RAPID RESPONSE OF THE BENTHIC COMMUNITY TO AN ICE ALGAL BLOOM IN THE BEAUFORT SEA, CANADIAN ARCTIC

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ABSTRACT

Understanding pathways of carbon cycling on Arctic shelves is critical if we are to evaluate the potential effects of climate change on these systems. We investigated the relationship between ice algal standing stock and benthic respiration between January and July 2004 at a time series station in the southeastern Beaufort Sea. Ice algal chlorophyll *a* increased dramatically between April and May, and was mirrored by >10-fold increase in benthic oxygen demand. While some of that increase can be attributed to bacteria and meiofauna, most was due to the activities of macro-infauna. We also observed a trend toward lower pigment content of the sediments during the pulse in benthic carbon remineralization. This suggests that at least some of the enhancement in oxygen demand was due to increased oxygen availability in the sediment due to bioturbation by epifaunal brittle stars. Carbon cycling patterns on Arctic shelves are dependent upon the interaction between temporal patterns in primary production and biomass and activity of resident epifaunal and infaunal communities.

INTRODUCTION

The Arctic is already experiencing drastic changes due to global warming: increased of air and water temperature and reduction in ice cover. It is predicted that these changes will accelerate over the next 50-100 years, but how they will be manifested is unclear.

The Arctic Ocean contains broad continental shelves (35% of the Arctic Ocean area). While Arctic continental-shelf ecosystems depend upon phytoplankton production, an unexplored carbon source is the strong pulse of phytodetritus provided by production of ice algae (Gosselin et al. 1997). Due to logistical difficulties, most studies on ice algae have been limited to late spring through early fall, but early season production of ice algae can represent a significant fraction of carbon flux to the benthos (Ambrose and Renaud 1997). Moreover, a large fraction of sedimenting carbon is buried in Arctic shelves.

Benthic-pelagic coupling is particularly tight in Arctic shelves, and the benthos plays an important role in the carbon cycle of these areas. This study represents the first effort to quantify the response of benthic communities to blooms of ice algae over an entire spring (from January to July 2004), at a station of 231m depth in the Beaufort Sea (Figure 1).

RESEARCH QUESTION

- **What are the seasonal dynamics of the ice algal community?**
- **How are these dynamics reflected un sediment biochemical parameters?**
- **What is the impact of the ice algal seasonality on benthic community respiration?**

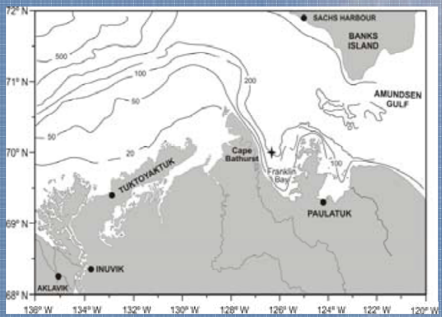

Figure 1. Map of the southern Beaufort Sea. The large star in the Franklin Bay identifies the study site for the time-series measurements.

MATERIALS AND METHODS

Ice algae measurements

Concentrations of chlorophyll *a* in the bottom 4 cm of ice cores were determined fluorometrically.

Sediment sampling and benthic respiration

From December 2003 through June 2004, the Canadian Coast Guard icebreaker *Amundsen* was frozen into the shore-fast ice in Franklin Bay.

Sediment was sampled on five dates between 14 January and 7 May 2004 and again on 4 July 2004.

Sub-samples (Figure 2) were taken for
- total benthic respiration (incubation; Figure 3)
- bacterial respiration (also called "minivials")
- sedimentary pigments
- organic carbon and nitrogen

Figure 2. Picture of the sub sampling cores in the box corer

Figure 3. Picture of the incubation in the cold room

RESULTS

Ice algae measurements

Chlorophyll a biomass was low from February through early March, due to limited light availability. From early April until mid-May, biomass of chlorophyll *a* increased dramatically (Figure 4a).

Benthic respiration

Sediment-community oxygen demand varied by more than one order of magnitude (Figure 4b): 1.75 vs. 21.0 mmol $O_2 m^{-2} d^{-1}$ between 10 February and 6 April. Respiration rates during 6 and 27 April were significantly higher than during other periods.

Bacterial respiration increased by only a factor of two during this time (Figure 4b).

Sediment parameters

Phytopigment (chlorophyll *a* and phaeopigments) concentrations in the top 9 cm of sediment at the overwintering station showed an opposite trend to that in the ice algae and respiration data (Figure 4c).

Organic carbon and nitrogen from the top 2 cm of sediment did not vary among sampling dates.

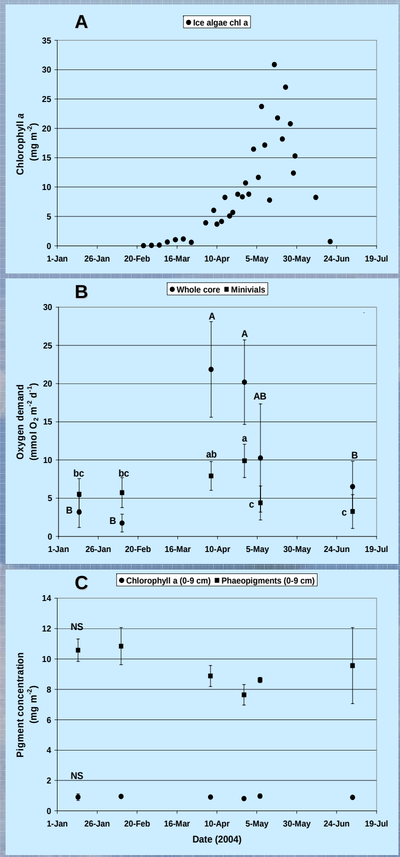

Figure 4. Time-series measurements of (a) chlorophyll a concentration within the sea ice, (b) sediment oxygen demand from whole-core (circles) and minivial (squares) incubations, and (c) concentration of sediment chlorophyll a (circles) and phaeopigments (squares). When analysis of variance indicated significant date effects ($p < 0.05$), letters appear beside or above symbols. Symbols marked with the same letter are not significantly different by Tukey's HSD test. NS indicates that the measurements did not vary significantly among dates. In (b), upper case letters refer to results of statistical tests for whole-core incubations; lower case letters reflect results from minivial incubations. All error bars represent ±1 standard deviation.

DISCUSSION

Rapid response

A sharp increase in benthic oxygen demand coincided with the onset of an ice algal bloom at our time-series station in the southeastern Beaufort Sea (Figure 4a, b). Upon release, the ice algae sink rapidly to the benthos, largely bypassing the ice and pelagic trophic systems (Michel et al. 1997; Leventer 2003). With high sinking rates and limited losses to grazing, ice algae has been proposed to be an important, high quality food source for benthic communities, especially early in the season before pelagic production increases (Ambrose and Renaud 1997; Carroll and Carroll 2004).

Importance of the macro vs. micro fauna

The enhanced community respiration was due primarily to macro-infauna and not to micro- and meio-fauna. Minivial incubations did indicate a doubling of respiration rates between February and late April, but that increase is modest compared with the 10-fold increase in rates for the entire community (Figure 4b).

Direct and indirect effect of ice algae

Ice algae is an important food source for the benthos, but the strong trend toward a significant decrease (Figure 4c) suggests that mechanisms responsible for the observed patterns may be direct, indirect or both.

Infaunal respiration, therefore, may have been stimulated directly by sedimenting ice algae, and fauna consumed all the ice algal material that was deposited *plus* pigmented matter from the sediment inventory.

Epifaunal invertebrates, primarily echinoderms (e.g. sea stars, brittle stars, sea cucumbers, sand dollars), are abundant and important components of Arctic shelf communities, including in the Beaufort Sea (Figure 5). Ophiuroids consume ice algae, and therefore may have had an indirect effect on the infaunal community via their feeding activity by increasing bioturbation and so oxygen consumption.

Figure 5. Bottom photography of the Beaufort Sea: ophiuroid density ranged from dozens to over 100 individuals m^2 at this site

Infaunal bioturbators enhance oxygen exchange in sediments by a factor of 1.5–3 (Glud et al. 2000), and it is likely that large densities of epifauna would have a similar effect. We propose, therefore, that any direct enhancement of sediment-community oxygen demand due to deposition of ice algae would have been augmented by the increased feeding and burrowing activities by epifaunal ophiuroids scavenging for the newly deposited phytodetritus.

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