Structure and Dynamics of Deep Chlorophyll Maxima in the Canadian Arctic

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Abstract

In ice-free Arctic waters, plant biomass typically concentrates within deep chlorophyll maxima (DCM) that constitute a major source of energy for the food web. Processes responsible for DCM generation and maintenance are poorly understood. Yet they may hold the key to quantify and predict the effects of climate change on marine productivity within ArcticNet IRISes. This poster introduces the first dedicated study of the nutritive and photosynthetic ecology of DCM in relation to environmental parameters.

1. Introduction and hypotheses

Microalgal photosynthesis sustains marine food webs and promotes air-sea fluxes of the greenhouse gas CO_2. In the Canadian Arctic, sea ice and snow constrain the timing of the productive period, whereas the supply of nitrate sets the maximum yield of organic matter production. Nitrate replenishment at the surface is severely limited by the halocline and the damping effect of ice on wind mixing and upwelling. When the ice clears, shade-adapted algae are exposed simultaneously to low nitrate and to high irradiances that potentially damage their photosystems. In this context the algae should grow best at an intermediate position between the surface and the deep nutrient-rich layer, relying on the modest upward supply of nitrate. This scenario is consistent with the nearly ubiquitous presence of deep chlorophyll maxima (DCM). Alternately, DCM are maintained by the transient accumulation of passively-sinking algae above the halocline. This project will test at least two hypotheses:

H1: The photosynthetic performance of phytoplankton is highest at the DCM

If DCM represent the best compromise between irradiance and nitrate supply for the algae then their photosynthetic performance and instantaneous growth rates should be highest there. Otherwise DCM are more likely maintained by the transient, accumulation of passively-sinking algae.

H2: Nitrate is the main form of inorganic nitrogen consumed by phytoplankton at the DCM

If DCM are maintained by nutrient supply from below then nitrate should be the main form of inorganic nitrogen taken up (new production). Otherwise the algae thrive primarily on locally-recycled ammonium and their production is mostly regenerated and independent of external nitrogen supply.

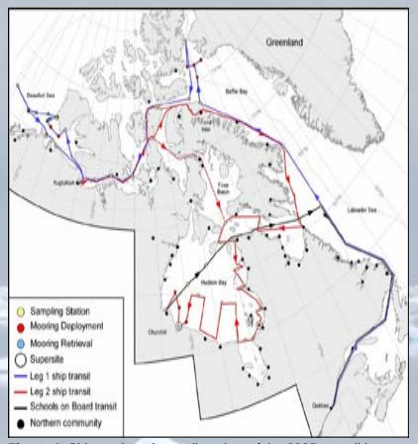

Figure 1- Ship track and sampling sites of the 2005 expedition

Figure 2- The *Rosette*

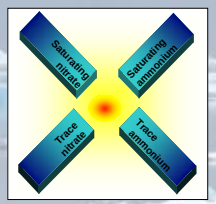

Figure 3- Light-gradient incubator

3. Preliminary results

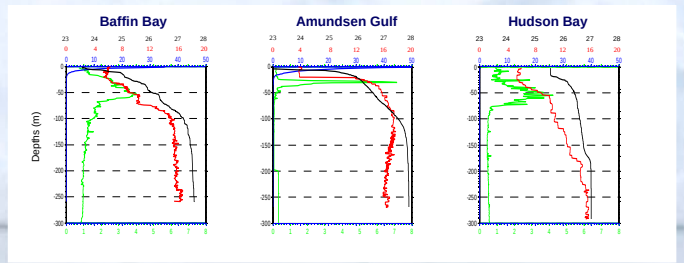

Figure 4- Vertical profiles of algal fluorescence (green), light (blue), nitrate (red) and density (black). Values are relative, pending final calibration. The strength, breadth and depth of DCM varied between regions. DCM were close to the nitracline, but weakly related to the density stratification. This preliminary result suggests that growth *in situ* is more important than passive accumulation for the maintenance of DCM.

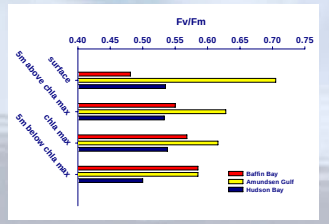

Figure 5- Vertical profiles of photosynthetic competence. In the Gulf, Fv/Fm was very high and maximum at surface, suggesting a healthy, actively growing community. The vertical trend was reversed in Baffin Bay, suggesting optimal growth at depth. No trend was detected in the Hudson Bay profile.

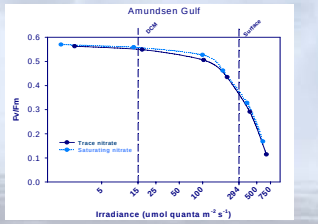

Figure 6- Changes in Fv/Fm after a light-gradient incubation of DCM algae from the Gulf with trace and saturating additions of nitrate. Algae were severely impaired by irradiances exceeding the daily DCM maximum. This effect was not suppressed by nitrate enrichment.

2. Methods

During the 2005 expedition of the *CCGS Amundsen* (Fig. 1), vertical profiles were obtained with a *Rosette* (Fig. 2) equipped with sensors to measure fluorescence, nitrate, temperature, salinity and irradiance. Water samples were taken with Niskin bottles and analyzed for chlorophyll-a (fluorometry) and nutrients (AutoAnalyzer 3 and fluorometry). Photosynthetic competence (maximum photochemical quantum yield of photosystem II = Fv/Fm) of the algae was estimated by Pulse-Amplitude-Modulated fluorometry. Photosynthesis and the uptake of nitrate and ammonium were estimated simultaneously with dual ^{13}C-^{15}N labelling in a light-gradient incubator (Fig. 3), with and without nitrogen enrichment. Post-incubation measurements of Fv/Fm were done to assess changes in photosynthetic and nutritive status.

4. Summary and future work

The profiles in Figures 4 and 5 imply that the processes generating and maintaining DCM are diverse. For the Gulf, the vertical profile and experimental response of Fv/Fm suggest distinct algal communities, each adjusted to its vertical position. More analyses are needed to tease apart the effects of taxonomy and nutritive/photosynthetic status on DCM:

All fluorescence profiles will be analyzed objectively and compared with irradiance, taxonomic composition, Fv/Fm and the position and strength of the nitracline and halocline.

The ^{13}C and ^{15}N enrichment of incubated samples will be determined by mass spectrometry and the rates of photosynthesis and nitrogen uptake calculated. The contribution of each nitrogen source to uptake will be used to estimate the extent of new *vs.* regenerated production.

To compare the nutritional and photochemical status of DCM algae between treatments and stations, parameters of the photosynthesis-irradiance and nitrogen uptake-irradiance curves will be established.

Acknowledgements

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