ARCTIC PHYTOPLANKTON: SURVIVING THE WINTER & PREPARING FOR SPRING

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Research overview – WHOI's Arctic Research Initiative supported a project developed by PI Laney (Biology Department) to take advantage of a unique opportunity on the US's first ever 'winter cruise' to the Bering and Chukchi Seas in 2011. Laney used this cruise opportunity to conduct exploratory studies in these high-latitude ocean regions to assess how phytoplankton prepare for the long, dark polar winters. As access to the Arctic in late fall and early winter is very limited, this November-December cruise provided invaluable observations of the late-fall early-winter ecosystem in this polar ocean region.

Phytoplankton living at high latitudes face a basic challenge that their lower latitude counterparts do not, in that high-latitude phytoplankton experience extended periods of no sunlight each year, during winter. Although phytoplankton do not hibernate per se, they do adopt special strategies that allow them to survive the dark winter months and be poised to jumpstart photosynthesis and growth with the onset of light in the spring. Our ecological understanding of how different phytoplankton cope with winter darkness in the Arctic and Antarctic remains very poor. We know little about which species stay suspended in the water column in wintertime, or how the abundances of these survivors vary spatially in polar seas. We also have almost no direct observations of the metabolic state of these overwintering species, and thus no basis for predicting which species, if any, will respond first or fastest to the restoration of daylight when spring arrives.

If current trends in Arctic climate continue, the reduction and thinning of seasonal sea ice will dramatically advance the timing of when under-ice light levels begin to be favorable for phytoplankton growth in the spring. How this will affect the seasonal onset of photosynthesis and primary production in phytoplankton assemblages, as springtime snow and ice cover decrease earlier, remains unclear. A major goal of this research was to collect preliminary, never-before-measured observations of the composition of late-fall phytoplankton assemblages, to begin to develop ways for assessing overwintering strategies of the most important species in these ecosystems.

Research activities – A primary tool used in this research to examine phytoplankton assemblages is an Imaging FlowCytobot (IFCB), specifically modified for use on icebreakers. This automated instrument takes photomicrographs of individual phytoplankton cells in a water sample, which are used to identify each cell or chain of cells taxonomically. From these data it is possible to determine the composition of late-fall/early-winter phytoplankton assemblages in these seas, which until this cruise had not been determined broadly in the Chukchi/Bering areas that were sampled (Fig. 1).

Discrete seawater samples were collected using Niskin bottles during vertical casts, from melted sea ice, from net tows or strained seawater from the ship's continuous supply, and from nutrient- and light-addition grow-out incubations conducted in the ship's walk-in climate chambers. Samples from Niskin bottles were collected at 98 of the 122 stations occupied or attempted during HLY1104, providing a broad survey of the phytoplankton assemblage composition across these ocean regions. For almost all of the discrete samples that were imaged using the IFCB, complementary measurements were also performed on the same seawater samples using a standard flow cytometer (FCM). These FCM analyses provided data about the very small phytoplankton cells that could not be well imaged using the IFCB (cells of size µm or smaller). This standard cytometer was made available to PI Laney through WHOI's Biology Department shared equipment pool. The use of this second cytometer in this study represents one of the first times such measurements have been made at-sea, on fresh (unpreserved) phytoplankton samples.

Spatial survey of the Chukchi and Bering using Imaging FlowCytobot:

The HLY1104 mission represented an opportunity to assess the composition of phytoplankton assemblages across a large portion of the US Arctic waters, including the Bering Sea, at a time of year that has been historically undersampled. Thus a major objective of this research was to determine which species lived where in this region, at this time of year. A second objective was to assess how their morphologies (shapes, sizes, and intracellular structure) differed in late fall and winter compared to the summer season, when PI Laney has collected extensive IFCB data on previous Healy cruises to the region. Preliminary analysis of the assemblage data from the Chukchi Sea indicates a dominance by *Thallasionema spp.*, *Ceratium spp.* , and *Dinophysis spp,* but a wide range of other species were also observed (Fig. 2). Despite almost total absence of natural light, these three species not only were numerically abundant but many cells also exhibited morphologies that suggested they were reasonably healthy and fit, and not chlorotic or senescent as might be expected of dimly-lit cells at the end of the Arctic growing season. Identifying which taxa appear fit compared to those that appear senescent is a major goal of the later post-processing and analysis.

Late fall and winter assemblages in the Bering and Chukchi should be expected to contain considerable numbers of diatom spores and dinoflagellates cysts, which were observed throughout the study region. Spores of *Chaetoceros spp.* were the most readily identified in these samples at this time (Fig 3). The microphotographs that were collected with Imaging FlowCytobot from these natural assemblages represent a significant addition of new cell morphologies to the image libraries that will eventually be used to help automate the classification of phytoplankton cells in the Bering and Chukchi, over broad seasonal scales.

Effort on HLY1104 focused primarily on the collection of these microphotographs. The majority of the effort required to use these images in an ecologically meaningful context required additional image processing and classification, which were done post-cruise.

Incubation experiments to assess the response to light additions:

During HLY1104 phytoplankton incubations ('grow-out' experiments) were also conducted to assess which phytoplankton taxa would respond most favorably to the reintroduction of light at this time of the year. The experiment was designed to mimic as much as possible the conditions that would occur in the region later in spring, when daylengths began to increase again. As the HLY1104 mission occurred in early winter (as opposed to later in the winter, which had been proposed earlier to the National Science Foundation but could not be accommodated in the ship's schedule), the preliminary findings from this experiment are as of yet inconclusive. Clear evidence was observed of certain taxa responding positively to the addition of light (*Cylindrotheca*-like cells, particularly), images of which clearly show cells beginning to divide and reproduce after

15+ days following the reintroduction of light. Physiological measurements of the photosynthetic activity of these cells, made during this cruise in collaboration with Dr. Dean Stockwell (University of Alaska Fairbanks), also indicated that fluorescence quantum yields were higher in the light-treated cells compared to their dark controls.

Research impact – This 'winter cruise' on USCGC Healy in 2011 has had major impact on US Arctic ocean science and WHOI's profile in Arctic research. The cruise itself was led by WHOI Senior Scientist Dr. Carin Ashian (Biology Department) and it included several WHOI researchers supported in part by the WHOI Arctic Research Initiative. Laney's unique phytoplankton assemblage data from this time of year have generated interest in the Arctic oceanographic community, with results presented at several national and international meetings including the 20212 Alaska Marine Science Symposium. A manuscript is in preparation for publication in a peer-reviewed journal. Further analyses of these unique data are ongoing, and Laney is working with HLY1104 Chief Scientist Ashjian to lay the groundwork for a follow-up 'true-winter' cruise to the region to better understand transitional dynamics in this ecosystem at a time of year that is still not yet well observed.

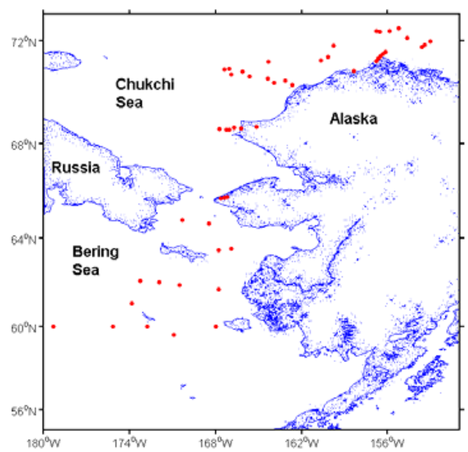

Fig. 1. Left: Sampling map of stations occupied during USCGC Healy cruise HLY1104, November-December 2011. Right: Ship's camera view in Seward Alaska, dockside in November during daytime, loading for this cruise.

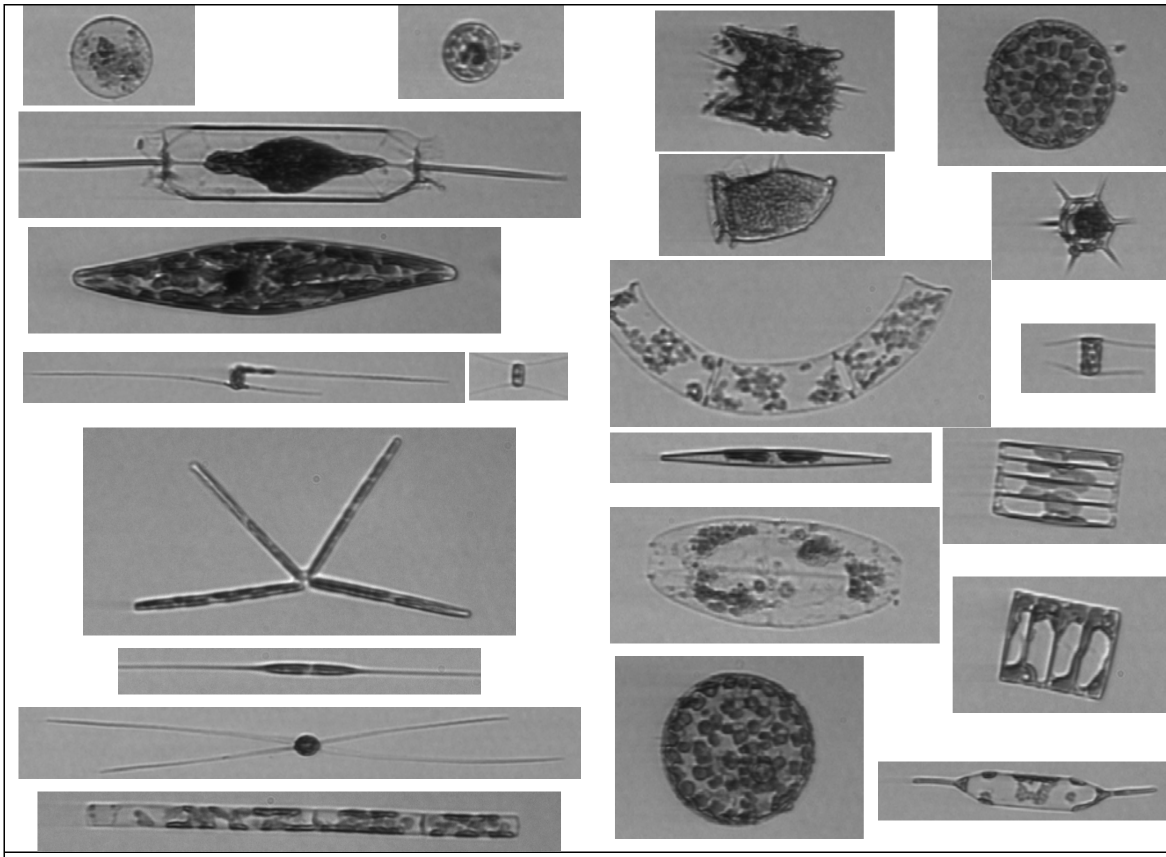

Fig. 2. Images of representative phytoplankton cells observed in the Chukchi and Bering on HLY1104. Certain cells appear healthy and photosynthetically capable (dark), despite extremely low light conditions.

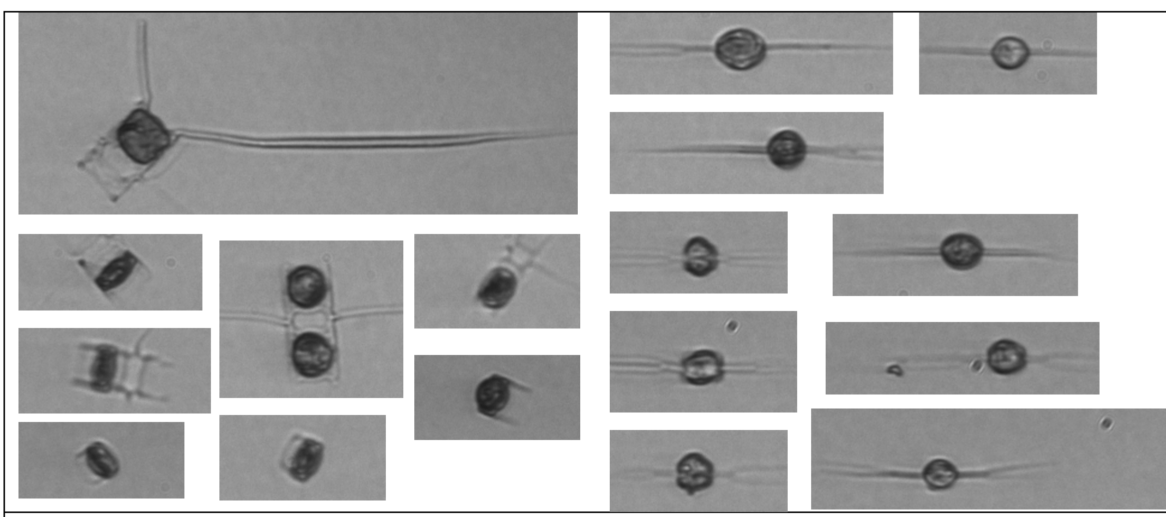

Fig. 3. Images of individual spores of the phytoplankton genus *Chaetoceros*, taken in the late fall and early winter in the Chukchi Sea (left half of panel) and the Bering Sea (right half). *Chaetoceros* forms spores as an overwintering strategy, and spores for *Chaetoceros* are easier to identify to the species level than this species is in its summertime vegetative state, for most species of *Chaetoceros*.