NOTE

Picocyanobacteria in the high Arctic

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ABSTRACT. The occurrence of picocyanobacteria was studied in May 1988 in the ice-covered East Greenland Current at 80° N. Within the upper 200 m of the water column the number of picocyanobacteria decreased from the warm Atlantic Intermediate Water (AIW) to the cold Polar Water (PW), where they were practically absent. It is suggested that picocyanobacteria can serve as indicator organisms for the advection of warm water masses into polar regions.

Coccolid Synechococcus-type cyanobacteria are considered to be an important compartment of the marine picoplankton (Johnson & Sieburth 1979, Waterbury et al. 1979). Many investigations have shown the numerical dominance of cyanobacteria over eucaryotic picoplankton in different sea areas (for review see Stockner & Antia 1986). Murphy & Haugen (1985) studied the abundance of cyanobacteria in the North Atlantic. The number of picocyanobacteria decreased with increasing latitude, i.e. with decreasing temperature. Marchant et al. (1987) investigated the occurrence of chroococcoid cyanobacteria in surface waters along a section between Australia and Antarctica during 2 cruises in austral summer. They found an exponential correlation between cell number and water temperature. Caron et al. (1985) made the same observation for the seasonal abundance of picocyanobacteria in surface waters of Lake Ontario.

Our study was carried out in the northwestern part of the Greenland Sea, within the ice-covered East Greenland Current. In this region, the water column is formed by 2 different water masses: cold, low-salinity Polar Water (PW) from the surface down to about 100 m depth and the warmer Atlantic Intermediate Water (AIW) below (Coachman & Aagard 1974). The main goal of our study was to ascertain whether cyanobacteria can be used as biological tracers for warm water masses in the Arctic or if they are evenly distributed in all water masses.

The investigation was carried out in May 1988 on board RV 'Polarstern'. The ice-breaker was moored to an ice floe and drifted for 3 wk in the pack ice in an area 80° 12' to 80° 52' N and 0° 20' W to 5° 24' E. At 14 stations temperature and salinity profiles were obtained by means of a CTD system by 'Meerestechnik' (Trappenkamp) in the upper 200 m water column and water samples collected from 6 different depths with a 6 x 30 l HydroBios rossette sampler. Samples of 250 ml were fixed with borax-buffered formalin (giving a final concentration of 0.4 % formaldehyde) and subsamples of 20 to 80 ml filtered onto 0.2 µm irgalab black stained Nuclepore filters, using a 0.45 µm back-up filter. Cyanobacteria were counted with a Zeiss epi-fluorescence microscope under blue light excitation (filter set 467 709). A yellowish fluorescence enabled their identification.

In Fig. 1 vertical temperature and salinity profiles for the upper 200 m of the water column are shown for a

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Temperature and salinity data of all water samples examined are plotted on a T/S-diagram (Fig. 2). The cores of the 2 characteristic water masses can be clearly distinguished: the warm AIW with a temperature range from 1.3 to 2.0 °C and with salinities between 34.8 and 34.95 × 10^-3, and the cold PW with temperatures below -1.5 °C and a salinity range between 34.1 and 34.7 × 10^-3 as a result of freezing and melting processes.

Coccoid Synechococcus-type cyanobacteria were the only cyanobacteria found in the investigation area. They measured ca 1.5 μm and the cells exhibited the yellowish fluorescence typical of phycoerythrin-rich oceanic picocyanobacteria (Waterbury et al. 1979, Caron et al. 1985). In Fig. 3 their abundance is plotted in relation to the corresponding temperature and salinity distribution. In all samples, cyanobacterial abundance was extremely low (< 23 cells ml^-1). The lowest concentration detectable by the filtering and counting procedure used was 1 cell ml^-1. Highest numbers were observed in AIW and lowest in PW (Table 1). In 35 of 42 PW-samples, no cyanobacteria were found at all, while they were always present in the AIW. The mixed water masses were characterized by a corresponding decrease in abundance.

Table 1. Abundance of cyanobacteria (cells ml^-1) in different water masses within the East Greenland Current. (n: number of samples; p: presence [%]; r: range of abundance; \( \bar{X} \): average abundance; SD: standard deviation of the mean abundance; PW: Polar Water; MW: mixed Polar and Atlantic Intermediate Water; AIW: Atlantic Intermediate Water

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PW</th>
<th>MW</th>
<th>AIW</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>42</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>p</td>
<td>16.6</td>
<td>90.0</td>
<td>100.0</td>
</tr>
<tr>
<td>r</td>
<td>0-7</td>
<td>0-12</td>
<td>5-22</td>
</tr>
<tr>
<td>( \bar{X} )</td>
<td>0.4</td>
<td>6.2</td>
<td>12.9</td>
</tr>
<tr>
<td>SD</td>
<td>1.3</td>
<td>4.1</td>
<td>5.9</td>
</tr>
</tbody>
</table>

In temperate and tropical seas, coccoid cyanobacteria are the most abundant autotrophic picoplankters (e.g. Glover et al. 1985, Jochem 1988), although the recent discovery by Chisholm et al. (1988) of a novel free-living prochlorophyte of even smaller size within the oceanic euphotic zone may change this view.

Murphy & Haugen (1985) and Marchant et al. (1987) found a decrease in abundance of picocyanobacteria with increasing latitude corresponding to the decrease

Fig. 3. Abundance of cyanobacteria (cells ml^-1) in relation to temperature (°C) and salinity.
in sea surface temperature. This also holds true for the 
East Greenland Current area. The abundance of 
cyanobacteria was extremely low and eucaryotic phy-
toplankters constituted the main fraction in the pic-
oplankton size class in all samples analyzed (Gradinger 
unpubl.). The cell numbers of the latter were generally 
in the range $10^2$ to $10^3$ m$^{-1}$ with decreasing abundance 
below 40 to 75 m, just the opposite of the vertical 
distribution of the cyanobacteria with peaks in the 
warmer AIW overlayed by the cold PW. It thus seems 
reasonable to exclude potential losses by grazing as the 
determining factor for the observed distribution pat-
tern.

The lack of cyanobacteria in most of the PW samples 
indicates that they are not an autochthonous element of 
the polar plankton community in the Greenland Sea. 
Their increase in numbers from PW to AIW implies that 
they are advected by currents from the warmer waters 
of the North Atlantic and that they thus can be used as 
biological tracers of these water masses.

Coccoid cyanobacteria are apparently capable of 
surviving adverse conditions for long periods. Silver et 
al. (1986) found live cells down to a depth of 2000 m in 
the southern North Pacific. The abundance observed in 
the deep sea, however, was as low as in the cold Polar 
Water, amounting to only a few cells per ml.

Future studies both in the Arctic and Antarctic will 
be necessary to test the validity of our observations. 
Physiological investigations on isolated cyanobacteria 
from polar seas should test the ability of these organ-
isms to survive or even to grow under the unique and 
 extreme environmental conditions of high latitude 
ecosystems. Were such studies to support the 
 hypothesis that coccoid picocyanobacteria can serve as 
tracers of warm water masses, their occurrence could 
be used as a sensitive technique in studying the origin 
of water masses in polar regions, where salinity and 
temperature, the traditionally used parameters in water 
mass identification, are being continually altered by 
freezing and melting processes and by frontal dyn-

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