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## Sixty Years of Treaty-Supported Antarctic Science

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# Sixty Years of Treaty-Supported Antarctic Science

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## Summary

Sixty years of research in, from and about Antarctica and the Southern Ocean have delivered extraordinary benefits to humankind. These range from fundamental understanding, such as of the nature of the Universe and the ability of life to exist in subglacial environments, to those with globally significant implications for the future of humankind, such as ozone depletion and the role of the Antarctic cryosphere in sea level variation.

The Treaty Parties have been prescient in their recognition of the societal importance of science, the benefits of open access to scientific results and data, and the extraordinary potential of evidence-based policy for improving the way we live in our world.

The successes of international scientific cooperation in the harshest environment on Earth demonstrate how nations working together can accomplish more than any nation working alone, providing a roadmap for action in an uncertain future.

## Background

In 1959, the preamble to the Antarctic Treaty acknowledged the *substantial contributions to scientific knowledge resulting from international cooperation in scientific investigation in Antarctica*. Article II entrenched freedom of scientific investigation and cooperation to that end, and Article III set out a suite of means to do so, including a prescient clause recognising the importance of scientific data and open access to it.

A little over 30 years later, the Consultative Parties emphasized the significance of scientific investigation in the Preamble to the Protocol on Environmental Protection to the Antarctic Treaty, and then entrenched those views in Article 2, designating Antarctica as a natural reserve, devoted to peace and science, and in Article 3.3, by according priority to scientific research activities, and activities which preserve the value of Antarctica as an area for the conduct of such research including, again presciently, research to understand the global environment.

The Parties also recognised the significant scientific and technical advisory capabilities of the Scientific Committee on Antarctic Research (SCAR) by providing for the contribution of independent advice by SCAR in Article 10.2, and by inviting the President of SCAR to attend the meetings of the Committee for Environmental Protection as an observer (Article 11.4).

Over the past sixty years, recognition of the value of scientific investigation in, from and about Antarctica and the Southern Ocean, and considerable support for it by the Antarctic Treaty Consultative Parties, have delivered extraordinary benefits to humankind.

Those benefits range from fundamental understanding of our world in all of its mystery and beauty, to its place in the Universe, and to the challenges facing humans from our very own activities and ways in which these challenges can be met.

Importantly, these benefits have demonstrated why Antarctica is important to the world, and how the world holds the keys to Antarctica's future. The successes of international scientific cooperation in the harshest environment on Earth demonstrate how nations working together can accomplish more than any nation working alone, providing a roadmap for action in an uncertain future.

Sixty years of Antarctic and Southern Ocean science cannot be encapsulated easily. But as the premier body facilitating science in, from and about Antarctica and the Southern Ocean, and providing evidence-based advice to the Antarctic Treaty System and others, SCAR can reflect on a few milestones.

In doing so, SCAR recognises that, as with all lists, its choices will not necessarily reflect those that might be made by others. Therefore, in advance, we salute all of those who have contributed to Antarctic science in the broadest sense, those who have supported this endeavour through national Antarctic programmes and by other means, and the friends, family and researchers themselves who have made many sacrifices in the quest to better understand our world and our place in it.

## Ozone Depletion Still Matters

The discovery of the ozone hole by British Antarctic scientists[1], and swift realisation of the implications for life on Earth, yielded an unprecedentedly rapid, globally-endorsed response to phase out the anthropogenic chlorofluorocarbons (CFCs) responsible for ozone depletion. Proving a causal link between the observed strengthening and poleward shift of the westerly winds over the Southern Ocean, along with their influence on Antarctic and Southern Ocean life, has been transformative[2]. There is now increasing evidence that the ozone hole is beginning to shrink, with indications that such change might already be having broad effects on Antarctic environments, such as changes to sea ice[3]. Nonetheless, some complexity remains, with indications that despite the universal ratification of the Montreal Protocol and its instruments, CFC-11 (trichlorofluoromethane) concentrations in the atmosphere have been increasing[4].

## Antarctica in Your Backyard…or Not?

It is no secret that the East and West Antarctic Ice Sheets have the potential to change sea level around the globe. Anthropogenic climate change means that, at the moment, our main concern is by how much, when and where, sea level will rise. Reducing that uncertainty requires investigations of the oceans, atmosphere and the cryosphere – including sea ice, ice shelves and ice sheets. Much of our understanding is very recent, including of processes such as the role of water in fracturing ice, ice cliff instability, basal melting of marine-based ice sheets, and the

[1] Farman et al. 1985 *Nature* 315: 207-10
[2] Bornman et al. 2019 *Photochemical and Photobiological Sciences* 18: 681-716; Weimerskirch et al. 2012 *Science* 335: 211-4
[3] Wang et al. 2019 *Nature Communications* 10: 13
[4] Montzka et al. 2018 *Nature* 557: 413-7

role of sea ice[5]. Both empirical data and modelling are developing rapidly. How much sea level rise coastal cities will experience, by when, and how effects differ among the world's regions needs concerted further research. This question is arguably Antarctic and Southern Ocean research's most pressing global one, particularly because the data generally show an increasing rate of ice mass loss for the region[6]. Answering this question will also influence decision-making about Antarctic environments because of expected changes to the extent and distribution of ice-free areas on the continent[7].

## History Trapped

Understanding the climate history of the planet through analysis of ice cores from the Arctic, Antarctic and high-mountain glaciers is one of polar science's most important stories[8]. That story has unfolded in a remarkable way in Antarctica, producing a 420 000-year record from the Vostok Ice Core[9], and a 740 000-year record from the Dome C ice core[10]. These records demonstrate the close relationship between Antarctic air temperature and atmospheric $CO_2$ concentration. They also show that current atmospheric concentrations of $CO_2$ and methane are unprecedented over their historical records. The search is now on for a record extending to a million years or more, which will provide much-needed insights into the Earth System's history and functioning.

## Under the Ice and Thriving

In the 1970s, international collaboration using radio echo-sounding discovered the first subglacial lake and quickly went on to document many such features, including the extraordinary Lake Vostok[11]. By 2012, Lake Vostok had been accessed by Russian scientists. Throughout, significant discussion of the likelihood and form of life in subglacial waters had been ongoing[12], including about how to ensure that any such life was not contaminated by efforts to investigate it. In 2014, subglacial Lake Whillans was accessed using clean methods. The international team discovered abundant microbial life forming an ecosystem driven by chemosynthesis, which can have an influence on Southern Ocean geochemical and biological systems[13]. The expectation is that life will be commonly found below the Antarctic ice sheets, given that more than 400 subglacial lakes have now been discovered.

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[5] DeConto & Pollard. 2016 *Nature* 531: 591-7; Massom et al. 2018 *Nature* 558: 383-9; Pattyn et al. 2018 *Nature Climate Change* 8: 1053-61; Golledge et al. 2019 *Nature* 566: 65-72
[6] Shepherd et al. 2018 *Nature* 558: 219-22
[7] Lee et al. 2017 *Nature* 547: 49-54
[8] Jouzel. 2013 *Climate of the Past* 9: 2525-47
[9] Petit et al. 1999 *Nature* 399: 429-36
[10] EPICA Community Members. 2004 *Nature* 429: 623-8
[11] Siegert. 2018 *Geological Society of London Special Publications* 462: 7-21
[12] Priscu et al. 1999 *Science* 286: 2141-4
[13] Christner et al. 2014 *Nature* 512: 310-4

## The Emperor of Birds

One of the planet's most well-known birds remains one of its most mysterious: the emperor penguin. The only bird known to breed predominantly on fast ice, and in the winter, little was understood about its life cycle until the 1950s, when pioneering work under difficult conditions revealed the remarkable circumstances of the species' winter breeding biology[14]. While much of the emperor penguin's life cycle within colonies is now known, its at-sea ecology remains poorly documented. New applications of satellite remote sensing have revealed 54 colonies around the Antarctic continent[15], with an estimated breeding population of more than 256 000 pairs. Yet spectacular and repeated failures of one of the largest colonies have also been detected in recent years[16], with future prognoses raising concerns about the species[17]. This symbol of Antarctica needs concerted research attention and policy interventions to ensure its survival.

## Massively Important Subglacial Mountains

Despite their discovery in 1958, the first detailed radar survey of the Gamburtsev Mountains was made by Chinese scientists as part of the International Polar Year Programme in the mid-2000s. Their work revealed a classic Alpine topography likely to have formed during the initial phases of Antarctic glaciation (from *ca*. 34 million years ago onwards), contributing a main centre for ice sheet growth[18]. Later work using a combination of techniques and data revealed a 2500 km rift system in East Antarctica surrounding the Gamburtsev Mountains[19]. Complex geological processes, possibly taking place over 1 billion years, explain the high elevation (maximum of 3000 m and a median of 1400 m) and general relief of these mountains, which remain covered by hundreds of metres of ice. These mountains reveal how important understanding the bedrock topography of Antarctica is for our knowledge of the Earth System.

## The Dry Valleys are Not Dead

Even as late as the 1970s, the McMurdo Dry Valleys were described as sterile, with the search for analogues of lunar and Martian environments suggesting that the Dry Valley soils contained, if anything, low levels of viable microbiota. Now we know that the contrary is true. Thanks to advances in genomic and other techniques, the Dry Valley microbiota is understood to be diverse, spatially variable, and extraordinary from a global perspective[20]. These discoveries have driven a broad programme to discover how life exists in seemingly ultra-harsh Antarctic environments. One of the most recent findings demonstrates that microbes can eke out an existence using an extraordinary mechanism to scavenge hydrogen gas from the atmosphere, so providing an alternative to typical solar or geological energy sources[21]. Trace-gas

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[14] Stonehouse. 1952 *Nature* 169: 760; Prévost. 1953 *Alauda* 21: 141-56
[15] Fretwell et al. 2012 *PLoS One* 7: e33751
[16] Fretwell & Trathan. 2019 *Antarctic Science* doi: 10.1017/S0954102019000099
[17] Jenouvrier et al. 2019 *Biological Conservation* 212: 63-73
[18] Bo et al. 2009 *Nature* 459: 690-93
[19] Ferracioli et al. 2011 *Nature* 479: 388-92
[20] Cary et al. 2010 *Nature Reviews Microbiology* 8: 129-38
[21] Ji et al. 2017 *Nature* 552: 400-03

scavenging may provide new insights for exobiology – the biology of putative life elsewhere.

## Earth as a Camera

Earlier this year, a suite of papers from The Event Horizon Telescope Collaboration[22] revealed to the world the first picture of the edge of a black hole – the event horizon. The creation of the image required more data than any experiment so far undertaken, and the use of the 'entire Earth as a telescope' – or at least a network of eight observatories around the globe, including the South Pole Telescope, and some clever techniques. The work has confirmed the predictions, in a spectacular way, of Albert Einstein's general theory of relativity[23].

## A Southern Ocean Engine for Fish

The Southern Ocean is widely known as a region relatively poor in the numbers of fish species that inhabit it[24], compared with tropical systems such as coral reefs. Indeed, the global latitudinal gradient in species richness – a pattern of high numbers of species in the tropics and lower numbers of species in polar regions – is one of biodiversity's strongest global signals[25]. New work, using novel genomics and biodiversity informatics approaches, has revealed that the engine for the production of new species, that is speciation rate, runs fastest in the polar regions and especially the Antarctic[26]. Despite low overall species diversity, new species of fishes have formed in the Southern Ocean at a faster rate than in any other marine region. This surprising result reveals how important the Antarctic is for the Earth System in ways other than just the climate.

## Time Has Not Run Out

The Paris Climate Agreement presents us with a choice. Either we will have, within the next 60 years, an Antarctic and Southern Ocean region that is markedly different from the one the Antarctic Treaty Parties have come to know over the 60-year history of the agreement, and on a trajectory for even bigger change, or one that stays familiar[27]. In essence, we have about 11-30 years of $CO_2$ emissions at the 2017 level to meet a target of 1.5°C[28]. Though large uncertainties remain about how the future will play out, the science is clear about the fact that we have little time left to avert changes we will struggle to undo, and which will have dangerous consequences for life as we have come to know it.

[22] The Event Horizon Telescope Collaboration. 2019 *Astrophysical Journal Letters* 875: L1
[23] Castelvecchi. 2019 *Nature* https://www.nature.com/articles/d41586-019-01155-0
[24] De Broyer et al. 2014. *Biogeographic Atlas of the Southern Ocean*. SCAR, Cambridge
[25] Chown et al. 2015 *Nature* 522: 431-8
[26] Rabosky et al. 2018 *Nature* 559: 392-5
[27] Rintoul et al. 2018 *Nature* 558: 233-41
[28] Leach et al. 2018 *Nature Geoscience* 11: 574-9