Sedimentary pigments as biomarkers of spatial and seasonal variations in the Beaufort Sea benthic-pelagic coupling

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ABSTRACT

The Arctic Ocean is characterized by broad continental shelves (51% of its surface area), which have high rates of primary productivity. In some areas, much of this production falls to the bottom, supplying food for rich and active communities of benthic organisms. Benthic-pelagic coupling over much of the Arctic shelves is thought to be particularly tight. In ice-covered areas, ice algae can be the main source of carbon for the food web, and thus for the benthos. It is now generally accepted that global warming effects are expected to be enhanced in the Arctic. Modification in the ice cover could lead to a drastic shift of the productivity regime (phytoplankton vs. ice algae), and thus to an entire restructuring of the food web. It is, therefore, important to characterize pathways of organic matter from the water column to the benthos as a function of the ice presence or absence.

Sedimentary pigments have demonstrated their usefulness in short-term and long-term studies of ecosystem changes, such as changes in organic matter production, pathways to the bottom, and cyanobacterial blooms, as well as larger scale sea level and hydrodynamic changes. In order to characterize variation in ecosystem functioning in the Arctic, organic matter inputs and benthic processes is studied in the oligotrophic Beaufort Sea, showing that benthic-pelagic coupling is particularly tight in the continental shelf and slope, while in the polynya area, most of processes occur in the water column.

INTRODUCTION

Primary production on the Arctic shelves can be particularly high. In some areas, a higher percentage of biological production sinks and reaches the sea floor where it is cycled by the benthos. In areas where benthic production is not sufficient, benthic community structure and function are tightly linked to production in overlying pelagic zone and vertical flux. Moreover ice algae may be a significant carbon source for these benthic systems.

The response from benthic communities to deposition of phytodetritus can be very rapid. Part of the organic matter input is stored in the biomass, another part is respired, and another is buried. A high percentage of fixed carbon is buried in Arctic shelf sediments.

How does the variation in productivity influence the organic matter patterns inputs to the benthos? How do benthic processes respond to these variations of inputs?

MATERIALS AND METHODS

Study area

The oligotrophic Beaufort Sea was studied in fall 2003 and summer 2004 during the CASES program. The studied area includes the Cape Bathurst Polynya (1), Mackenzie River delta (2), the continental shelf (3) and slope (4) (Figu

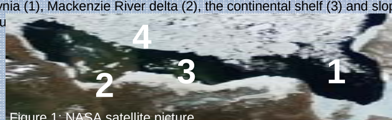

Figure 1: NASA satellite picture

Ice algae and phytoplankton chlorophyll *a*

Water was collected at the chlorophyll maximum depth. Ice samples were melted in filtered sea water. These were then filtered and filters were extracted in acetone for ice algae and phytoplankton pigments analysis by HPLC.

Sediment sampling for sedimentary pigments and benthic respiration

Sediment cores were collected from a boxcore. Top 2 cm of sediment were extracted in acetone for pigment analysis by fluororometer. Chlorophyll *a* is used as a marker of fresh organic matter while phaeopigments represent degradation products. Larger cores were incubated for benthic oxygen demand.

SPATIAL PIGMENT CONCENTRATION AND BENTHIC OXYGEN DEMAND DURING FALL 2003 AND SUMMER 2004

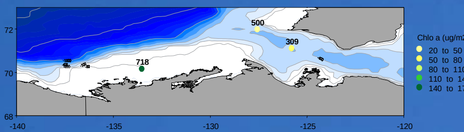

Figure 2: Fall 03, chlorophyll *a* concentration in the ice

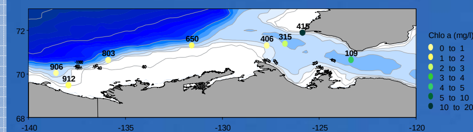

Figure 3: Summer 04, chlorophyll *a* concentration in POM

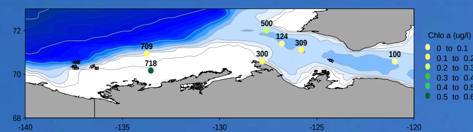

Figure 4: Fall 03, chlorophyll *a* concentration in POM

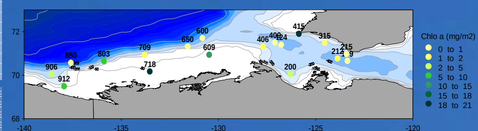

Figure 5: Summer 04, chlorophyll *a* concentration in sediment (0-2 cm)

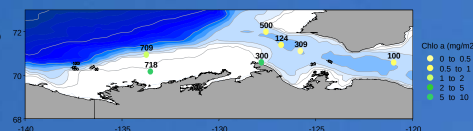

Figure 6: Fall 03, chlorophyll *a* concentration in sediment (0-2 cm)

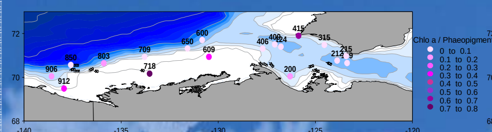

Figure 7: Summer 04, ratio chlorophyll/phaeopigments in sediment (0-2 cm)

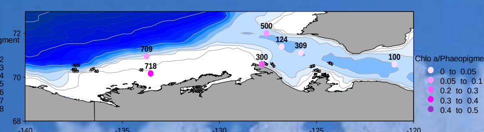

Figure 8: Fall 03, ratio chlorophyll/phaeopigments in sediment (0-2 cm)

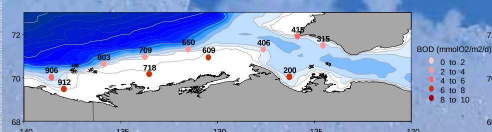

Figure 9: Summer 04, benthic oxygen demand

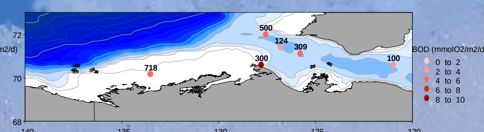

Figure 10: fall 03, benthic oxygen demand

Sedimentary pigments

Sedimentary chlorophyll *a* (chla) is a marker of fresh organic matter input to the benthos. It varies spatially and temporally (Figure 7 and 8). In both summer and fall, it correlates positively with depth (Figure 11c and 11d). In both cases, sedimentary chla is minimal in the polynya area, while it is more important in the continental shelf and near the Mackenzie River delta.

The ratio chla/phaeopigments indicates the state of the organic matter. A small ratio indicates a very degraded material. In both summer and fall, the organic matter in the polynya is highly degraded, while the ratio is higher in the continental shelf and slope.

Water column and ice algae production

Phytoplankton production is much higher in the summer (Figure 3) than in the fall (Figure 4). During the summer, stations in the polynya show higher chla concentrations while in the fall, higher chla concentrations are found on the continental shelf. Ice is nearly absent in the summer, while in the fall, chla content in the ice can be important (Figure 2).

Sedimentary pigments are not always directly correlated to water column production (Figure 11a and 11b), especially in the polynya, where this high summer production is not coupled with a high chlorophyll content in the sediment. However in the fall, ice area where ice algae production is important tend to present a higher chlorophyll content.

Benthic processes

Benthic oxygen demand vary spatially and temporally (Figure 9 and 10). It is at a maximum on continental shelves, and directly correlates to the chla concentration (Figure 11e and 11f).

CORRELATION BETWEEN SEDIMENTARY PIGMENTS AND DEPTH, BOD, AND POM

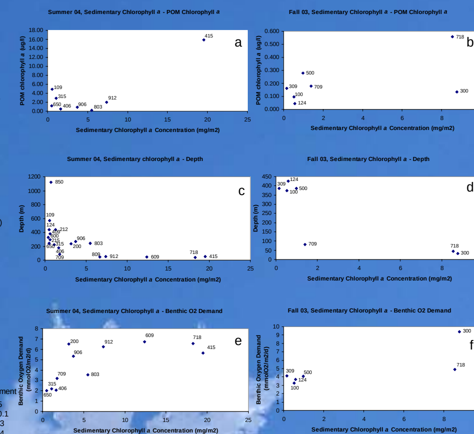

Figure 11: Correlation between sedimentary chlorophyll a and POM during summer 2004 (a) and fall 2003 (b). Correlation between sedimentary chlorophyll a and depth during summer 2004 (c) and fall 2003 (d). Correlation between sedimentary chlorophyll a and benthic oxygen demand suring summer 2004 (e) and fall 03 (f)

CONCLUSION

Organic matter inputs to the benthos

Phytoplankton production is higher in the summer than in the fall, and thus higher sedimentary chla concentrations are also found during the summer in the continental shelf and slope. However, this is not the case in the polynya.

In the fall, stations where ice algae production is high also have higher sedimentary chla content. Ice algae production can locally be responsible for input of organic matter to the benthos.

Benthic response

Benthic oxygen demand also increases during the summer, especially on the continental shelf and slope.

The benthic-pelagic coupling is particularly tight on the continental shelf, while in the polynya, most of processes seem to occur in the water column.

FUTURE WORK

HPLC allows the separation of various chlorophylls and carotenoids, which are typical of the species they are coming from, or the processes they went through. Combined with other sedimentary biomarkers, the study of the various sedimentary pigments by HPLC will allow a better determination of the Arctic ecosystem and the processes occurring on the shelves, slopes, and polynya.