Polar Research

ISSN: (Print) 1751-8369 (Online) Journal homepage: http://www.tandfonline.com/loi/zpor20

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To cite this article: Monika Kędra, Alexey K. Pavlov, Carolyn Wegner & Alexandre Forest (2015) Foreword to the thematic cluster: the Arctic in Rapid Transition—marine ecosystems, Polar Research, 34:1, 30684, DOI: 10.3402/polar.v34.30684

To link to this article: http://dx.doi.org/10.3402/polar.v34.30684

PERSPECTIVE

Foreword to the thematic cluster: the Arctic in Rapid Transition—marine ecosystems

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Keywords
Climate change; biogeochemical processes; forcing; ecosystem; sea ice; Arctic Ocean.

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Abstract

The Arctic is warming and losing sea ice. Happening at a much faster rate than previously expected, these changes are causing multiple ecosystem feedbacks in the Arctic Ocean. The Arctic in Rapid Transition (ART) initiative was developed by early-career scientists as an integrative, international, multidisciplinary, long-term pan-Arctic network to study changes and feedbacks among the physical and biogeochemical components of the Arctic Ocean and their ultimate impacts on biological productivity on different timescales. In 2012, ART jointly organized with the Association of Polar Early Career Scientists their second science workshop—Overcoming Challenges of Observation to Model Integration in Marine Ecosystem Response to Sea Ice Transitions—at the Institute of Oceanology, Polish Academy of Sciences, in Sopot. This workshop aimed to identify linkages and feedbacks between atmosphere–ice–ocean forcing and biogeochemical processes, which are critical for ecosystem function, land–ocean interactions and productive capacity of the Arctic Ocean. This special thematic cluster of *Polar Research* brings together seven papers that grew out of workgroup discussions. Papers examine the climate change impacts on various ecosystem elements, providing important insights on the marine ecological and biogeochemical processes on various timescales. They also highlight priority areas for future research.

Environmentally, socially, economically and politically unique, the Arctic is in a state of rapid transition exemplified by the reduction of sea-ice age, thickness and extent (Steele et al. 2008; Meier et al. 2014; Serreze & Stroeve 2015). Alarmingly, this reduction is occurring more rapidly than has been predicted: over the past decade, summer sea-ice extent has decreased by nearly 50% and shifted from a thick, multiyear to a largely thinner, first-year ice cover (Comiso 2012). The linear decline rate for September Arctic sea-ice extent (1979–2015) has been estimated as 13.4% per decade relative to the 1981–2010 average (NSIDC 2015). Recent modelling suggests that the Arctic Ocean may become seasonally ice-free as early as 2040 (Overland & Wang 2013). Changes in sea-ice cover will have major impacts on ecosystem functioning and biogeochemical processes leading into large, cascading changes with implications for the entire Arctic ecosystem. Apart from severe environmental changes, the Arctic Ocean is also affected by our easier access to oil and gas resources, trans-Arctic shipping, intensified tourism and shifts in the distribution of harvestable resources. Understanding and predicting how ecological and biogeochemical processes in the Arctic Ocean are impacted by global changes, how their modifications may feed back to the Earth's climate system and how shifts in food-web functioning could affect the people who depend upon marine resources require an integrated approach (Wegner et al. 2011). Reliable projections into the future are essential for protection-oriented operation and sustainable use of resources, and are of high interest to policy makers, land-use managers and Arctic residents.

In this context, the Arctic in Rapid Transition (ART; www.iarc.uaf.edu/ART/) initiative was developed as an integrative, international, multidisciplinary, long-term

Citation: *Polar Research* 2015, *34*, 30684, http://dx.doi.org/10.3402/polar.v34.30684

pan-Arctic network to study changes and feedbacks among the physical and biogeochemical components of the Arctic Ocean and their ultimate impacts on biological productivity (Wegner et al. 2010). ART was developed and is still led by early-career scientists (ECS). It is focused on bridging timescales, science disciplines and geographic regions to better understand the past, present and future response of Arctic marine ecosystems to sea-ice transitions and climate change (Fig. 1). ART holds a holistic approach with a strong linkage to the human dimension as we expect to provide to people who live and work in the Arctic a better comprehension of the impacts of sea-ice changes on coastal and marine ecosystems (Wegner et al. 2011).

Toward this goal, ART and the Association of Polar Early Career Scientists organized the science workshop Overcoming Challenges of Observation to Model Integration in Marine Ecosystem Response to Sea Ice Transitions at the Institute of Oceanology Polish Academy of Sciences, in Sopot, from 23 to 26 October 2012 (Forest et al. 2013). Entirely developed by ECS, the workshop gathered 64 participants—23 PhD students, 25 post-doctoral researchers and 16 senior scientists—coming from 12 countries and representing diverse scientific backgrounds, such as physical–biological modelling, palaeoceanography, marine ecology, coastal and glacier dynamics and atmospheric sciences, as well as social sciences. The workshop addressed the challenge of integrating modelling and observation approaches. Thematically, it aimed to identify linkages and feedbacks between atmosphere–ice–ocean forcing and biogeochemical processes, which are critical for ecosystem function, land–ocean interactions and to the productive capacity of the Arctic Ocean. The main objective of the workshop was to bring together scientists with a common interest in improving our understanding of the changing Arctic Ocean as a whole, with the aim of developing interdisciplinary papers. The workshop was divided into two parts: the first comprised training sessions on theoretical and practical aspects of marine sciences, and the second part was dedicated to plenary talks and break-out sessions to discuss and initiate the writing of collaborative papers. ECS led the sub-group discussions that gave rise to manuscript planning and later writing. Additionally, ECS taking part in the workshop were encouraged to submit individual papers on the Arctic ecosystem responses to climate change.

In this thematic cluster, we introduce seven papers that comprise the main output of the workshop. Three synthesis papers review trends in relation to changing sea-ice conditions: one paper on marine carbon-cycle processes (Findlay, Gibson et al. 2015), one on benthic food webs (Kędra et al. 2015) and one on the transport of terrigenous material in the past (Wegner et al. 2015). Two of these (Findlay, Gibson et al. 2015; Kędra et al. 2015) also present scenarios of future change, and the conclusions of the third paper (Wegner et al. 2015) serve a similar purpose. Four papers cover case studies of the plankton responses to temperature increase and changing conditions in the Arctic Ocean over short and long timeframes (Nöthig et al. 2015) and in experimental studies (Weydmann et al. 2015), patterns and trends of benthic macrofauna in the deep Arctic Ocean (Degen et al. 2015) and winter biogeochemical conditions under sea ice in the Canadian High Arctic (Findlay, Edwards et al. 2015). It is anticipated that further papers stemming

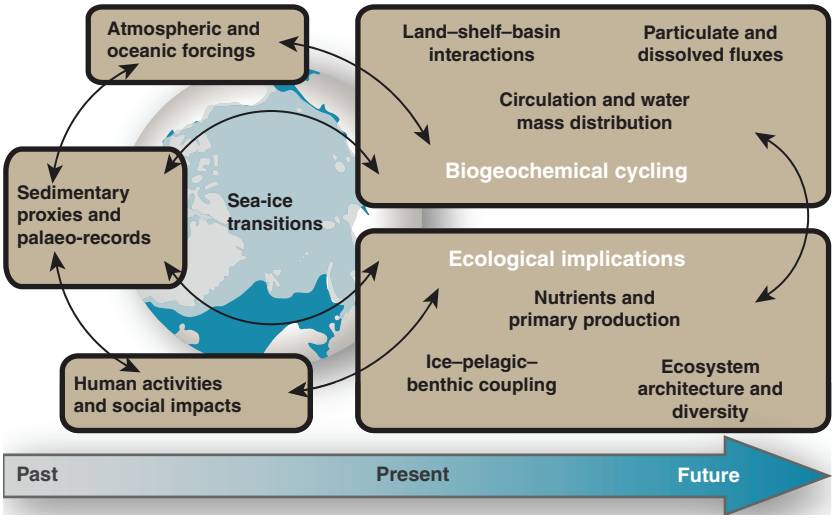

Fig. 1 Conceptual diagram summarizing the questions that are the focus of the Arctic in Rapid Transition network.

Citation: *Polar Research* 2015, *34*, 30684, http://dx.doi.org/10.3402/polar.v34.30684

from the Sopot workshop and other ART meetings, for example, the Integrating Spatial and Temporal Scales in the Changing Arctic System workshop in Plouzané in 2014, will be published elsewhere.

Acknowledgements

This thematic cluster is an output of the first joint ART and Association of Polar Early Career Scientists Science Workshop, in Sopot, Poland, 23–26 October 2012. This cross-cutting initiative was generously supported by the International Arctic Science Committee, the Prince Albert II of Monaco Foundation, the Polish Academy of Sciences, Institute of Oceanology Polish Academy of Sciences, the Polish Scientific Committee on Oceanic Research, the International Arctic Research Center, the Centre National de la Recherche Scientifique–Laval Takuvik Joint Laboratory, the Alfred Wegener Institute for Polar and Marine Research, and Fisheries and Oceans Canada.

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