Marine Genomics xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Genomics

journal homepage: www.elsevier.com/locate/margen

Review

Cross-disciplinarity in the advance of Antarctic ecosystem research

J. Gutt[a,*], E. Isla[b], A.N. Bertler[c], G.E. Bodeker[d], T.J. Bracegirdle[e], R.D. Cavanagh[e], J.C. Comiso[f], P. Convey[e], V. Cummings[g], R. De Conto[h], D. De Master[i], G. di Prisco[j], F. d'Ovidio[k], H.J. Griffiths[e], A.L. Khan[l], J. López-Martínez[m], A.E. Murray[n], U.N. Nielsen[o], S. Ott[p], A. Post[q], Y. Ropert-Coudert[r], T. Saucède[s], R. Scherer[t], S. Schiaparelli[u,ad], I.R. Schloss[v,ae,1], C.R. Smith[w], J. Stefels[x], C. Stevens[g], J.M. Strugnell[y,af], S. Trimborn[a], C. Verde[j], E. Verleyen[z], D.H. Wall[aa], N.G. Wilson[ab], J.C. Xavier[e,ac]

[a] Alfred Wegener Institute, Hemholtz Centre for Polar and Marine Research, PO Box 120161, 27515 Bremerhaven, Germany
[b] Institut de Ciències del Mar-CSIC, Passeig Marítim de la Barceloneta, 37-49, Barcelona 08003, Spain
[c] Antarctic Research Centre, Victoria University and GNS Science, PO Box 600, Wellington, New Zealand
[d] Bodeker Scientific, 42 Russell Street, Alexandra 9320, Central Otago, New Zealand
[e] British Antarctic Survey, NERC, High Cross, Madingley Rd, Cambridge CB3 0ET, United Kingdom
[f] NASA Goddard Space Flight Center, Code 615, 8800, 20 Road, Greenbelt, MD 20771, USA
[g] National Institute of Water and Atmospheric Research, 301 Evans Bay Parade, Greta Point, Wellington, New Zealand
[h] Department of Geosciences, University of Massachusetts-Amherst, Amherst, MA 01003, USA
[i] Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695-8208, USA
[j] Institute of Biosciences and Bioresources, National Research Council, Via Pietro Castellino 111, IT 80131 Naples, Italy
[k] Sorbonne Université (UPMC, Paris 6)/CNRS/IRD/MNHN, Laboratoire d'Océanographie et du Climat (LOCEAN), Institut Pierre Simon Laplace (IPSL), 75252 Paris Cedex 05, France
[l] National Snow and Ice Data Center and Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, USA
[m] Universidad Autónoma de Madrid, Facultad de Ciencias, Dept. Geología y Geoquímica, 28049 Madrid, Spain
[n] Division of Earth and Ecosystem Sciences, Desert Research Institute, 2215 Raggio Parkway, Reno, NV 89512, USA
[o] Hawkesbury Institute for the Environment, Western Sydney University, Locked Bag 1797, Penrith, NSW 2751, Australia
[p] Heinrich-Heine-Universität Düsseldorf, Institut für Botanik, Universitätsstraße 1, Gebäude 26.13, D-40225 Düsseldorf, Germany
[q] Geoscience Australia, GPO Box 378, Canberra, ACT, 2601, Australia
[r] Centre d'Etudes Biologiques de Chizé Station d'Écologie de Chizé-La Rochelle, CNRS UMR 7372, 79360 Villiers-en-Bois, France
[s] UMR 6282 Biogéosciences, Univ Bourgogne Franche-Comté, 6 boulevard Gabriel, 21000 Dijon, France
[t] Department of Geology & Environmental Geosciences, Northern Illinois University, DeKalb, IL, 60115, USA
[u] DISTAV, Università degli Studi di Genova, C.so Europa 26, I-16132, Genova, Italy
[v] Instituto Antártico Argentino, 25 de Mayo 1143, San Martín Pcia. de Buenos Aires C1064AAF, Argentina
[w] Department of Oceanography, University of Hawaii at Manoa, 1000 Pope, Honolulu, HI 96822, USA
[x] University of Groningen, Groningen Institute for Evolutionary Life Sciences, Ecophysiology of Plants, PO Box 11103, 9700, CC, Groningen, The Netherlands
[y] Centre for Sustainable Tropical Fisheries and Aquaculture, College of Science and Engineering, James Cook University, Townsville, Qld 4811, Australia
[z] Ghent University, Biology Department, Research group Protistology and Aquatic Ecology, Campus Sterre, S8, Krijgslaan 281, B-9000 Ghent, Belgium
[aa] School of Global Environmental Sustainability, Colorado State University, Fort Collins, CO 80523-1036, USA
[ab] Western Australian Museum, 49 Kew Street, Welshpool 6106, Western Australia, Australia
[ac] MARE - Marine and Environmental Sciences Centre, Faculty of Sciences and Technology, University of Coimbra, Portugal
[ad] Museo Nazionale dell'Antartide (Sede di Genova), Genova, Italy
[ae] Institut des sciences de la mer de Rimouski, 310 Allée des Ursulines, Rimouski, QC G5L 3A1, Canada
[af] Department of Ecology, Environment and Evolution, La Trobe University, Melbourne, Vic 3086, Australia

* Corresponding author.
E-mail addresses: julian.gutt@awi.de (J. Gutt), isla@icm.csic.es (E. Isla), nancy.bertler@vuw.ac.nz (A.N. Bertler), greg@bodekerscientific.com (G.E. Bodeker), tjbra@bas.ac.uk (T.J. Bracegirdle), rcav@bas.ac.uk (R.D. Cavanagh), josefino.c.comiso@nasa.gov (J.C. Comiso), pcon@bas.ac.uk (P. Convey), Vonda.Cummings@niwa.co.nz (V. Cummings), deconto@geo.umass.edu (R. De Conto), demaster@ncsu.edu (D. De Master), guido.diprisco@ibbr.cnr.it (G. di Prisco), Francesco.dovidio@locean-ipsl.upmc.fr (F. d'Ovidio), hjg@bas.ac.uk (H.J. Griffiths), alia.khan@colorado.edu (A.L. Khan), jeronimo.lopez@uam.es (J. López-Martínez), Alison.Murray@dri.edu (A.E. Murray), U.Nielsen@westernsydney.edu.au (U.N. Nielsen), otts@uni-duesseldorf.de (S. Ott), Alix.Post@ga.gov.au (A. Post), yan.ropert-coudert@cebc.cnrs.fr (Y. Ropert-Coudert), thomas.saucede@u-bourgogne.fr (T. Saucède), reed@niu.edu (R. Scherer), Stefano.Schiaparelli@unige.it (S. Schiaparelli), ireschloss@gmail.com (I.R. Schloss), craigsmi@hawaii.edu (C.R. Smith), j.stefels@rug.nl (J. Stefels), Craig.Stevens@niwa.co.nz (C. Stevens), jan.strugnell@jcu.edu.au (J.M. Strugnell), scarlett.trimborn@awi.de (S. Trimborn), cinzia.verde@ibbr.cnr.it (C. Verde), Elie.Verleyen@UGent.be (E. Verleyen), Diana.Wall@ColoState.edu (D.H. Wall), Nerida.Wilson@museum.wa.gov.au (N.G. Wilson), jxavier@zoo.uc.pt, jccx@cantab.net (J.C. Xavier).
[1] Present address: Centro Austral de Investigaciones Científicas, CONICET and Universidad Nacional de Tierra del Fuego, Ushuaia, Argentina.

http://dx.doi.org/10.1016/j.margen.2017.09.006
Received 17 May 2017; Received in revised form 20 September 2017; Accepted 20 September 2017
1874-7787/

ARTICLE INFO

Keywords:
Scaling
Risk maps
Response to environmental changes
Sea-ice
Multiple stressors
Southern Ocean

ABSTRACT

The biodiversity, ecosystem services and climate variability of the Antarctic continent and the Southern Ocean are major components of the whole Earth system. Antarctic ecosystems are driven more strongly by the physical environment than many other marine and terrestrial ecosystems. As a consequence, to understand ecological functioning, cross-disciplinary studies are especially important in Antarctic research. The conceptual study presented here is based on a workshop initiated by the Research Programme Antarctic Thresholds – Ecosystem Resilience and Adaptation of the Scientific Committee on Antarctic Research, which focussed on challenges in identifying and applying cross-disciplinary approaches in the Antarctic. Novel ideas and first steps in their implementation were clustered into eight themes. These ranged from scale problems, through risk maps, and organism/ecosystem responses to multiple environmental changes and evolutionary processes. Scaling models and data across different spatial and temporal scales were identified as an overarching challenge. Approaches to bridge gaps in Antarctic research programmes included multi-disciplinary monitoring, linking biomolecular findings and simulated physical environments, as well as integrative ecological modelling. The results of advanced cross-disciplinary approaches can contribute significantly to our knowledge of Antarctic and global ecosystem functioning, the consequences of climate change, and to global assessments that ultimately benefit humankind.

1. Introduction

The Antarctic continent, including its surrounding Southern Ocean, overlying atmosphere, and its portion of the biosphere, is an integral component of the Earth system. As Antarctic ecosystems change, so do the services they provide to global ecosystems and humankind. In the context of this framework, cross-disciplinary science is essential to conducting Antarctic ecosystem research. Physical-chemical (including geological) drivers, especially ice, temperature close to or below freezing, wind and drought, are more relevant to life on the Antarctic continent and in the Southern Ocean than in many other ecosystems. In addition, important biological interactions, such as energy flux between trophic levels, are also important influences at varying scales. (Convey et al., 2014; Gutt et al., 2015). Conversely, biological activity in turn modulates the physical-chemical environment, for example through the emission of the climatically active gas dimethylsulphide (DMS) by algae (Stefels et al., 2007), by shaping marine sediments (Graf and Rosenberg, 1997), biological contributions in rock weathering and soil formation (Thomas et al., 2008) and the production of oxygen (Field et al., 1998). As a result, it is essential to (a) understand the response of the biosphere to climate change by taking into account species-specific adaptations to the specific environment, (b) estimate the proportion of endemic Antarctic biota in relation to the global biodiversity, and (c) quantify Southern Ocean contributions to global ecosystem goods and services including fishery and other natural products, biogeochemical cycling, climate regulation, oxygen production, maintenance of biodiversity and ethical benefits (Grant et al., 2013). Linking the physical and biological components of Antarctic ecosystems is also a key challenge since many parts of the Antarctic and Southern Ocean climate system are heterogeneous in space and time (Mayewski et al., 2009; Turner et al., 2009, 2014; Jones et al., 2016), but descriptions of the physical environment, and associated modelling, often differ widely from those applied to biological processes.

As a consequence, Antarctic research is at the forefront of important scientific challenges, applying holistic approaches that combine systematic assessments of key physical predictors and key biota. Antarctic interdisciplinary research also helps to provide societal benefits by delivering new technologies and projections of potential impacts of the Antarctic environment to change and the impacts of those changes on ecosystem goods and services. Challenges range from increasing the availability of quantitative information, such as increasing the number of studies and publicly available data sets, to more functional requirements such as developing new analytical tools and progressing our ability to resolve and simulate systems of greater complexity. Many of these challenges can only be tackled synergistically and need to be addressed to provide a framework for future development of research in Antarctica, and elsewhere.

The Antarctic science community has made remarkable progress over the past 20 years. However, despite some outstanding exceptions, this has largely been achieved within single disciplines. It is not only the traditional structure of how scientific research is organised and funded that encourages single-discipline approaches, but it is also the extreme Antarctic environment, including difficulty of accessing support, that has resulted in generally narrow science programmes. This has led to the current silo structure of Antarctic research. Today we can sequence genes and modify genomes, and we can remotely observe area-wide temperature, sea-ice cover and primary production including their spatial patchiness and temporal dynamics from space. This allows us to make projections, for instance, of sea-ice change for the next 100 years; we can also count penguins, seals and whales by satellites, drones, helicopters and airplanes, and we can survey marine habitats by remotely operated and autonomous vehicles. We can also conduct physiological, ecological and 'omics' experiments on terrestrial or marine environments, either in situ, or in the laboratory, by manipulating environmental variables. A drawback of such rapid and successful advances in single disciplines is that it leaves gaps in cross-disciplinary developments. To date, we are left with a mosaic of information that does not provide a coherent and robust picture of past, present and future Antarctic ecosystems. With access to emerging new technologies, the collaboration of Antarctic biological, geological and physical scientists provides an exciting opportunity to develop a comprehensive assessment of future ecosystem vulnerabilities and resilience. But this is only likely to happen if scientists extend their research interests beyond their discipline and are encouraged to establish true interdisciplinary collaborations. To achieve this, historical barriers dividing distinct areas of expertise need to be removed so that a new era of research targeted at systematically addressing specific cross-disciplinary questions is ushered in. Biologists need support from the climate and physical research fields (including chemistry and geology) to solve the challenges of understanding complexity of real life systems. In turn, physicists benefit from approaches that address obvious requirements of society. Large international initiatives, once sufficiently developed, could in the future provide an appropriate 'home' for advanced cross-disciplinary research e.g. the Southern Ocean Observing System (SOOS; Rintoul et al., 2012), the Polar Climate Predictability Initiative (PCPI; www.climate-cryosphere.org/wcrp/pcpi, last access: 20 September 2017) or ongoing Scientific Research Programmes (SRP) of the Scientific Committee on Antarctic Research (SCAR). Even more