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Patchiness of sympagic algae and meiofauna from the fast ice of North Open Water (NOW) Polynya

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ABSTRACT: During the spring of 1998 sympagic algae and meiofauna were studied in Ross Bay on the western coast of the Kane Basin between Ellesmere Island and Pim Island (Canada). Ice samples were collected by ice coring and the lowermost 2 cm sections were analysed. The sea-ice flora was composed of 59 taxa and was dominated by *Nitzschia frigida*, *Navicula pelagica*, *Fragilariopsis oceanica* and unidentified flagellates (over 60% of total number). Abundance of algae ranged from 1×10^9 to 3×10^9 cells per square meter. Sea-ice meiofauna was composed of Nematoda and Harpacticoida and was strongly dominated by nematodes (99.76%). Total sympagic meiofauna abundance ranged from 37.5×10^3 to 146.1×10^3 ind. and biomass from 2.88 to 8.83 mg C per m^2. There was no clearly marked patchiness in the horizontal distribution of sympagic algae and meiofauna.

Key words: Arctic polynya, sea-ice, algae, meiofauna.

Introduction

The sea-ice cover of the Arctic Ocean serves as a habitat for a diverse community and plays a significant role in the biology and ecology of polar marine systems (Horner 1974). Sea-ice decreases light transmission and is a limiting factor in the development of algae in the water column (Horner 1985a). It absorbs and reflects up to 99.9% of incoming PAR when covered with heavy snow cover, as it was measured in Antarctica (Palmisano *et al*. 1986), and about 80% when the ice is snow-free (Maykut and Grenfell 1975, Sakshaug and Slagstad 1992). However, sea-ice supports a productive community of microalgae (Smith *et al*. 1988, Gosselin *et al*. 1997) as well as a diversity of heterotrophs ranging from bacteria (Bunch and Harland 1990, Laurion *et al*. 1995) and protozoa (Sime-Ngando *et al.* 1997, Gradinger and Ikävalko 1998) to metazoans (Gulliksen and Lønne 1991, Friedrich 1997). The bio-

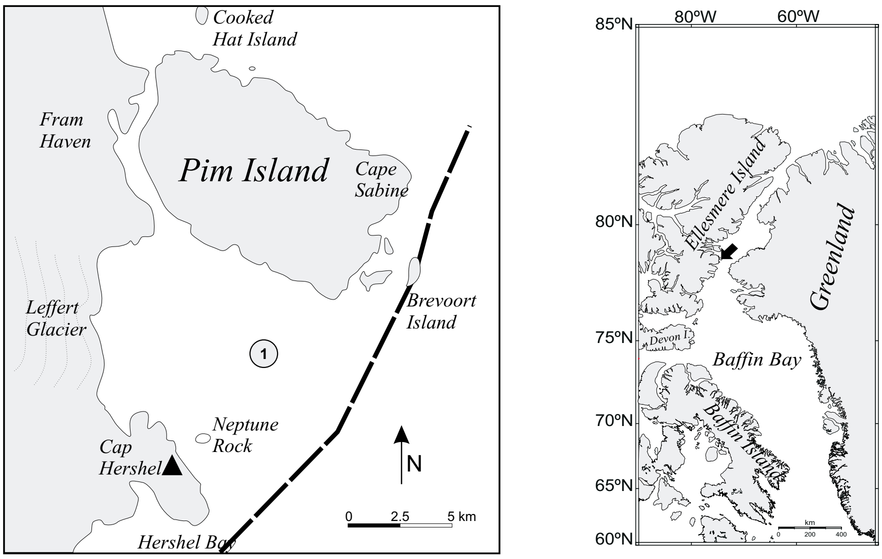

Fig. 1. Sampling site position (1 – sampling locality).

mass of the ice-attached algae often reaches high values; 1.93–7.0 mg chl *a* m^{-3} (Gradinger *et al*. 1991), up to 20–307 mg chl *a* m^{-3} (Nozais *et al*. 2001) with annual production rates ranging from 0.15 to 23 g C m^{-2} (Hegseth 1988). Sympagic algae may provide from 5 to 20% of total Arctic primary production (Longhurst *et al*. 1989).

The transformation of inorganic carbon to organic form supports both ice-associated and pelagic biota with "fresh" energy during the spring and sometimes early summer. In relatively shallow coastal zones during the melting period, „marine snow" of sinking cells, supports the benthic community (Wiktor 1999). The knowledge of sympagic fauna biomass, its distribution and rate of development is important for the understanding of the functioning of the ice-covered seas. The bottom part of sea-ice is not uniform, and the thickness and the surface of ice sheets is not even. These factors influence the ice transparency and changes the light regime below. Snow coverage, often driven by wind, plays an important role as well. (Gosselin *et al.* 1986). The heterogeneity in the physical characteristics of sea-ice creates non-uniform distributions of ice algae over small spatial scales which makes estimations of biomass and productivity of ice-covered regions difficult.

The aim of this study was to present the level of sympagic algae and meiofauna patchiness under an even, fast ice cover.

Material and methods

The study site was located in the area covered by fast ice of the Ross Bay on the western coast of the Kane Basin between Ellesmere Island and Pim Island (Fig. 1).

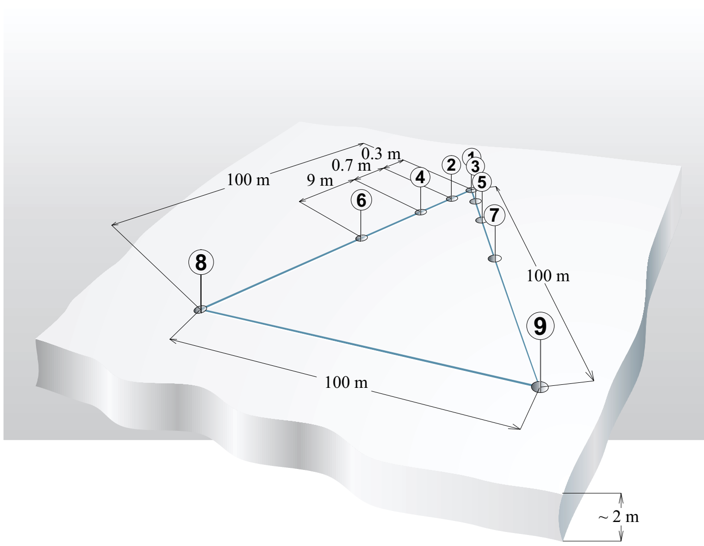

Fig. 2. Distribution of the sampling points.

Ice-algae and sympagic meiofauna samplings were carried out on 22 April and on 6 May 1998 respectively.

At each time nine ice cores were collected along a track in the shape of a triangle, which was 100 m long on each side (Fig. 2). Cores were taken with the use of a SIPRE ice corer – which was 7.6 cm in diameter. The lower 2 cm of ice was cut off and melted in 0.5 dm^3 of filtered sea-water at 0–4°C. Samples were preserved with Lugol's solution, and after 24 hours formaldehyde was added in a final concentration of 1%. Meiofauna was preserved in 4% formaldehyde.

After the expedition, subsamples of 2 ml volume for algae identification and abundance were analysed under an inverted microscope according to Utermöhl (1958). Large taxa were counted under magnification of 100x while small specimens under 400 x. At least 500 individuals were counted in each sample. In the laboratory each sample of meiofauna, after staining in Rose Bengal, was passed through the set of sieves (1000, 500, 200, 100 and 50 μm). Sea-ice meiofauna were sorted from all screenings (excluding 1000 μm) and identified to major taxa under a stereomicroscope. Biomass of the sympagic meiofauna was estimated by size measurements of fixed animals using computer-image analysis. The length and width of organisms (10% of the number in case of Nematoda and all Harpacticoida specimens) were taken for further conversion into biomass using conversion factors corresponding to each taxonomic group (Feller and Warwick 1988).

Simmilarity (Bray-Curtis) of cores was calculated by means of PRIMER v. 5 package (Primer-E; Plymouth). Fourth root transformation was done according to Clarke and Gorley (2001) recommendations.

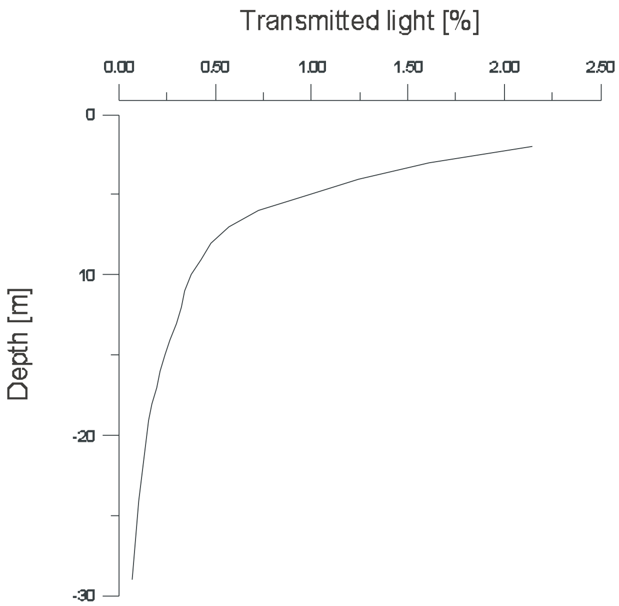

Fig. 3. Attenuation (%) of the incoming radiation (PAR) by 2 m thick ice at the sampling site.

Physical environment

Due to its geographic position (78°35'00''N 74°37'46''W) the Ross Bay shows strictly High Arctic features with ~110 day of darkness, and ice cover lasting 6 months from November to June–July. Polar Day, when algal growth explode, begins on the 18th of April when the sun starts to be visible above the horizon all day. Temperatures steeply increase from ~ –20°C at the beginning, to around 0°C at the end of June. The ice sheet was 2 m thick and due to low precipitation and strong winds was sparsely covered by snow. The sea-ice was relatively transparent, transmitting approximately 4% of incoming radiation (PAR) (Fig. 3.). This is a relatively high value in comparison with the 1% of snow covered fast ice of Svalbard fjords (Wiktor 1999) and 0.3–14% transmission in 1.6 m sea-ice covered by 30 cm of snow (Rysgaard *et al*. 2001).

Results and discussion

Ice algae. — During the study 59 taxa of ice algae were found, with a mean density of 30 million cells per square meter. The most abundant, exceeding 60% of total abundance, were *Nitzschia frigida* Grunow, *Navicula pelagica* Cleve, unidentified flagellates size range of 3 μm, 3–7 μm, 10 μm, and *Fragilariopsis oceanica* (Cleve) Hasle with a mean density over 1 million cells under m^2. Among all taxa the most frequently occurring (>80%) were ice-associated *Pinnularia quadratarea* (Schmidt)

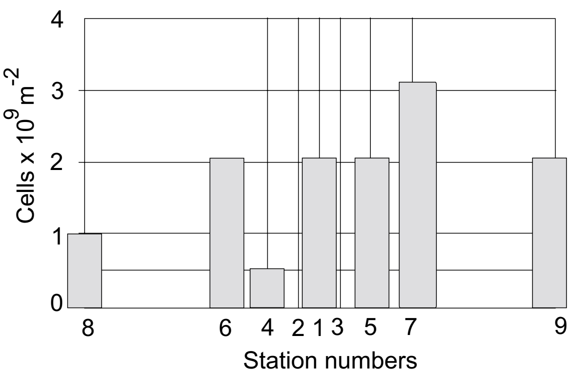

Fig. 4. Abundance of ice algae in particular cores.

Cleve, *Nitzschia polaris* Grunow in Cleve et Möller, *N. promare* Medlin, *Navicula transitans* Cleve, *Euglena* sp., *Attheya septentrionalis* (Østrup) Crawford, *Entomoneis paludosa* (Grunow) Poulin et Cardinal, *Synedropsis arctica* (Grunow) Hasle, Medlin et Syvertsen, *Pleurosigma stuxbergii* Cleve et Grunow, *Navicula pelagica*, *Fragilariopsis oceanica* and unidentified flagellates 3 µm (Table 1). Total values of abundance varied from 1000×10^6 up to 3000×10^6 cells under square meter (Fig. 4) with a coefficient of variation (CV%) over 35%. Abundances of algae were of the same order of magnitude in all cores, and differences were not related to the distance between particular cores. Cluster analysis showed the similarity of species composition and abundances of ice algae associations in all taken cores (Fig. 5).

Species composition was typical of sympagic flora reported for Arctic first-year ice (Hsiao 1980, 1983; Horner 1985b, Syvertsen 1991, Lee *et al.* 2001), as well as in the water column of ice-associated waters (Hegseth 1992, Quillfeldt 2000, own observation). Numbers of algal cells were in the lower range of reported values (4000 – ~20000 cells $\times10^6$ m^{-2} (Sime-Ngando *et. al.* 1997) for the High Canadian Arctic. The lower values may be explained by fact that sampling took place at the beginning of spring season while data from the scientific literature report values from the middle of April to late May.

Meiofauna. — The sea-ice meiofauna of the Ross Bay polynya was composed of Nematoda and Harpacticoda only (Table 2). It was quite different from other Arctic regions where more meiofauna major taxa like Turbellaria, Rotatoria and Copepoda (nauplii) have been reported (Kern and Carey 1983, Friedrich and Gradinger 1994, Gradinger 1999). Nematoda strongly dominated the meiofauna community of the Ross Bay polynya averaging to 99.76% of abundance and 94.06% of biomass of sympagic meiofauna. In contrast to these results in other investigations of Arctic Ocean sea-ice, the dominance of Nematoda was not so pronounced. In the shallow southwestern Beaufort Sea, nematodes comprised about 77% in abundance (Carey 1992). In northern Baffin Bay, Nematoda accounted for 98.5%, but, when present, copepods and nauplii contributed up to 100% of total

Table 1

Abundance and number of taxa of the ice algae in analysed samples.

Core No.	Abundance [cells 10^6 m^{-2}]	Number of taxa	Share of taxa [%]
1	2000	22	36.07
2	3000	33	54.10
4	1000	24	39.34
6	2000	25	40.98
8	1000	19	31.15
7	3000	31	50.82
5	2000	24	39.34
9	2000	30	49.15
mean	2000	26	
SD	700	4.48	
CV	35.94	18.62	
total number of taxa	59		

Table 2

Composition, abundance, and biomass of sympagic meiofauna major taxa in particular ice cores.

Station	Taxon	Abundance [ind. m^{-2}]	Biomass [mg C m^{-2}]	Percentage [%]	
				abundance	biomass
1	Nematoda	37450	2.88	100.0	100.0
2	Nematoda	73630	4.14	99.48	88.33
	Harpacticoida	380	0.55	0.52	11.67
3	Nematoda	52990	3.01	100.0	100.0
4	Nematoda	99620	5.69	100.0	100.0
5	Nematoda	86370	3.88	99.71	92.25
	Harpacticoida	250	0.33	0.29	7.25
6	Nematoda	61270	4.58	99.59	93.45
	Harpacticoida	250	0.32	0.41	6.55
7	Nematoda	145860	8.53	99.83	96.22
	Harpacticoida	250	0.30	0.17	3.38
8	Nematoda	80130	5.95	100.0	100.0
9	Nematoda	85480	4.67	99.26	75.86
	Harpacticoida	640	1.49	0.72	42.14

meiofauna abundance (Nozais *et al*. 2001). On the other hand Turbellaria (62%) were the numerically dominating organism group in the ice located between Greenland and Svalbard in the western part of the Fram Strait (Gradinger *et al*. 1991).

In this study total abundance of sympagic meiofauna ranged from 37.5×10^3 to 146.1×10^3 ind. and biomass from 2.88 to 8.83 mg C per m^2, with mean values

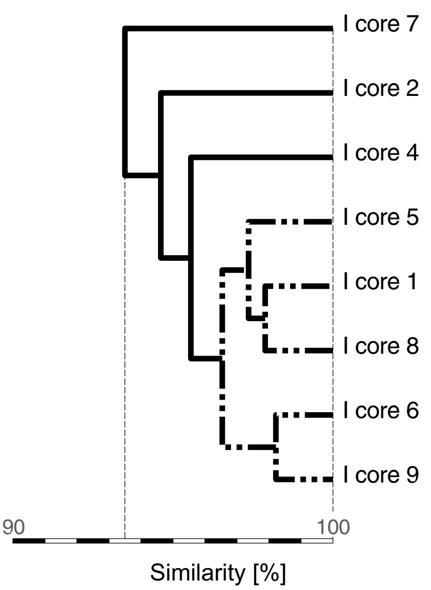

Fig. 5. Similarity between particular sympagic algae samples.

80.51×10³ ind. m⁻² and 5.15 mg C, respectively (Table 2, Fig. 6). There were no distinct differences in the horizontal distribution of sympagic meiofauna. The coefficient of variation (CV%) for abundances was 39 and for biomass about 32. Average abundance and biomass of the sea-ice meiofauna observed in western Ross Bay were generally low but comparable to those available from various parts of the Arctic Ocean. Gradinger (1999) assumed that the integrated abundance of Arctic sea meiofauna ranged from 1.3×10^3 to 221.3×10^3 organisms and from 0.1 to 7.4 mg C m^{-2} (average 3.0) of ice. In northern Baffin Bay Nozais *et al.* (2001) reported 34.5×10^3 ind. and 19.4 mg C per m^2 maximally. The sympagic meiofauna of the Greenland Sea pack ice contained on average 31.7×10^3 ind. m^{-2} (Gradinger *et al.* 1999). In the shallow southwestern Beaufort Sea total meiofauna densities varied between 4.51×10^3 and 48.2×10^3 specimens per m^2 (Carey 1992). Friedrich (1997) noted on average in the Greenland Sea 118.5×10^3 ind. m^{-2} with 5.6 mg C m^{-2}, in the Laptiev Sea 14.3×10^3 ind. m^{-2} with 0.6 mg C m^{-2} and in the Barents Sea 6.8×10^3 ind. m^{-2} with 0.5 mg C m^{-2}.

The discrepancy between the results obtained by various authors can be explained not only by diverse environmental conditions (seasons, locations) but partly by differences in the sampling procedures and methodologies. Apart from metazoans some authors included Ciliata in sea-ice meiofauna investigations, which can greatly increase the number of specimens. There is no consistency regarding the lowest mesh size as well.

Nevertheless, average sea-ice meiofauna number of taxa, abundance, and biomass were much lower than in benthic habitats of the Arctic Sea. For example in

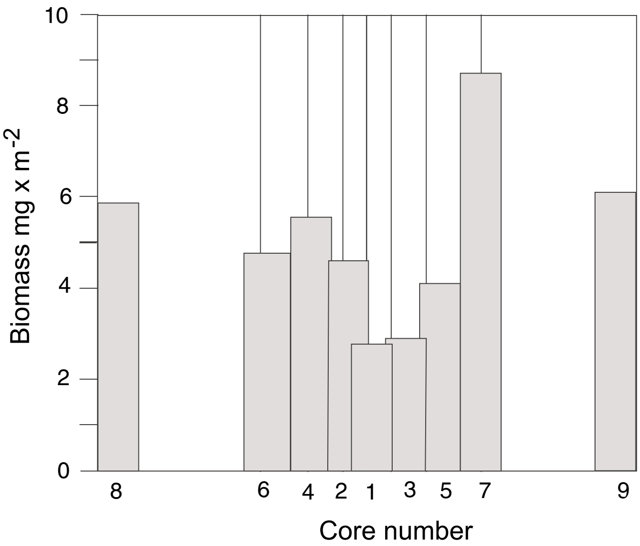

Fig. 6. Biomass distribution of ice meiofauna in particular cores.

the Laptiev Sea meiobenthic total densities (12 taxa) decreased with depths from 2683×10^3 to 418×10^3 ind. m^{-2} (Vanaverbeke *et al*. 1997). The abundance and biomass of meiobenthos obtained for the South Spitsbergen intertidal zone showed mean abundance higher than 900×10^3 ind. m^{-2} with biomass 136 mg C m^{-2} (Szymelfenig *et al*. 1995). In the intertidal and shallow sublittoral of Bjornøya these values ranged from 0 to 169×10^3 ind. m^{-2} and up to 164 mg C m^{-2} in abundance and biomass respectively (Węsławski *et al*. 1997).

Conclusion

Patchiness of distribution of sympagic algae and meiofauna over small scales is low and can be omitted to comparisons of large areas.

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