ARCTIC 2022 – IMPLEMENTED PROJECTS

Under-ice phytoplankton distribution and diversity across poles

INSTITUTION

Oregon State University, USA

ABSTRACT

Under-ice environments are extreme habitats that occasionally allow enough light through the ice that phytoplankton, the base of the entire ecosystem, can bloom. Although it has been recognized that phytoplankton live underneath sea ice, there are very few studies in the Arctic and even fewer in the Antarctic that characterize phytoplankton community composition (PCC) under sea ice (Ardyna et al. 2020a,b) and the special light conditions under which they thrive. Virtually no studies characterize PCC across the wide range of locations enabled by the planned transects of *Le Commandant Charcot*. Changes in the composition of phytoplankton can have important implications on the polar food web and functioning of the ecosystem (Ardyna and Arrigo 2020); thus, quantifying phytoplankton communities, and their physiology and growth is important to understand ecosystem function, not to mention the impact phytoplankton have on atmospheric CO_2 via photosynthesis and myriad carbon export processes. The cryosphere is rapidly changing with climate change, and the scientific community needs to understand, at minimum, the drivers for phytoplankton in these regions, as well as the broader ecological and biogeochemical implications of changing PCC, in order to build a predictive understanding of how these fragile environments will change in the coming years. How the light scape under sea ice is currently changing is key to understand and predict under-ice phytoplankton dynamics. Lately, Southern Ocean sea ice has resembled the thinning sea ice of the Arctic, and it is possible the under-ice environment in the Antarctic could support substantial amounts of phytoplankton biomass, given light, stratification and nutrient conditions, although this claim has not yet been tested by *in situ* studies. We recently explored the under ice phytoplankton environment with remote techniques and ecological modeling (Bisson and Cael, 2021; Horvat, Bisson et al., in review; Ardyna et al. 2020a,b, Ardyna and Arrigo, 2020) and seek to explore previously unsampled areas with high sampling resolution of targeted optical and biological parameters. Our primary question is: How does phytoplankton community composition and pigment diversity change with decreasing sea ice thickness and increasing under-ice light, and what are the biological transitions between sea ice environments and the open ocean environment?

Additional research objectives include:

- Assessing local, high quality observations of sea ice characteristics (thickness, snow depth, roughness), critical to validate and develop algorithms for NASA's ICESat-2 satellite.
- Determining the spatial variability in snow and sea ice optical properties and how they related to their physical properties, in order to better model under-ice phytoplankton growth under a changing icescape.

Phytoplankton may act as a positive feedback loop to melt sea ice by absorbing light via photosynthesis, lowering the albedo. Very little (if any) research in this area exists to link phytoplankton activity in meltwater ponds to broader meltwater pond geometry, and our sampling will help fill in this gap and inform future directions.

Collectively, our research will contribute to several outstanding research questions in polar regions:

1. What is the role of leads, snow, melt ponds and sea ice dynamics in shaping under ice light fields and mixed layer depth?
2. To what extent does snow covered sea ice (and other sea ice characteristics) affect phytoplankton biomass and composition?
3. How do phytoplankton in melt ponds influence the under ice optical environment? How does PCC in melt ponds compare to both the under ice communities and open ocean communities?
4. How do phytoplankton-sea ice interactions and their optical signatures compare/contrast between the two poles?

We will characterize phytoplankton community composition, pigment diversity, and biomass through a combination of optical and laboratory techniques. Our Arctic and Antarctic sampling plan involves sampling the water column in ice-covered regions at various degrees of light limitation, under a gradient of sea ice thickness. Compared to the Antarctic, the Arctic has many melt ponds which offer a rich opportunity to sample the phytoplankton community in the melt ponds and in the waters below the melt ponds. We will deploy radiometers and various optical sensors to characterize the optical properties of snow and sea ice, and the light field in the water column and in the melt ponds. Aside from biology, melt ponds influence heat in the Arctic and more information is needed about the absorbing constituents in meltwater.

In both the Arctic and Antarctic, we will complement the discrete water sampling (pending LN2 or a -80 freezer) with in-line sampling using the peristaltic pump aboard that will funnel seawater through several of our optical instruments to characterize optical properties such as particulate backscattering and phytoplankton absorption at all hours of the day. We will also collect discrete water samples from this inline system 2-3 times daily. Discrete samples from the inline and from depth-resolved water column samples will be filtered for later analysis to measure particulate organic carbon (POC), high-performance liquid chromatography (HPLC) phytoplankton pigments, and DNA metabarcoding (targeting the V9 and V4 regions of the 18S gene) to characterize changes in PCC along our transect. We will also measure the snow depth (using a magnaprobe) and density on the sea ice at each location.

Finally, funding for our science will come as an amendment to Bisson's funded ICESat-2 proposal through NASA (we spoke with the program manager and she is very supportive). The participation of Marcel Babin and Mathieu Ardyna will be supported by Canadian funding (NSERC). We will share our data publicly through storage in NASA's SeaBASS database, and we will share code used to process and publish our results, following the principles of open science.

***Bisson, K. M**., & Cael, B. B. (2021). How are under ice phytoplankton related to sea ice in the Southern Ocean?. Geophysical Research Letters, e2021GL095051.*

*Horvat, C., **Bisson, K. M.**, Seabrook, S., Cristi, A., & Matthes, L. (2021). Phytoplankton Blooms Under Antarctic Sea Ice, In Review, Communications Earth & Environment.*

***Ardyna M**., K.R. Arrigo, 2020. Phytoplankton dynamics in a changing Arctic Ocean. Nature Climate Change. doi:10.1038/s41558-020-0905-y.*

***Ardyna M**., C.J. Mundy, N. Mayot, L. Matthes, L. Oziel, C. Horvat, E. Leu, P. Assmy, V. Hill, M. Gale, P. Matrai, I. Melnikov, K.R. Arrigo, 2020. Under-ice phytoplankton blooms: shedding light on the 'invisible' part of Arctic primary production. Frontiers in Marine Science. doi:10.3389/fmars.2020.608032.*

***Ardyna M**., C.J. Mundy, M. Mills, L. Oziel, P.-L. Grondin, L. Lacour, G. Verin, G. van Dikjen, J. Ras, E. Alou, M. Babin, M. Gosselin, J.-É. Tremblay, P. Raimbault, P. Assmy, M. Nicolaus, H. Claustre, K. R. Arrigo, 2020. Environmental drivers of under-ice phytoplankton bloom dynamics in the Arctic Ocean. Elementa: Science of the Anthropocene. doi:10.1525/elementa.430.*