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Editorial: Biogeochemical Consequences of Climate-Driven Changes in the Arctic

Adam J. Reed^{1*†}, Robyn E. Tuerena^{2†}, Philippe Archambault^{3,4†} and Martin Solan^{1†}

¹School of Ocean and Earth Science, National Oceanography Centre Southampton, Waterfront Campus, University of Southampton, Southampton, United Kingdom, ²Scottish Association for Marine Science, Dunstaffnage, United Kingdom, ³ArcticNet, Université Laval, Québec, QC, Canada, ⁴Québec Océan, Takuvik, Département de Biologie, Université Laval, Québec, QC, Canada

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Editorial on the Research Topic

Biogeochemical Consequences of Climate-Driven Changes in the Arctic

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Vera I. Slaveykova,
Université de Genève, Switzerland

*Correspondence:

Adam J. Reed
adam.reed@noc.soton.ac.uk

†ORCID:

Adam J. Reed
orcid.org/0000-0003-2200-5067
Robyn E. Tuerena
orcid.org/0000-0001-7664-840X
Philippe Archambault
orcid.org/0000-0001-5986-6149
Martin Solan
orcid.org/0000-0001-9924-5574

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INTRODUCTION

The Arctic Ocean is warming at an unprecedented rate, leading to the loss of multi-year sea ice, and changes to stratification and ocean circulation patterns (Polyakov et al., 2017; Lind et al., 2018; Stroeve and Notz 2018). Increased discharge of freshwater (McClelland et al., 2006) and terrestrial organic matter into Arctic coastal water (Parmentier et al., 2017) further influence the timing of natural cycles. The ecological consequences of these changes manifest in adjusted primary productivity cycles (Lewis et al., 2020), alterations in the quality and quantity of organic matter reaching the seafloor (Krajewska et al., 2017; Stevenson and Abbott 2019; Olivier et al., 2020), benthic biogeochemical cycles (MacDonald et al., 2015; Solan et al., 2020) and the food-web (Yunda-Guarin et al., 2020). Mechanistic understanding of these processes requires continual revision, and in this research topic, we report new findings and emerging insights about how Arctic biogeochemical processes are responding to climate change and altering system dynamics. The contributions received present nuanced perspectives on the role of spatial and temporal variability, the connectivity between terrestrial and marine systems, the context dependency of organic matter degradation, and they highlight some emerging ecological consequences from a range of Arctic locations.

Spatial and Temporal Influences on Biogeochemistry

As sea ice melts, areas of once permanent sea ice are now shifting to seasonal sea ice zones, with concomitant changes in light availability, upper-ocean mixing, and community structure. In this issue, Matthes et al. document the spatial variability of UV and PAR transmission through melting sea ice and conclude that spatial averages in transmission are more representative than single point irradiance measurements used for estimating nutrient availability and, by inference, primary production. Marmillot et al. exploit spatial variations in physiochemical seawater properties to explore its relationship with lipid and fatty acid distributions, and highlight the importance of long-lived subsurface chlorophyll maximum layers in supplying PUFA-rich POM to the food web. Using biogeochemical modelling, Benkort et al. include a sea-ice component for the Barents Sea, which links the dynamics of the sea-ice, pelagic and benthic environments. Their findings indicate the important role of sea-ice algae in influencing the timing and amplitude of pelagic primary and secondary production, and in seeding pelagic diatoms.

Terrestrial–Marine Connectivity

The Arctic Ocean is surrounded by the northernmost regions of the American and Eurasian continents where glaciers and permafrost are decreasing in areal extent (Chadburn et al., 2017). The Arctic basin is unique in that it holds less than 2% of the ocean's volume but receives 10% of global riverine discharge and, therefore, processes occurring in Arctic rivers can have disproportionate consequences for biogeochemical cycling across the wider Arctic Ocean (Holmes et al., 2012). As climate forcing progresses, increases in riverine discharge associated with increases in precipitation and permafrost thaw emphasize land–ocean connectivity. McGovern et al. describe the effects of increased terrestrial riverine input on a fjordal system in Svalbard, and highlight the need for detailed and high resolution sampling to explore biogeochemical and ecological responses over time. Similarly, Juhls et al. describe the dynamics of the Lena River biogeochemistry. Using an unprecedented high temporal frequency of samples, they reveal seasonal changes in the composition and sources of dissolved organic matter (DOM). These new data indicate a shift in subsurface DOM properties towards older sources which are mobilized from within deeper soil horizons and permafrost deposits, raising concerns about positive climatic feedbacks.

Effects of Changing Biogeochemistry on the Ecosystem

Changes to biogeochemical properties in the Arctic can also influence the broader ecosystem, although the mechanistic basis of many of these linkages are poorly understood, and do not always follow expected patterns. O'Daly et al. measure sinking particulate organic carbon during a particularly ice free and warm summer in the Pacific-influenced Arctic. Contrary to expectations, they find high carbon fluxes which suggest the potential for high productivity in a warming Arctic ocean. Meanwhile, using a mesocosm study, Reed et al. investigate the reproductive response of abundant benthic invertebrates to projected temperature and CO₂ concentrations. They show no change in oocyte size frequency, and suggest that the quantity and quality of food, often available *ad libitum* in laboratory experiments, is likely to be an important determinant of physiological responses to projected environmental change.

Organic Matter Degradation

The characteristics and degradability of organic matter has important implications for climate. Jongejans et al. describe the organic matter characteristics in a thermokarst lake in Siberia and postulate on the ecological landscape through time while exploring the degradation of organic matter through permafrost thaw. They find that the organic carbon inventory of thawed permafrost reflects poor

deposition, partial mobilization and release as methane from the lake, while the frozen elements of the permafrost indicate that the input signal of the organic matter still exceeds the degradation signal from thaw underneath. Their study indicates that changes in environmental circumstance can have substantive effects on organic matter retention and release. Indeed, Saidi-Mehrabad et al. considers whether or not climatic-induced transitions in state could occur in Arctic regions by examining how soil chemical and microbial parameters operate across the Pleistocene–Holocene boundary. As modern cold-adapted systems near a climatic threshold they conclude that cold soils could transition in ways similar to those seen across the Pleistocene–Holocene boundary with unknown ecosystem consequences.

CONCLUSION

Biogeochemical influences in the Arctic are often studied in the context of seasonality and climate forcing. However, it is now becoming clear that a greater understanding of the temporal influences in biogeochemistry overshadow our knowledge of spatial variations, which may constrain efforts to project regional responses to climate forcing. Previous work has emphasized the importance of primary productivity in controlling Arctic biogeochemistry, but as shown throughout the contributions in this thematic issue, multiple components of the system, from sea ice to seafloor, can have a substantive role in determining system response. It will be important to incorporate this knowledge to identify thresholds and feedbacks, vulnerabilities and surprises, and to improve projections of biogeochemical and wider ecosystem responses to climate change.

AUTHOR CONTRIBUTIONS

AR wrote the first editorial draft. RT, PA, and MS provided editorial suggestions and critical comments for revision. All authors agreed on the final submission.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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