Phytoplankton communities in a changing Arctic Ocean: Biogeography, phenology and productivity

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Mathieu Ardyna dedicated his PhD (UMI Takuvik, Canada) to assessing the response of phytoplankton communities to ongoing environmental changes in the Arctic Ocean, using both historical database and remotely-sensed observations. He recently received a European post-doc fellowship (remOcean) at LOV (UPMC-CNRS, France) where he will address a similar problematic in the Southern Ocean.

The Arctic Ocean is undergoing unprecedented change with respect to its sea ice cover. Between 1979 and 2010, a downward trend in September ice extent of –12.8% per decade was observed in addition to drastic changes in thickness, concentration and duration of the sea-ice cover (Arrigo et al., 2011). Consequently, the phytoplankton growing season has increased by about 20 days over the last 30 years, whereas that of sea-ice algae has decreased. Concomitantly, other observations show an enhanced upper ocean stratification driven by increases in river discharge/melting waters to the Arctic Ocean, for instance, in the Beaufort Gyre. This process tends to reduce vertical mixing and thus decreases the input of nutrients for phytoplankton growth from the deep pool to the sunlit surface layer (Li et al., 2009). The key and vigorously debated question about possible changes in primary production and marine ecosystems in the Arctic Ocean is whether the decrease in summer sea ice, which increases light availability and lengthens the growing season, is also conducive to enhanced vertical mixing and thereby only to additional primary production.

Nevertheless, before making any predictions, a better understanding of the biogeography and ecology of the Arctic Ocean is clearly needed. To partially fill this knowledge gap, Ardyna et al. (2013) published a global and regional portrayal of the productivity of the Arctic Ocean based on a novel compilation of more than 5000 stations. The large range of primary production values (PP; 40 to 150 g C m⁻² y⁻¹) observed across the Arctic Ocean was related to local vertical mixing regimes. Briefly, when the vertical stratification is strong enough to dampen nutrient renewal in surface waters, PP will be generally low and dominated by small and flagellates cells (Li et al., 2009). In such oligotrophic conditions, phytoplankton communities are located deeper in the water column, following the depth of increasing nutrient availability (i.e., the nitracline in polar waters). These features, namely subsurface chl-a maxima (SCM), are prevalent and productive features during the post-bloom/summer period in highly stratified Arctic regions (i.e., 3D representation of SCMs in the Beaufort Sea during the Malina expedition; figure 1a & b, Ardyna et al., 2015). For satellite-derived PP studies conducted in the Arctic Ocean, the occurrence of SCMs remains challenging and generates significant underestimations of PP due to a lack of detection from surface satellite measurements (figure 1c; Ardyna et al., 2015).
In Ardyna et al. (2013), an empirical model predicting the vertical chl-a distribution from the surface chl-a was also developed to (1) take into account the lack of homogeneous chl-a profiles and (2) define phytoplankton phenotype (i.e., study of annual and recurrent biological events, such as the springfall blooms or SCMs features) for new operational satellite-derived applications. For example, an unexpected consequence of Arctic ice loss was revealed: regions are now experiencing a second phytoplankton bloom in the fall, which coincides with delayed freeze up and increased exposure of the sea surface to wind stress (figure 2, Ardyna et al. 2014). This implies that wind-driven vertical mixing during fall is significant enough to promote further PP. The Arctic Ocean is undergoing a fundamental shift from a polar to a temperate mode, which is likely to alter the structure and functioning of marine ecosystem.

The Arctic Ocean is undeniably experiencing drastic changes in its atmospheric and oceanic compartments, affecting clearly both marine and terrestrial ecosystems. Faced with these challenges, new collaborative and international initiatives/partnerships are essential, such as the recent launch of the French Arctic Initiative (http://www.chantier-arctique.fr/).

References


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Figure 2: Current shifts in Arctic phytoplankton phenology above the Arctic Circle (>66.58°N). (a) Histogram of different types of annual cycles for three periods. (b) Map adapted from the World Wildlife Fund showing per cent change in double bloom occurrence between two periods (1998–2001 versus 2007–2012) for each Arctic region: 1-Chukchi Sea, 2-East Siberian Sea, 3-Canadian Basin, 4-Eurasian Basin, 5-Laptev Sea, 6-Kara Sea, 7-North and East Barents Sea, 8-northern Norway and Finnmark, 9-Norwegian Sea, 10-Fram Strait, 11-East Greenland Shelf, 12-North Greenland, 13-West Greenland Shelf, 14-Baffin Bay, 15-Canadian Shelf, 16-Lancaster Sound, 17-Arctic Archipelago, 18-Amundsen Gulf, 19-Beaufort Sea (Ardyna et al., 2014).