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SCAR Annual Report 2014-15

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1. Background

The Scientific Committee on Antarctic Research (SCAR) is a non-governmental, Interdisciplinary Scientific Body of the International Council for Science (ICSU), and Observer to the Antarctic Treaty and the UNFCCC.

SCAR's mission is (i) to be the leading, independent, non-governmental facilitator, coordinator, and advocate of excellence in Antarctic and Southern Ocean science and research and (ii) to provide independent, sound, scientifically-based advice to the Antarctic Treaty System and other policy-makers, including the use of science to identify emerging trends and bring these issues to the attention of policy-makers.

2. Introduction

SCAR's scientific research adds value to national efforts by enabling researchers to collaborate on large-scale scientific programmes to accomplish objectives not easily obtainable by any single country. SCAR's Members currently include 39 countries and 9 ICSU Scientific Unions. During the SCAR Delegates' Meeting held in New Zealand in September 2014, the Czech Republic and the Islamic Republic of Iran joined SCAR.

SCAR's success depends on the quality and timeliness of its scientific outputs. Descriptions of SCAR's research programmes and scientific outputs are available at: www.scar.org/science. Appendix I highlights recent science papers published since the last Annual Report.

SCAR produces an electronic quarterly Newsletter highlighting relevant science and other SCAR related issues. Please email: info@scar.org if you wish to be added to the mailing list. SCAR is also available on social media such as Facebook, LinkedIn and Twitter.

3. SCAR Highlights (2014/15)

SCAR has a number of groups and programmes that focus on different science or science-related activities in the Antarctic region. Here we highlight updates to SCAR activities that we believe to be of particular interest.

The Standing Committee on the Antarctic Treaty System (SCATS)
(www.scar.org/antarctic-treaty-system/scats)

SCATS is the body tasked with developing SCAR's scientific advice to the Antarctic Treaty System. In addition to providing and coordinating scientific advice for SCAR, SCATS members are also actively involved in research. During the last SCAR Delegates' meeting, a new Chief Officer, Aleks Terauds, was appointed, as were several new members (see www.scar.org/antarctic-treaty-system/scats). SCAR is

supporting the Antarctic Environments Portal where the SCATS Chief Officer sits on the editorial board, playing an important role in content development.

Southern Ocean Acidification *(www.scar.org/ssg/physical-sciences/acidification)*

SCAR has undertaken a synthesis of the scientific understanding of Southern Ocean acidification. This landmark report was highlighted at the ATCM XXXVIII - CEP XVIII in Sofia, Bulgaria, being the topic of this year's SCAR Treaty Lecture (see Treaty paper BP001 at www.scar.org/treatypapers/atcm38). A PDF of the report will be made available from the SCAR website.

The Biogeographic Atlas of the Southern Ocean (http://atlas.biodiversity.aq)

The Biogeographic Atlas presents the distribution patterns and processes of a significant representation of Southern Ocean organisms, illustrated by more than 800 distribution maps and 200 pictures and graphs. The Atlas is a legacy of the International Polar Year 2007-2008 and a contribution to the SCAR scientific research programmes AntEco (State of the Antarctic Ecosystem) and AnT-ERA (Antarctic Thresholds - Ecosystem Resilience and Adaptation). The Atlas was launched at the last SCAR Meeting and Open Science Conference (Auckland, New Zealand, 25-28 August 2014).

The SCAR Science Horizon Scan *(www.scar.org/horizonscanning/)*

Following the crowdsourcing of over 850 unique scientific questions by the SCAR community, the 1st SCAR Antarctic and Southern Ocean Science Horizon Scan assembled more than 70 of the world's leading Antarctic scientists, policy-makers and visionaries (including early career scientists) in Queenstown, New Zealand, in April 2014. Their remit was to identify the most important scientific questions that should be addressed by research in and from the southern polar regions over the next two decades and beyond. The initial outcomes were published in the journals *Nature* (http://www.nature.com/news/polar-research-six-priorities-for-antarctic-science-1.15658) and *Antarctic Science* (http://dx.doi.org/10.1017/S0954102014000674). For more information, see the Horizon Scan section of the SCAR website (www.scar.org/horizonscanning) and the 2015 Treaty paper IP020 (www.scar.org/treatypapers/atcm38).

Many national Antarctic programmes are now developing their own strategies on how they will deliver their science programmes in the future. Delivery of such a "roadmap" is not without its challenges. Therefore, with SCAR's assistance, the Council of Managers of National Antarctic Programs (COMNAP) is leading a second stage in the process with the Antarctic Research Challenges (ARC) project (www.comnap.aq) in order to assist national Antarctic programmes to understand and develop ways to address the challenges, and share any innovation or access to such technology. The ARC project focuses on answering the question: "How will national Antarctic programmes meet the challenges of delivery of their Antarctic science in the next 20 to 30 years?"

Antarctic Conservation in the 21st Century *(www.scar.org/antarctic-treaty-system/scats)*

SCAR, in collaboration with several partners, continued its development of the 'Antarctic Conservation for the 21st Century' strategy. The activity has encouraged participation from all stakeholders in the region. The approach is also structured to align with both the Protocol on Environmental Protection to the Antarctic Treaty and the Five Year Work Plan of the Committee for Environmental Protection. It also links closely with the Antarctic Environments Portal (See Treaty papers WP021 and IP011 at www.scar.org/treatypapers/atcm38). As part of this process, a symposium was held during the SCAR Open Science Conference in New Zealand in August 2014, which will feed into the final process.

Antarctica and the Strategic Plan for Biodiversity 2011-2020: The Monaco Assessment *(www.scar.org/monaco-assessment/)*

On 8-10 June 2015, together with the Government of the Principality of Monaco and other partners, SCAR jointly organized a workshop on *Antarctica and the Strategic Plan for Biodiversity 2011-2020: The Monaco Assessment.* The central purpose of the meeting was to examine the extent to which conservation of the biodiversity of Antarctica and the Southern Ocean is realizing a set of ambitions agreed for the world as part of the Strategic Plan for Biodiversity 2011-2020. The meeting also aimed to provide guidance for action that can effectively help deliver further conservation successes for Antarctica and the Southern Ocean. The outcomes and products of this initiative will be made available over the next several months.

SCAR Data and Products *(www.scar.org/data-products)*

SCAR promotes free and unrestricted access to Antarctic data and information through open and accessible archives, managed by its Standing Committees on Antarctic Data Management (SCADM) and Antarctic Geographic Information (SCAGI). SCAR also has several products of use to the Antarctic community, such as the recent Quantarctica (www.scar.org/data-products/quantarctica) and the Antarctic Map Catalogue (www.scar.org/data-products/mapcat).

New SCAR groups

Several new groups were approved in 2014 during the last SCAR Delegates' Meeting, including:

- **EXPERT *Group on Antarctic Volcanism (ANTVOLC)*** will promote the study of Antarctic volcanism; discuss protocols, methods and best practices; and integrate and share geological information. *(www.scar.org/ssg/geosciences/antvolc)*.
- ***SnowAnt (Snow in Antarctica) Action Group***, which aims to identify undisturbed snow areas in Antarctica and to characterize their properties. *(www.scar.org/ssg/physical-sciences/snowant)*.
- ***ANTOS (Antarctic Near-shore and Terrestrial Observing System) Action Group*** aims to establish an integrated and coordinated trans-continental and trans-regional environmental surveillance system to identify and track

environmental variability and change at biologically relevant scales, and to use this information to inform biological, physical, and earth science studies. *(www.scar.org/ssg/life-sciences/antos).*

- ***Action Group on Geological Mapping Update of Antarctica (GeoMap)*** aims to capture existing geological map data, update its spatial reliability, improve representation of glacial sequences and geomorphology, and enable data delivery via web-feature services. *(www.scar.org/ssg/geosciences/geomap).*
- The establishment of an ***Action Group on Geological Heritage and Geoconservation*** was approved during the last Delegates Meeting. Formal approval will be granted by the SCAR Executive Committee, once details of its leadership, membership and Terms of Reference are finalized. Advances are expected during the meeting to be held in the margins of XII ISAES (the International Symposium on Antarctic Earth Sciences), taking place from 13-17 July 2015 in Goa, India.

4. SCAR Fellowships and Prizes

In order to expand capacity in all its Members, SCAR runs several Fellowship and Prize Schemes (*www.scar.org/awards*):

- ***SCAR/COMNAP Fellowships*** are focused on early-career scientists and engineers in Antarctic scientific research, to build new connections and further strengthen international capacity and cooperation in Antarctic research. The fellowships are being launched in tandem with the CCAMLR Scholarships. In 2014 four fellowships were awarded. *(www.scar.org/awards/fellowships).*
- ***SCAR Visiting Professor Scheme*** provides mid- to late-career scientists the opportunity to undertake short-term visits to a facility in, or operated by, another SCAR member country, to provide training and mentoring. Three Visiting Professorships were awarded in 2014. *(www.scar.org/awards/visitingprofs).*
- ***Martha T Muse Prize for Science and Policy in Antarctica***, sponsored by the Tinker Foundation, is a USD $100,000 unrestricted award presented to an individual in the fields of Antarctic science or policy. Tim Naish was awarded the 2014 Muse Prize, for his outstanding research in understanding Antarctica's response to past and present climate change and the role of Antarctica's ice sheets in global sea-level change through time. *(www.museprize.org).*
- ***SCAR Medals*** were awarded during the SCAR Open Science Conference in New Zealand, 2014. The SCAR Medal for Excellence in Antarctic Research went to Steven Chown (Australia) for his extensive contributions to Antarctic Science and policy and to SCAR; and the SCAR Medal for International Scientific Coordination was awarded jointly to Mahlon "Chuck" Kennicutt (USA) and Rasik Ravindra (India) for their collaborative and coordination roles in the science community. *(www.scar.org/awards/medals).*
- A new ***Communications Award*** has been instigated for the most innovative presentation of Antarctic research results in any discipline at the SCAR Open

Science Conference. See www.scar.org/communicating/videos for the 2014 winner, Molly Zhongnan Jia.

5. Other News

During the SCAR Delegates' meeting, two new Vice Presidents were elected – Azizan Abu Samah (Malaysia) and Terry Wilson (USA). In December 2014, Eoghan Griffin was appointed as SCAR Executive Officer, replacing Renuka Badhe who became the new Executive Secretary of the European Polar Board.

6. Future major SCAR Meetings

There are several major SCAR Meetings coming up (www.scar.org/events), including:

- **XII International Symposium on Antarctic Earth Sciences (ISAES) 2015**. 13-17 July 2015, Goa, India. *(www.isaes2015goa.in)*.
- **XXXIV SCAR Meetings and Open Science Conference**. 19-31 August 2016, Kuala Lumpur, Malaysia. The SCAR Open Science Conference will be held on 25-29 August. See: *(http://scar2016.com*).
- **The XXXV SCAR Meetings and Open Science Conference in 2018** in Davos, Switzerland. The Open Sience Conference will cover both polar regions, being organized jointly with the International Arctic Science Committee (IASC).

Appendix 1

Selected Antarctic and Southern Ocean Science Highlights for 2014/15

Here we highlight some recent key science papers published in the last twelve months. Although not highlighted below, the latest ACCE update should also be consulted (see Treaty paper IP092 at www.scar.org/treatypapers/atcm38) as it contains many pertinent references to climate change in the Antarctic region. In addition, see the two Kennicutt et al. (2014) papers on the SCAR Horizon Scan (Treaty paper IP020 plus attachment at www.scar.org/treatypapers/atcm38). It should also be noted that this is by no means a complete list (there have been many highly significant papers published over the last year) but represents a sample of key science papers highlighted by SCAR groups.

Ice Sheet Mass Balance:

The floating ice shelves surrounding the Antarctic Ice Sheet restrain the grounded ice-sheet flow. Thinning of an ice shelf reduces this effect, leading to an increase in ice discharge to the ocean. Using 18 years of continuous satellite radar altimeter observations, the authors computed decadal-scale changes in ice-shelf thickness around the Antarctic continent. Overall, average ice-shelf volume change accelerated from negligible loss at 25 ± 64 cubic kilometres per year for 1994–2003 to rapid loss of 310 ± 74 cubic kilometres per year for 2003–2012. West Antarctic losses increased by ~70% in the past decade, and earlier volume gain by East Antarctic ice shelves ceased. In the Amundsen and Bellingshausen regions, some ice shelves have lost up to 18% of their thickness in less than two decades.

> *Paolo, F.S., Fricker, H.A. & Padman, L. 2015. Volume loss from Antarctic ice shelves is accelerating. Science, 348 (6232): 327-331 DOI: 10.1126/science.aaa0940*

Thwaites Glacier is one of West Antarctica's most prominent, rapidly evolving, and potentially unstable contributors to global sea level rise. Uncertainty in the amount and spatial pattern of geothermal flux and melting beneath this glacier is a major limitation in predicting its future behaviour and sea level contribution. In this paper, a combination of radar sounding and subglacial water routing is used to show that large areas at the base of Thwaites Glacier are actively melting in response to geothermal flux consistent with rift-associated magma migration and volcanism. This supports the hypothesis that heterogeneous geothermal flux and local magmatic processes could be critical factors in determining the future behaviour of the West Antarctic Ice Sheet.

> *Schroeder, D.M., Blankenship, D.D., Young, D.A. & Quartini, E. 2014. Evidence for elevated and spatially variable geothermal flux beneath the West Antarctic Ice Sheet. Proceedings of the National Academy of Sciences, 111(25): 9070–9072. doi:10.1073/pnas.1405184111*

Past Climate:

The paper by Patterson et al (2014) reveals that before 3.5 million of years, under a warm climate state, the East Antarctic Ice Sheet (EAIS) demonstrates high sensitivity on orbital timescales to a relatively small increase in atmospheric CO_2 concentration and mean global surface temperature. With atmospheric CO_2 concentrations and global surface temperatures projected to remain above 400 ppm and >+2ºC beyond 2100, these results have implications for the equilibrium response of the Antarctic ice sheets, and suggest that the marine margins of the EAIS, as well as the marine-based West Antarctic Ice Sheet, may become increasingly susceptible to ocean warming, with the potential for widespread mass loss raising sea level by metres over the coming centuries to millennia.

> *Patterson, M.O., McKay, R., Naish, T., Escutia, C., Jimenez-Espejo, F.J., Raymo, M.E., Meyers, S.R., Tauxe, L., Brinkhuis, H. & IODP Expedition 318 Scientists. 2014. Orbital Forcing of the East Antarctic Ice Sheet during the Pliocene and Early Pleistocene. Nature Geosciences, 7: 841-846.*

Geological data indicate that global mean sea level has fluctuated during the last 25 million years, at times reaching 20 metres or more above modern levels. Most climate and ice sheet models, however, have not been able to simulate significant East Antarctic Ice Sheet from continental size, given that atmospheric CO_2 levels were relatively low throughout this period. The paper by Pollard et al (2015) applies a simple Pliocene-like warming scenario incorporating the combined mechanisms of Marine Ice Sheet Instability, melt-driven hydro-fracturing and cliff failure that cause a very rapid collapse of West Antarctic ice, on the order of decades. This is followed by retreat of East Antarctic basins within several hundred to a few thousand years. The total Antarctic ice loss corresponds to +17 metres sea-level rise, in good agreement with high-stands in geologic sea-level records, although uncertainty in the geologic records themselves should be considered.

> *Pollard, D., DeConto, R.M. & Alley, R.B. 2015. Potential Antarctic Ice Sheet retreat driven by hydrofracturing and ice cliff failure. Earth and Planetary Science Letters, 412: 112-121*

The paper by Weber et al (2014) provides high-resolution Iceberg Rafted Debris (IBRD) records that capture a spatially-integrated signal of Antarctic Ice Sheet (AIS) variability during the last deglaciation. They document eight events of increased iceberg flux from various parts of the AIS between 20,000 and 9,000 years ago, in marked contrast to previous scenarios which identified the main AIS retreat as occurring after meltwater pulse 1A, and continuing into the late Holocene epoch. The highest IBRD flux occurred 14,600 years ago, providing the first direct evidence for an Antarctic contribution to meltwater pulse 1A. Climate model simulations with AIS freshwater forcing identify a positive feedback between poleward transport of Circumpolar Deep Water, subsurface warming and AIS melt, suggesting that small perturbations to the ice sheet can be substantially enhanced, providing a possible mechanism for rapid sea-level rise.

> *Weber, M.E., Clark, P.U., Kuhn, G., Timmermann, A., Sprenk, D., Gladstone, R., Zhang, X., Lohmann, G., Menviel, L., Chikamoto, M.O., Friedrich, T. & Ohlwein, C. 2014. Millennial-scale variability in Antarctic ice-sheet discharge during the last deglaciation. Nature, 510: 134-138*

Earth sciences multidisciplinary:

The Special Issue of the journal *Global and Planetary Change* dedicated to the Scotia Arc, edited by Maldonado et al. (2014), is a significant contribution towards understanding this important region and its global influence. The Scotia Arc represents the last continental bridge in the process of the break-up of the supercontinent Gondwana. The rupture of this bridge facilitated the oceanographic connection between the Pacific and Atlantic oceans through Drake Passage and initiated the thermal isolation of Antarctica at about the Eocene/Oligocene transition, with profound effects on subsequent species evolution. The isolation of Antarctica facilitated the development of major ice-caps and eventually a continental ice sheet, which in turn increased the production of cold water that flowed northward and inundated the deep low latitude ocean basins. This Special Issue addresses some of these key issues through the work of an international, multidisciplinary group of authors.

> *Special Issue "Scotia Arc Evolution: Global Implications". Edited by A. Maldonado, I.W.D. Dalziel & P.T. Lead. Global and Planetary Change, 123-B: 151-413. 2014*

Permafrost and Periglacial Environments:

The special issue of the journal *Geomorphology*, edited by Gugliemin et al. (2014), shows the main results from the SCAR Antarctic Permafrost, Periglacial Environments and Soils Group (ANTPAS), which were presented at the SCAR Open Science Conference in Portland in 2012. This Special Issue includes nine papers on a range of geomorphological issues, and reviews important contributions from the last two years.

> *Special Issue "Permafrost and periglacial research in Antarctica: new results and perspectives". Edited by M. Guglielmin, G. Vieira & A. Harvey. Geomorphology, 225: 1-100*

Gugliemin et al. (2014) show that despite the lack of a clear warming trend in air temperatures in Continental Antarctica, there is an active layer thickening occurring in Victoria Land, as well as measurable ecosystem changes, with modifications in ground water associated with improved soil drainage conditions. Such changes in soil conditions will likely change the distribution of mosses and lichens. The authors support their observations with an observational dataset from the CALM network starting in 2000.

> *Guglielmin, M., Dalle Fratte, M., Cannone, N. 2014. Permafrost warming and vegetation changes in continental Antarctica. Environmental Research Letters, 9, 045001 (14pp).*

Ecology and Biology:

Subglacial:

Liquid water has been known to occur beneath the Antarctic ice sheet for more than 40 years, but only recently have these subglacial aqueous environments been recognized as microbial ecosystems that may influence biogeochemical

transformations on a global scale. Here, Christner et al (2014) present the first geomicrobiological description of water and surficial sediments obtained from direct sampling of a subglacial Antarctic lake. The water column of subglacial Lake Whillans (SLW) contained metabolically active microorganisms and was derived primarily from glacial ice melt with solute sources from lithogenic weathering and a minor seawater component. Heterotrophic and autotrophic production data, together with small subunit ribosomal RNA gene sequencing and biogeochemical data, indicate that SLW is a chemosynthetically driven ecosystem inhabited by a diverse assemblage of bacteria and archaea. Our results confirm that aquatic environments beneath the Antarctic ice sheet support viable microbial ecosystems, corroborating previous reports suggesting that they contain globally relevant pools of carbon and microbes that can mobilize elements from the lithosphere and influence Southern Ocean geochemical and biological systems.

Christner, B.C., Priscu, J.C., Achberger, A.M., Barbante, C., Carter, S.P., Christianson, K., Michaud, A.B., Mikucki, J.A., Mitchell, A.C., Skidmore, M.L., Vick-Majors, T.J. & the WISSARD Science Team. 2014. A microbial ecosystem beneath the West Antarctic ice sheet. Nature, 310 (512): 310-315

Marine:

The Biogeographic Atlas of the Southern Ocean provides the most thorough audit of marine life in the Southern Ocean. In an unprecedented international collaboration, 147 scientists from 91 institutions across 22 countries (Australia, Belgium, Brazil, Canada, Chile, Denmark, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Poland, Portugal, Russia, South Africa, Spain, Switzerland, the UK and the USA) combined their expertise and knowledge to produce the new Biogeographic Atlas of the Southern Ocean. More than 9000 species are recorded, ranging from microbes to whales. Hundreds of thousands of records show the extent of scientific knowledge on the distribution of life in the Southern Ocean. In 66 chapters, the scientists examine the evolution, physical environment, genetics and possible impact of climate change on marine organisms in the region. The data, and expert opinions, in the Atlas will help inform conservation policy, including the debate over whether or not to establish marine protected areas in the open ocean. Sophisticated environmental models coupled with existing species distribution data provide a valuable outlook on the possible future distribution of key species as they adapt to climate change.

De Broyer, C., Koubbi, P., Griffiths, H.J., Raymond, B., Udekem d'Acoz, C. d', Van de Putte, A.P., Danis, B., David, B., Grant, S., Gutt, J., Held, C., Hosie, G., Huettmann, F., Post, A. & Ropert-Coudert, Y. (eds.). 2014. Biogeographic Atlas of the Southern Ocean. Scientific Committee on Antarctic Research, Cambridge, 510 pp.

ANDEEP-SYSTCO (ANtarctic benthic DEEP-sea biodiversity: colonization history and recent community patterns - SYSTem COupling) aimed to uncover responses of the abyssal benthos to differences and longer-term changes in primary productivity. Investigations on pelagic-benthic coupling included the analysis of a phytoplankton bloom from the surface down to the abyssal seafloor at a single station in the South Polar Front. These analyses also suggested a strong benthic-pelagic coupling at certain stations. As expected, sediment oxygen consumption measurements revealed higher values after the bloom. The response of bacteria and metazoan meiofauna

indicated that enhanced oxygen consumption was related to respiratory activity of the living benthic component. High relative nematode abundance in the top centimetre layer of sediment only after the phytodetritus had settled suggests an early stage of a meiofaunal response. The study also showed that foraminiferans collect a diluted and sparse food resource (phytoplankton) and concentrate it as they build up their cytoplasm. As benthic foraminiferans serve as a food source for many abyssal metazoans, this study highlights the link between the degraded food resources, phytodetritus and metazoan organisms.

Brandt, A. & Würzberg, L. 2014. Southern Ocean deep sea – a benthic view to pelagic processes. Deep Sea Research II: 108: 1-112.

Raymond et al. 2014 uses two decades of satellite tracking data for Adélie and emperor penguins, light-mantled albatross, Antarctic fur seals, southern elephant seals and Weddell seals. Statistical modelling techniques were used to identify the preferred habitat of each species. The overlap amongst the foraging areas of individual species identified six major hotspots of important marine habitat. These areas were generally over the Antarctic shelf and waters immediately to its north, excluding deep, open oceanic areas, and were characterized by proximity to breeding colonies and by sea-ice dynamics, particularly locations of winter polynyas.

Raymond, B., Lea, M.-A., Patterson, T., Andrews-Goff, V., Sharples, R., Charrassin, J.-B., Cottin, M., Emmerson, L., Gales, N., Gales, R., Goldsworthy, S.D., Harcourt, R., Kato, A., Kirkwood, R., Lawton, K., Ropert-Coudert, Y., Southwell, C., van den Hoff, J., Wienecke, B., Woehler, E.J., Wotherspoon, S. & Hindell, M.A. 2014. Important marine habitat off east Antarctica revealed by two decades of multi-species predator tracking. Ecography 38: 121-129. doi: 10.1111/ecog.01021

Antarctic marine ecosystems have been changing for at least the past 30 years. This article reviews current and expected changes in physical habitats in response to climate change. It then reviews how these changes may impact the autecology of marine biota of this polar region. The general prognosis for the physical environment is for an overall warming, and freshening and strengthening of westerly winds. A potential pole-ward movement of those winds and the frontal systems, and an increase in ocean eddy activity is also predicted. Many habitat parameters will have regionally specific changes, particularly relating to sea ice dynamics.

Constable, A.J., Melbourne-Thomas, J., Corney, S.P. et al. 2014. Change in Southern Ocean ecosystems I: How changes in physical habitats directly affect marine biota. Global Change Biology, 20(10):3004-25. doi: 10.1111/gcb.12623.

Human impacts threaten not only species, but also entire ecosystems. Ecosystems under stress can collapse or transition into different states, potentially reducing biodiversity at multiple scales. This study highlighted the vulnerability of Antarctic shallow invertebrate-dominated ecosystems, through the identification of several threatening processes. Climate change is likely to cause early breakout of seasonal sea ice in parts of Antarctica, which will dramatically increase the amount of light reaching shallow seabed. This is predicted to result in ecological regime shifts, in which invertebrate-dominated communities are replaced by macroalgal beds. Habitat

for these endemic Antarctic ecosystems is globally rare, and the fragmented nature of their distribution along Antarctic coast increases their sensitivity to change. The authors estimate their spatial distribution around Antarctica using sea ice and bathymetric data, and apply the International Union for Conservation of Nature (IUCN) Red List of Ecosystems criteria to assess their vulnerability. Best available data suggest that shallow ice-covered ecosystems are likely Near Threatened to Vulnerable in places, although the magnitude of risk is spatially variable and requires additional data to strengthen the assessment.

Clark, G.F., Raymond, B., Riddle, M.J., Stark, J.S. & Johnston, E.L. 2015. Vulnerability of Antarctic shallow invertebrate- dominated ecosystems. Austral Ecology, doi:10.1111/aec.12237

Terrestrial:

In the very first metaviromics survey of an Antarctic soil habitat, these authors demonstrate, among other things, that there is an extremely wide diversity of bacteriophage and eukaryotic viruses present in Dry Valley soils. The identification of a number of highly novel phage sequences, including an entire virophage genome (comprising portions of both prokaryotic and eukaryotic origin), reflects the novelty of this environment.

Zablocki, O., van Zyl, L., Adriaenssens, E.M., Rubagotti, E., Tuffin, M., Cary, S.C. & Cowan, D. 2014. Level Diversity of Tailed Phages, Eukaryote-Associated Viruses, and Virophage-Like Elements in the Metaviromes of Antarctic Soils. Appl. Environ. Microbiol., 80(22):6888. doi: 10.1128/AEM.01525-14.

In a comprehensive review of climate change impacts in polar region, Royles and Griffiths (2015) describe how moss bank archives provide insights into long-term environmental change in the region. By looking at moss form and function in these long-term deposits, these authors provide a framework in which the potential impact of climate change on Antarctic terrestrial habitats can be assessed.

Royles, J. & Griffiths, H. 2015. Invited review: climate change impacts in polar regions: lessons from Antarctic moss bank archives. Global Change Biology, 21: 1041-1057

The current status of biological invasions in terrestrial Antarctica was documented by Hughes et al. (2015), who also look at the capacity to respond to these incursions. They provide an up-to-date inventory of known terrestrial non-native species introductions on the Antarctic continent and Peninsula. They conclude that practical management action is more likely to succeed with improved co-operation, communication and engagement by nations and industries operating across the region.

Hughes, K.A., Perierra, L.R., Molina-Montenegro, M.A. & Convey, P. 2015. Biological invasions in terrestrial Antarctica: what is the current status and can we respond? Biodiversity Conservation, doi: 10.1007/s10531-015-0896-6

Herbold et al. (2014) present evidence in aerobiology that challenges the assumption that geographical isolation is an effective barrier to microbial transport. However,

given the uncertainty with which aerobiological organisms are recruited into existing communities, the ultimate impact of microbial dispersal is difficult to assess. Here the authors use molecular genetic approaches to examine microbial communities inhabiting fumarolic soils on Mount Erebus, the southern-most geothermal site on Earth, to evaluate the ecological significance of global-scale microbial dispersal. There, hot, fumarolic soils provide an effective environmental filter to test the viability of organisms that have been distributed via aeolian transport over geological time. We find that cosmopolitan thermophiles dominate the surface, whereas endemic Archaea and members of poorly understood Bacterial candidate divisions dominate the immediate subsurface. These results imply that aeolian processes readily disperse viable organisms globally, where they are incorporated into pre-existing complex communities of endemic and cosmopolitan taxa.

Herbold, C., Herbold, W., Lee, C.K., McDonald, I.R. & Cary, S.C. 2014. Evidence of global-scale aeolian dispersal and endemism in isolated geothermal microbial communities of Antarctica. Nature Communications, 5:3875. doi: 10.1038/ncomms4875

This study by LaRue et al. (2014) explored the hypothesis that emperor penguins are strictly philopatric using satellite imagery, counts from aerial photography, and literature reports on emperor penguin distributions. There were six instances over three years in which emperor penguins did not return to the same location to breed, and there was also one newly discovered colony on the Antarctic Peninsula that may represent the relocation of penguins from the Dion Islands. This study is the first to use remote sensing to suggest that emperor penguins move between and establish new colonies, and suggests that emigration may have been partly responsible for the population decline at Pointe Géologie during the 1970s. Metapopulation dynamics of emperor penguins have not been previously considered and represent an important avenue for future research. Life history plasticity may be an important aspect of climate change adaptation, and our study offers new insight for the long-term future of emperor penguins.

LaRue, M.A., Kooyman, G., Lynch, H.J. & Fretwell, P. 2015. Emigration in emperor penguins: implications for interpretation of long-term studies. Ecography, 38: 114–120.

The paper by Lynch and LaRue (2014) reports on the first global census of the Adélie penguin, achieved using a combination of ground counts and satellite imagery, finding a breeding population 53% larger (3.79 million breeding pairs) than the last estimate in 1993. This global population assessment, which provides the first abundance estimates for 41 previously unsurveyed colonies, and reports on 17 previously unknown colonies, provides a robust baseline for understanding future changes in abundance and distribution and finds that Adélie penguin declines on the Antarctic Peninsula are more than offset by increases in East Antarctica. These results represent a critically-needed contribution to ongoing negotiations regarding the design and implementation of Marine Protected Areas for the Southern Ocean.

Lynch, H.J. & LaRue, M.A. 2014. First global survey of Adélie penguin populations. The Auk, 131(4): 457-466, doi: http://dx.doi.org/10.1642/AUK-14-31.1

Astronomy and Astrophysics:

The possible detection of the signature of gravity waves from the early Universe, in early 2014, caused great excitement across the scientific world. However, a joint analysis of 150 GHz data from two telescopes at South Pole (BICEP2 and Keck), with data from the Planck satellite at (principally) 353 GHz, shows that somewhere between half and all of the signal observed at 150 GHz is due to polarized emission from dust in our own galaxy. Once this is accounted for, there is no significant evidence for an inflationary gravitational wave component.

> *Ade P.A.R. et al. 2015. A Joint Analysis of BICEP2/Keck Array and Planck Data. Physical Review Letters, 114: 101301. doi: 10.1103/PhysRevLett.114.101301*

The detection and study of transiting extrasolar planets (i.e., those whose orbits momentarily eclipse their host star when viewed from the earth) is one of the most important elements in the search for habitable extrasolar planets and the possible existence of extraterrestrial life. This study compared the best observing sites in Chile with Dome C, Antarctica. Two weeks of observations at Dome C yield a transit detection efficiency that typically requires a whole observing season in Chile. Combination of data from both continents improves detection yield by a further 12 to 18%.

> *Fruth, T. et al. 2014. Transit Search from Antarctica and Chile - Comparison and Combination. Publications of the Astronomical Society of the Pacific, 126: 227 - 242. doi: 10.1086/675684*

Humanities and Social Sciences:

The Consultative Parties to the Antarctic Treaty have frequently declared their collective ambition to manage Antarctica "in the interest of all mankind". However, the concrete implications of these declarations are not clear. As part of an international research project, the authors asked people from different parts of the world to respond to a questionnaire about Antarctica, its values, and the way it should be managed. Notwithstanding differences in respondents' nationalities, ages and the time of data collection, our results indicate that a significant proportion of the public values Antarctica both as a scientific laboratory and as one of the world's last wildernesses. Is this "public's dream" of co-existence of science and wilderness a Mission Impossible? In this article, we contend that: 1) in theory, it is a Possible Mission that would connect well with the recognition of science and wilderness in the Antarctic Treaty System (ATS) instruments; 2) in practice, science in Antarctica has gradual and cumulative impacts on all three main wilderness qualities of Antarctica (absence of permanent infrastructure, naturalness and large size); 3) currently, the coexistence of science and wilderness is not an important consideration in the management of human activities in Antarctica; and 4) in the future, unless a proactive and concerted effort is taken by the Consultative Parties, it appears to be a Mission Impossible, as the expansion of scientific activities and associated logistics remains uncontrolled, inexorably eroding the Antarctic wilderness. The authors propose the adoption of principles providing clear and concrete guidance on scientific facilities and international cooperation as a constructive step forward in realising the "public's dream" of coexistence of science and wilderness in Antarctica.

Bastmeijer, K. & Tin, T. 2015. Antarctica - A Wilderness Continent for Science: The 'Public's Dream' as a Mission Impossible? The Yearbook of Polar Law VI. 559-597. doi: 10.1163/1876-8814_020.

This book discusses concerns for the sensitive environments and ecosystems of Antarctica and looks ahead to the state of the continent as it might be in 2060. At the beginning of the 21st century, Antarctica stands at the edge of a warmer and busier world. The editors have gathered leading researchers to examine the challenges of Antarctic environmental governance, and to address such important questions as: What future will Business-As-Usual bring to the Antarctic environment? Will a Business-As-Usual future be compatible with the objectives set out under the Antarctic Treaty, especially its Protocol on Environmental Protection? What actions are necessary to bring about alternative futures for the next 50 years? In three main sections the authors a) examine the future state of Antarctic ecosystems in general, and specifically focuses on baleen whales, fisheries, introduction of non-native species, and the consequences of human trampling on soils; b) provide regional case studies with detailed summaries of human activities and environmental management in three regions as microcosms of current practice from which lessons can be learned, and c) provide a diverse set of perspectives from representatives of environmental non-governmental organizations and governmental institutions, as well as from tourism and sustainability researchers on how Antarctica is used, valued and governed, and how strategic thinking can assist in exploring, and potentially reaching, desirable futures for the Antarctic environment.

Tin, T., Liggett, D., Maher, P.T. & Lamers, M. (Eds.). 2014. Antarctic Futures: Human Engagement with the Antarctic Environment. Dordrecht, Heidelberg, Berlin, London: Springer.

Appendix 2

List of Acronyms

AIS	Antarctic ice sheet
ANDEEP-SYSTCO	ANtarctic benthic DEEP-sea biodiversity: colonization history and recent community patterns - SYSTem COupling
AntEco	State of the Antarctic Ecosystem
AnT-ERA	Antarctic Thresholds - Ecosystem Resilience and Adaptation
ANTOS	Antarctic Near-shore and Terrestrial Observing System (Action Group)
ANTPAS	Antarctic and sub-Antarctic Permafrost, periglacial environments And Soils group
ANTVOLC	Action Group on Antarctic Volcanism
ARC	Antarctic Research Challenges project
ATCM	Antarctic Treaty Consultative Meeting
ATS	Antarctic Treaty System
BICEP	Background Imaging of Cosmic Extragalactic Polarization
CALM	Circumpolar Active Layer Monitoring network
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CEP	Committee for Environmental Protection (Antarctic Treaty)
CO_2	carbon dioxide
COMNAP	Council of Managers of National Antarctic Programs
DOI / doi	digital object identifier
EAIS	East Antarctic Ice Sheet
e.g.	for example (from Latin: exempli gratia)
EPB	European Polar Board
GeoMap	Geological Mapping Update of Antarctica (Action Group)
GHz	Gigahertz
IASC	International Arctic Science Committee
IBRD	iceberg rafted debris
ICSU	International Council for Science
i.e.	that is (from Latin: id est)
IODP	Integrated Ocean Drilling Program
ISAES	International Symposium on Antarctic Earth Sciences
IUCN	International Union for Conservation of Nature
PDF	Portable Document Format
ppm	parts per million
RNA	Ribonucleic acid
SCADM	Standing Committee on Antarctic Data Management

SCAGI	Standing Committee on Antarctic Geographic Information
SCATS	Standing Committee on the Antarctic Treaty System
SCAR	Scientific Committee on Antarctic Research
SLW	subglacial Lake Whillans
SnowAnt	Snow in Antarctica (Action Group)
UK	United Kingdom
UN	United Nations
UNFCCC	United National Framework Convention on Climate Change
WAIS	West Antarctic Ice Sheet
WCRP	World Climate Research Programme
WISSARD	Whillans Ice Stream Subglacial Access Research Drilling