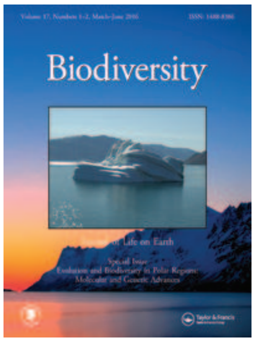

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EDITOR'S CORNER

Molecular-genetic studies of polar biodiversity

> '*Evolution is the major unifying principle of biology, and evidence of evolutionary processes pervades all levels of biological organisation from molecules to ecosystems.*'
> (Eastman 2000)

Evolution has produced biological diversity. Present patterns of biodiversity and distribution, in Polar Regions and elsewhere, are a consequence of processes occurring on physiological, ecological and evolutionary timescales, which can be modified by environmental changes.

Human health is inseparable from the physical and biological wellbeing of the planet, of which we are an interconnected part. The concept of a 'sustainable world' is strongly linked to the idea of biodiversity being as pristine as possible, namely with the natural ecological systems undergoing minimal human interference and alterations. Biodiversity encompasses the variability (within and between species) among living organisms. It is related to diversity of genes, individuals, species and habitats on Earth, as well as their interconnections and relationships. The term encompasses far more than a simple species count – it includes all aspects of variation and function at all levels of biological organisation, from genomic expression, through biochemistry, physiology, life history, ecology, biogeography, up to macroecology.

All regions of the planet are undergoing environmental changes, which are occurring at much higher speed in the Polar Regions (the Arctic and some regions – the Peninsula – of the Antarctic). Global warming will have impacts on marine and terrestrial systems, and will thus influence biodiversity. In East Antarctica, short-term environmental changes even develop in the unexpected direction of an increase of polar conditions by increasing sea-ice extent.

Environmental changes, in particular temperature increase or decrease, drive evolution. The Antarctic offers an immensely valuable model for studying biological responses to environmental change, across scales of biological organisation ranging from molecules to ecosystems. Small temperature changes may have considerable direct impacts on the physiology of organisms as well as indirectly through changes in sea ice on the life history and general biology of many species. Many organisms are susceptible to current temperature changes, and those of the Antarctic marine environment are particularly vulnerable, because of their stenothermal nature.

Marine organisms are adapted to low temperature and have evolved suitable mechanisms to cope with the cold. While stenothermal organisms may be harmed by only a 1–2 °C change, already seen in some regions and predicted to occur widely in the next century, others (e.g. a large proportion of the present-day Antarctic terrestrial biota) are adapted to wide temperature ranges, and can survive changes over timescales from the physiological to the evolutionary.

Compared to lower latitudes, warming is having stronger impacts in the Arctic, where models suggest that summer sea ice will disappear in a few decades. Antarctica, known to have a decisive role in driving the world's climate and ocean circulations, is not spared. The Antarctic Peninsula is currently experiencing one of the fastest rates of warming on the planet. Spectacular consequences are already being seen on land, in vegetation extent ('greening' of Antarctica). Ice loss leads to new land available for rapid colonisation. Reduction of annual sea ice causes displacement of key invertebrate and fish species, whose reproductive processes, closely associated with sea ice, are disturbed. Impacts at one level in a food web generally affect other taxa along the line. The human-induced ozone hole, formed in the latter decades of the twentieth century, may have shielded most of the continent, mainly in East Antarctica, from global warming until now, and its expected decrease over the next century is predicted to result in rapid climatic changes over this currently largely stable region.

Current global changes are prompting scientists and governments to consider the risk of extinction of species inhabiting environments influenced by ice. How well are polar organisms able to cope with daily, seasonal and longer-term environmental changes? Will climate change result in relaxation of selection pressure on genomes, or will constraints tighten and ultimately lead to extinction of species and populations? In fact, many species could, at least regionally, become extinct over the next few decades. This may be averted only by committing to concerted, multidisciplinary, international programmes aimed at understanding life processes, evolution and adaptations in the Polar Regions, in order to protect life and ecosystems.

The Antarctic is a fundamental part of the Earth System, and the study of its biota is intimately linked to its climate and tectonic history, through the interconnection between living and abiotic environments. Due to the speed of current changes, and the broad relevance of Antarctica in the study of biodiversity, in 2004 the Scientific Committee on Antarctic Research (SCAR) launched the flagship programme 'Evolution and Biodiversity in the Antarctic – The Response of Life to Change' (EBA; www.eba.aq; www.scar.org), aimed at understanding life processes, evolution and adaptations in Antarctic marine and terrestrial environments. EBA, conceived to understand and protect biodiversity in Antarctica, maintained that threats to biodiversity caused by climate and other environmental changes must be, if not eliminated, at least minimised. It had four main objectives: (1) to understand the evolution and diversity of life in the Antarctic; (2) to explore how this influenced the properties and dynamics of present Antarctic and Southern Ocean ecosystems; (3) to predict how organisms and communities are responding and will respond to current and future changes; (4) to identify scientific outcomes relevant to conservation and management, and to disseminate these through the Antarctic Treaty System.

EBA was an overarching umbrella for over 600 scientists from the 31 SCAR member countries. Co-chaired by Guido di Prisco and Pete Convey, the programme commenced in 2006 and ended in 2013. It was a forum for discussion and a coordinating body for the vast majority of the international Antarctic biological community, and provided advice to the Antarctic Treaty Consultative Meetings (ATCM) and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). It assembled many SCAR and Arctic projects, including the TUNU-Programme: Euro Arctic Marine Fishes – Diversity and Adaptation (TEAM-Fish). The cooperative and cross-disciplinary EBA research was a long-term legacy of the 2007–2009 International Polar Year (IPY).

The 2009 SCAR ACCE Report (Turner et al. 2009) provides the first comprehensive review of the state of Antarctica's climate and its relationship to the global climate system, integrating climate effects on ecosystems. It is the southern counterpart to the Arctic Climate Impact Assessment (ACIA 2005), presenting the latest research, identifying areas for future research, and addressing the questions that policy makers have about Antarctic climate change, ice melting, sea-level rise and biodiversity. There was a very close connection between EBA and ACCE in many critical issues. These include: (a) changes in Antarctic ecosystems caused by warming of the Southern Ocean; (b) rapid decrease of ice and sea ice west of the Antarctic Peninsula, leading to rapid warming on the adjacent land, with increases in plant communities; (c) direct impacts on krill levels and penguin colonisation; (d) warming of Antarctica as a whole, predicted to be around 3°C over the next century; and (e) improved modelling of polar processes required for accurate predictions.

EBA developed links with research in the Arctic. Some IPY programmes linked to EBA were either Arctic or bipolar. The Arctic (together with the sub-Antarctic) generally experiences less severe environmental extremes than the Antarctic, strongly isolated from lower latitudes. Its climate exhibits spatial and temporal variability, and there are areas with different climatic features, which are intermediate between polar and temperate latitudes. The progressive and rapid decrease of sea and land ice has ecological implications, and acute relevance to the native human communities.

As EBA approached its end, SCAR decided to lead Antarctic biology towards two new science programmes as EBA's legacy, focussed on distinct but complementary aspects of polar biology and working across marine, freshwater and terrestrial environments: 'State of the Antarctic Ecosystem' (AntEco, which describes biological patterns and their evolutionary history over the past hundred million years) and 'Antarctic Thresholds – Ecosystem Resilience and Adaptation' (AnT-ERA, which addresses recent biological processes, their adaptive capacity, and how sensitive and resilient they are to environmental forcing). For an overview of the SCAR biology programmes, see di Prisco et al. (2012).

AntEco and AnT-ERA therefore refer to different timescales. They will continue fostering multi-national and cross-disciplinary initiatives by (i) encouraging integration across all biological disciplines, (ii) upgrading synergy with physical sciences, including modelling, palaeoscience, geophysics, glaciology, oceanography and climatology, in order to establish firmer links between evolution and tectonics, climate evolution and glacial processes, and (iii) maintaining and developing links with bodies such as the Intergovernmental Panel for Climate Change (IPCC). In continuity with EBA, it is argued that, as the evolution of Antarctic organisms has taken millions of years to gradually build cold adaptation, insights on the ability of cold-adapted organisms and communities to cope with changes is likely to provide fundamentally important information for understanding predicted changes and responses also at lower latitudes and in less extreme environments.

AnT-ERA provided the basis for the Workshop 'Molecular and genetic advances to understanding evolution and biodiversity in the Polar Regions – the legacy of EBA' (Steering Committee: D Giordano, C Verde, G di Prisco), IBBR-CNR, Naples, October 2014.

In light of this, it was decided a Polar Special Issue of *Biodiversity* would be born. Thus, contributions within take the climate-driven risks for polar biodiversity and evolution in the polar regions in due account. The contributors are amongst the Workshop participants and belong to the AnT-ERA member list. Biological diversity and, even more, chemical diversity are important challenges; recent results on the complex marine benthic ecosystems include species new to science, new natural products never seen before, and the interactions network that exists between species. Investigations on the species diversity and distribution of the giant amphipod Eurythenes suggest that only a mere fraction of all species has been discovered, that conclusions regarding diversity and distribution may drastically change when increasing sampling intensity and coverage, and that a more complete knowledge of the ecology of the species is mandatory for interpreting their evolution. Peat bog pools are poorly surveyed and understood; one has been taken as a study case to investigate the role of climate-related features in setting the environment of pools and in shaping the structure and dynamics of their plankton communities, including interaction of pool morphometry and hydrological connectivity with temperature and precipitation. The effects of long-term incubation to near-future combined warming and ocean acidification stressors on the energetics of food processing in an Antarctic sea urchin were studied, including endogenous seasonal cycles and environmental variability on organism capacity. In a biogeography study, patterns of mitochondrial DNA diversity in Nacella species from the Antarctic Peninsula, Kerguelen Island and Patagonia were compared, showing strong impact of ice advances and retreats over respective demographies, and suggesting the occurrence of a more dramatic demographic process in the Peninsula than in the sub-Antarctic.

As polar scientists working in some of the most rapidly changing environments on Earth, we are well placed to make the danger understandable, contributing to the efforts of IPCC, by acquiring better knowledge of the impacts on polar life of the combined effects of natural and human-driven global environmental changes.

To attract the attention of the results of own studies, scientists (in particular early career researchers) are now able to look for a larger context to formulate scientific questions of general relevance to the scientific and non-scientific communities already at the beginning of a project, e.g. by checking the most challenging questions resulting from the 1st SCAR Antarctic and Southern Ocean Horizon Scan (http://www.scar.org/2014/598-roadmap-for-antarctic-science), checking open questions, challenging approaches of the ACCE report or consulting the IPCC report in order to identify gaps that are worth to be filled by projects, including conservation issues and the search for metabolically active substances. All these approaches include a wide range of fundamental and applied science. The available tools comprise the *AnT-ERA mailing list* (lists.scar.org/mailman/listinfo/antera) to get information and send questions to the community (e.g. on method problems, rare references, opportunities to join expeditions or share equipment) and the *AnT-ERA webpage* (http://www.scar.org/srp/ant-era), so that it will be possible to send relevant information on important issues to julian.gutt@awi.de to be uploaded, e.g. job opportunities in polar science, initiatives to organise small meetings and workshops (limited support can be provided by AnT-ERA), description of 'Scientific Highlights' and scientifically focussed projects.

This Special Issue is timely, given the universal concerns produced by the impacts of ongoing global changes in climate and environment. This scenario is at the origin of current scientific thinking on perspectives of future polar research in all biological domains, and largely dictates the goals of large international collaborative projects. When investigating biodiversity, ecology and evolution in all forms of life in the Polar Regions, the concept of the welfare of Earth being a leading necessity will deeply influence field and laboratory research. However, other important outcomes ought to have a proper place, e.g. applications in industrial production, medical science and human health that will establish further sought-after connections between basic and applied research.

This detailed introduction hopefully provides a useful and adequate framework for the Special Issue, yielding a wide range of opportunities for contributions. The target of the Special Issue is – in accordance with major SCAR objectives – to gather contributions of leading experts addressing the above-mentioned issues, leaving proper space to the advantageous use of recent advances in 'omics' and identifying the mostly needed developments and perspectives.

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