Effect of sea ice melting processes on phytoplankton physiology in the northern Chukchi Sea

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Abstract

- Goal: 1) To understand the physiological state of phytoplankton according to the retreat of sea ice
  2) To observe nutritional stress (nitrate) for phytoplankton growth

We investigated phytoplankton physiology in the northern Chukchi Sea in the late summer of 2015 and 2016 during icebreaker R/V Araon cruises. The amount of sea ice was greater in the late summer of 2016 than in 2015. Due to difference in sea ice extent, the thickness of the surface low-salinity layer was larger in 2015 than in 2016. The influence of fresh water content enhanced the stratification in the upper ocean. The stratification index calculated by the density profile was larger in 2015 than in 2016. Previous studies reported that the thickness of freshwater layer may also affect the depth of nitracline, which was closely related to depth of sub-surface chlorophyll maximum (SCM), because nitrate is usually the main limiting nutrient in the Arctic Ocean. As a result, depths of nitracline in 2015 were 39.1 m and 53.6 m, which were deeper than the depths of 30.11 m and 45.10 m in 2016. There was a statistically significant correlation between freshwater content and the depth of nitracline (r=0.78, p<0.01, n=26). In physiological parameters of phytoplankton, the quantum efficiency of photochemistry in PSII (Fv/Fm = 0.43±0.09) in MLD was about 20% lower than that (0.55±0.03) in SCM, because of nitrate depletion in the surface layer. The functional absorption cross section of PSII (εpsii) in SCM depth were higher than those in MLD, indicating that the phytoplankton improved its light-harvesting capability of the photosynthetic pigments under low light condition in depth of SCM.

Methods

- Field survey (Icebreaker R/V Araon): Period: 2015. 08. 02. ~ 20. / 2016. 08. 06. ~ 19.
- Sea ice concentration & retreat time: Data (25x25km) from NSIDC (http://www.nsidc.org)
- Less than 15% sea ice conc. – Retreat time
- Phytoplankton physiology & P-E measurements:
  - Mini-FIRE (Miniaturized Fluorescence Induction & Relaxation system)
  - Samples were kept in dim light for 30 min, before being estimated.
- Nutrients enrichment experiment:
  - Samples were collected between about 10 and 20 m.
- Triplicate treatments and 2 ~ 3 days incubation on deck
- Nutrients enrichment in three conditions
  - Control
  - + Nitrate [5 µM]
  - + All nutrients [Na, Si, NO3, P (µM), Fe (10µM)]

Sea ice retreat time

- Early sea ice retreat time by region
  1. A region in 2016
  2. B & C regions in 2015

Hypothesis: sea ice melting process for comparison between 2015 and 2016

- Although more freshwater caused by earlier sea ice retreat enhanced stratification, it was not related to photosynthetic efficiency. On the contrary, temperature had good relationship with photosynthetic efficiency.
- Like previous studies, this study confirmed that freshwater affected the SCM depth. The photosynthetic efficiency was high and the light harvesting capacity was improved as the SCM was deepened.
- In both years, Nitrate was depleted in the northern Chukchi Sea. Therefore, low photosynthetic efficiency was shown in the upper layer.
- Through the photosynthetic parameter from P-E curves, phytoplankton was generally adapted to very low light (E0 < 100).

Test 1: More freshwater induced by early sea ice retreat can make ...

1-1) Strengthen stratification ? Yes!
1-2) Deepening nitracline depth ? Yes!
1-3) Deepening euphotic depth ? Yes!

Sea ice retreat time by region

- Differences in sea ice retreat time
  - Early sea ice retreat time by region
    1. A region in 2016
    2. B & C regions in 2015

Hypothesis: sea ice melting process for comparison between 2015 and 2016

- We established a hypothesis in terms of light and nutrient
- Next, the hypothesis was verified in these tests

Conclusion

- Although more freshwater caused by earlier sea ice retreat enhanced stratification, it was not related to photosynthetic efficiency. On the contrary, temperature had good relationship with photosynthetic efficiency.
- Like previous studies, this study confirmed that freshwater affected the SCM depth. The photosynthetic efficiency was high and the light harvesting capacity was improved as the SCM was deepened.
- In both years, Nitrate was depleted in the northern Chukchi Sea. Therefore, low photosynthetic efficiency was shown in the upper layer.
- Through the photosynthetic parameter from P-E curves, phytoplankton was generally adapted to very low light (E0 < 100).

Freshwater input promotes water column stratification, which affects nutrient fluxes to the euphotic zone and hence phytoplankton physiology. One analysis revealed that Arctic ecosystem are severely nitrogen limited in late summer.