Antarctic continent where recent ice shelf retreat has occurred (Peck et al. 2010). However, other factors such as melting permafrost and changing distributions of vertebrate herbivores also need to be taken into account when predicting community-level responses. For instance, as reported in this issue, loss of sea-ice cover in the Canadian archipelago may provide a locally increased barrier to island migrations leading to the possible extinction of some island populations and potentially, in the long-term, local genetic differentiation. It is predicted that ice bridges will disappear altogether in this century, restricting the immigration of southern species to Arctic islands, possibly leaving certain Arctic archipelagos as the last refuge for typical Arctic mammals.

The impacts of climate change are likely to be compounded by other human activities such as changes in land use possibly obstructing migration or colonisation routes, resource extraction, development and pollution. As in other parts of the world, the introduction of non-indigenous organisms to polar regions by anthropogenic means, for example by ballast water release from ships or on cargo or personal clothing, appears to far outweigh the frequency of natural colonisation events. The impacts of those species that become invasive can be drastic in terms of ecosystem structure and function (ACIA 2005; Frenot et al. 2005). Many consider invasive species, coupled with climate change, to be the most important environmental challenge facing the world today and in polar regions the threat is even more severe due to the limited functional redundancy found in these ecosystems. Until recently, the terrestrial ecosystems of Antarctica in particular have been protected from such human impacts but this is now breaking down (Hughes and Convey 2010; Chown et al. 2012). The greater connectivity of the Arctic with lower latitudes, facilitating natural northwards movements, may result in this challenge being less significant in the Arctic than in the more isolated Antarctic regions.

The biological responses to climate-related change, particularly in the Arctic, may have far wider importance than just within the region and its contained communities. A clear example is given by the extensive consequences of melting permafrost. As well as having direct impacts on the overlying surface communities, drainage regimes and human infrastructure, the melt will also have important feedbacks into large-scale carbon and nitrogen cycles and, through the release of stored carbon, into the atmosphere (in particular as methane) and into the global climate system affecting future climate scenarios (Oechel et al. 2000; IPCC 2007; Dorrepaal et al. 2009).

Human influence in the polar regions

The Arctic and Antarctic have contrasting histories of human discovery, activity and governance. After the last Ice Age, human populations colonised the boreal landmasses as far north as some of the islands of the Arctic Ocean relatively rapidly, leading to the current indigenous populations present throughout these regions. With a largely 'hunter-gatherer' lifestyle, these populations clearly interacted with and impacted the native biodiversity, particularly the larger and more charismatic elements of the vertebrate fauna. Even today, local peoples in the Arctic maintain a close relationship with the land and the biodiversity it supports, continuing to practice elements of traditional lifestyles. Indigenous peoples of the Arctic offer a unique opportunity to expand our understanding of environmental change through the intergenerational knowledge that has been passed along as oral history. As well, local peoples in the Arctic can act as 'human sensors' employing, in a cost-effective manner, local observations and measures to help detect important changes in the Arctic's biodiversity.

In recent centuries, the rapid development of industrialisation, in combination with global population expansion, has led to further waves of colonisation and even more drastic exploitation of Arctic natural resources, with attendant threats both to regional diversity and indigenous peoples. Growth in human populations has led to pollution, and the all too common 'tragedy of the commons' resulting in resource over-exploitation and land use change. A fragmented landscape often leads to the loss of connectivity for biological populations such as through the disruption of migration routes. As the ice-free period of the Arctic Ocean becomes longer in duration and expands in area, concurrent with the decline of more southerly fish stocks and oil and gas supplies, pressure for increased resource exploitation (e.g. commercial fishing, oil and gas exploration and development) is already occurring. This will inevitably be accompanied by increased shipping and industrial and population development on land, resulting in further anthropogenic pressures on marine and terrestrial biodiversity.

In contrast, Antarctica has no history of long-term human contact or colonisation, and there is complete reliance on maintaining scientific research facilities on a year-round basis. Its outlying Southern Ocean islands only started to be discovered during the seventeenth and eighteenth centuries, the Antarctic Peninsula was first landed upon in the early nineteenth century and the main continent itself just before the start of the twentieth. Even over this short timescale, however, some parts of the region already show profound human impacts (Tin et al. 2009). This is particularly the case in the Southern Ocean marine environment, which faced uncontrolled exploitation of living resources (seals, whales and, more recently, fish and krill) from shortly after their discovery, only curtailed by the almost complete destruction of stocks (Trathan and Reid 2009). In principle, fisheries exploitation in this region is controlled today under the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR; www.ccamlr.org), which takes an 'ecosystem approach' to management issues. Nevertheless, it is clear that the Southern Ocean marine ecosystem has undergone drastic perturbation, with little or no certainty either whether trajectories will lead to recovery of its original state or to any other stable condition.

The Antarctic terrestrial environment has no exploitable biological resources, notwithstanding microbial bioprospecting, which in itself will remove only very small quantities of material (Cowan et al. 2011). Antarctica is yet to face exploitation of geological resources. However, the sub- and maritime Antarctic islands have not been immune to impacts from the marine industries, with considerable construction of local infrastructure, land use change, pollution, and the first phase of anthropogenic introduction of non-indigenous biota (Convey and Lebouvier 2009). Since the collapse of the whaling industry in the first half of the twentieth century, and the subsequent development and signing of the Antarctic Treaty in 1961, human activity on land was focussed initially on governmental activities associated with national scientific research programmes. This was followed by the rapid development of the Antarctic tourism industry over the last two to three decades, between them leading to further impacts, including pollution, and a new wave of non-indigenous biota increasingly affecting Antarctica as well as the sub-Antarctic, with attendant threats to and impacts on regional and local biodiversity (Bargagli 2005; Frenot et al. 2005; Tin et al. 2009; Hughes and Convey 2010; Aronson et al. 2011; Chown et al. 2012).

In part stemming from their different histories regarding human presence, the geopolitical structure and governance systems of the two regions contrast widely. All land in the Arctic is sovereign territory under the direct governance of one of the Arctic states. Some discussions/disagreements over the status of areas of associated continental shelf continue, and are likely to become increasingly important as economic opportunities for circumpolar seaways and resource exploitation open up as sea ice diminishes. Mechanisms do exist within the relevant international treaties that should facilitate the resolution of disagreements. In 1996 the eight sovereign nations encompassing the Arctic formed the Arctic Environmental Protection Strategy (AEPS) as a framework for intergovernmental cooperation on environmental protection initiatives. The AEPS distinguished itself by its intention to engage Arctic indigenous peoples in the cooperation in recognition of their right to be consulted in issues concerning the stewardship of their ancestral homelands. In 1996 the AEPS evolved with the establishment of the Arctic Council (http://www.arctic-council.org) as a high-level intergovernmental forum which aimed to provide a means for promoting cooperation, coordination and interaction among the Arctic States, with the involvement of the Arctic's indigenous communities and other Arctic inhabitants on common Arctic issues, in particular, issues of sustainable development and environmental protection in the Arctic. As such, it provides a useful mechanism to discuss and resolve issues facing the Arctic; to date, it has largely focussed on environmental issues. However, in 2011 the signing of an agreement on Cooperation in Aeronautical and Maritime Search and Rescue in the Arctic as the first legally binding agreement negotiated under the auspices of the Arctic Council signified a shift to a new more decisive role. The Council also includes a range of non-Arctic states and organisations as observers and participants in its activities.

The Svalbard archipelago, while recognised as being under Norwegian sovereignty and governance under the Treaty of Svalbard (Spitsbergen Treaty) of 1920, provides the only partial exception of the Arctic resembling the system of Antarctic governance. The Spitsbergen Treaty provides for access to nationals of other signatory nations (Arlov 2003). Before the signing of this Treaty, Svalbard was *terra nullius*, a no man's land. Increasing activity in the archipelago, primarily for coal and other mineral exploration, required the legal formalisation of the archipelago. The primary principle of this Treaty relates to non-discrimination and open access in regard to commercial or mining activities. Ironically, science is not included explicitly, but in effect the Norwegian state practices non-discrimination in this area as well.

The primary international legislation concerning Antarctica is the Antarctic Treaty. Signed in 1959 it came into force in 1961 and applies to the area south of 60°S latitude. A major contributing factor to the successful development of this Treaty was the level of international interaction and cooperation fostered through the International Geophysical Year of 1957/58, which took place at the height of the Cold War and in the face of rapidly increasing tensions between some of the regional territorial claimant nations. As of 2012 the Treaty includes 50 signatory nations, including 28 consultative parties which participate in consensus decision making, and 22 non-consultative parties. The Treaty dictates that pre-existing national territorial claims in the region are in abeyance, and it prohibits various potentially damaging activities including exploitation of the Antarctic environment, military and nuclear test activity. The intent of the Treaty is to promote international cooperation in scientific investigation in Antarctica, and the development of measures for the '*preservation and conservation of living resources in Antarctica*'. While the Antarctic Treaty provides the framework, the Parties implement its agreements via national laws (Kriwoken and Rootes 2000), leading to some inconsistencies in interpretation and application. Under the Antarctic Treaty System, the Protocol on Environmental Protection to the Antarctic Treaty (also known as the Madrid, or Environmental, Protocol) which entered into force in 1998 is now the instrument most concerned with conservation of biota and ecosystems within the Antarctic Treaty area. In effect, the Treaty assigns a degree of special conservation to the entire Antarctic Treaty area, and the Protocol further designates it as a '*natural reserve, devoted to peace and science*'. Governance of the various sub-Antarctic islands, which do not fall within the area of Antarctic Treaty control, falls under their respective national sovereignty. Finally, further complication can arise where nations can be signatory to the Antarctic Treaty itself but not to a component Convention such as CCAMLR or the Madrid Protocol. Similarly, Treaty Parties are not all members of the related but fully independent body, the Scientific Committee on Antarctic Research (SCAR; www.scar.org), or vice versa.

As well as operating under contrasting systems of governance, the Arctic and Antarctic face different immediate challenges and priorities resulting from the consequences of environmental change. In simple terms, in the Arctic these challenges and priorities are essentially driven by the economics of exploitation and the development and expansion of trade routes and human populations. In the Antarctic, contemporary challenges relate more directly to conservation, environmental protection and biosecurity.

The importance of science as a peaceful and positive international interaction is emphasised in both polar regions. In the Antarctic and Southern Ocean region, international science efforts and coordination are achieved mainly through the SCAR, a component body of the International Council for Science (ICSU; www.icsu.org), often in partnership with other bodies such as the Scientific Committee on Oceanic Research (SCOR) and the World Climate Research Programme (WCRP). SCAR's primary relationship to the Antarctic Treaty System (within which it has Observer status) is to provide objective and independent scientific advice. The International Arctic Science Committee (IASC; http://iasc.info/) provides a somewhat analogous international forum for scientific information exchange and research coordination in the Arctic and is an Observer to the Arctic Council. The Conservation of Arctic Flora and Fauna (CAFF; www.caff.is) is the biodiversity working group of the Arctic Council. CAFF was formed in 1991 by the 8 Arctic States, as a component of the Arctic Environmental Protection Strategy (AEPS) and in 1996 was incorporated within the Arctic Council. The CAFF signatories agreed to cooperate for the conservation of Arctic flora and fauna, their diversity and their habitats creating a forum for scientists, indigenous peoples and conservation managers to exchange data and information on issues such as shared species and habitats and to collaborate for more effective research, sustainable utilisation and conservation. Over the subsequent two decades, CAFF has become an important forum for the discussion and development of strategies, assessments and monitoring of Arctic biodiversity. CAFF is currently preparing the release of the first Arctic Biodiversity Assessment (ABA; www.caff.is/aba) which will provide policy makers and conservation managers with a synthesis of the best available scientific and traditional ecological knowledge on Arctic biodiversity. It will provide a much needed description of the current state of the Arctic's ecosystems and biodiversity, create a baseline for use in global and regional assessments of biodiversity, and provide a basis to inform and guide future Arctic Council work. In addition, it will identify gaps in the data record, identify key mechanisms driving change, and produce policy recommendations regarding Arctic biodiversity.

Examples of effective/successful biodiversity programmes which have advanced knowledge of polar biodiversity include CAFF's Circumpolar Biodiversity Monitoring Programme (CBMP; www.cbmp.is), the Arctic Council's Sustaining Arctic Observing Networks (SAON; www.arcticobserving.org), the International Study of Arctic Change (ISAC; www.arcticchange.org), SCAR's umbrella scientific programmes such as Evolution and Biodiversity in Antarctica (EBA; www.e-ba.aq; di Prisco et al. 2012), the SCAR MarBIN Antarctic marine biodiversity database (www.scarmarbin.be), and its larger and more ambitious successor ANTABIF (www.biodiversity.aq) and the newly established Southern Ocean Observing System (SOOS; www.soos.aq). Further major but time limited initiatives such as the recent International Polar Year of 2007–2009 (IPY; www.ipy.org) have provided a large impetus to international multi- and cross-disciplinary research in the polar regions. One particularly striking example of advancing knowledge of polar diversity is the Census of Antarctic Marine Life (CAML; www.caml.aq; Schiaparelli and Hopcroft 2011), an IPY initiative within the global Census of Marine Life (CoML; www.coml.org).

Learning from polar diversity

Ecology and physiology provide insights into the possible mechanisms used in response to environmental stress. For instance, at the molecular level, the comparison of structure and function of proteins from polar cold-adapted and non-cold-adapted species is a powerful tool to analyse gene selection and expression. Studies can, for instance, address the extent to which strategies of cold adaptation are similar or vary in different phylogenies, and whether extreme environments require specific adaptations or simply select for phenotypically different life styles. At different times during the Cenozoic, tectonic and oceanographic events played a key role in delimiting the two polar regions and in influencing the evolution of their biota. Biodiversity is strongly linked to geological history. The modern polar biotas therefore differ from each other in many aspects. The remarkable differences between Arctic and Antarctic organisms in basic biological mechanisms, such as freezing resistance and oxygen transport, indicate that distinct evolutionary pathways in the regulatory mechanisms have been followed in the two environments (Verde, Parisi, and di Prisco 2006). Studies on the genes of Arctic and Antarctic antifreeze glycoproteins (AFGPs) have shown that they are the result of convergent evolution (Cheng and Chen 1999), as each type derives from a distinct ancestral gene sequence.

Integration of studies across both polar regions, marine and terrestrial environments, biological groups and disciplines, is thus not only useful but necessary. It is encouraged by both SCAR and IASC, and many of the multinational and multidisciplinary programmes performed during the IPY envisaged such integration. With this background, the intent of this special issue is to encourage integration of research findings across both poles, marine and terrestrial environments, biological groups and disciplines, placed in the twin contexts of threats to biodiversity conservation and responses to environmental (including climate) change. Lessons from the polar regions can provide indications of what effects climate change may have on other areas, species and ecosystems, and the impacts that terrestrial, marine and freshwater organisms may endure in the future. To that end, the issue includes specific case studies, position papers, reviews, pure and applied research topics, and links into human social issues and challenges.

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