Vol. 52: 99–101, 1989 | MARINE ECOLOGY PROGRESS SERIES Mar. Ecol. Prog. Ser. | Published February 16

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.

Coccoid *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 × 30 l HydroBios rosette 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 irgalan-black stained Nuclepore filters, using a 0.45 µm backup filter. Cyanobacteria were counted with a Zeiss epifluorescence microscope under blue light excitation (filter set 487 709). 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

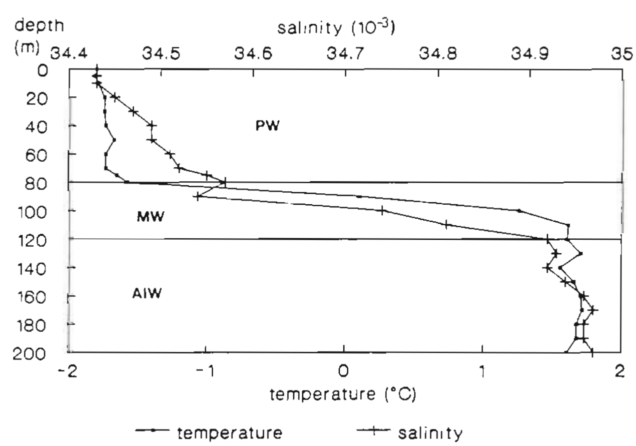

Fig. 1. Temperature and salinity profiles for a typical station within the East Greenland Current with Polar Water (PW) at the top, mixed Polar and Atlantic Intermediate Water (MW) in between and Atlantic Intermediate Water (AIW) below

typical station within the East Greenland Current. The upper 80 m was occupied by very cold and low-salinity PW. In the water layer between 80 and 120 m PW is mixed with AIW and below 120 m only AIW is encountered.

0171-8630/89/0052/0099/$ 03.00

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

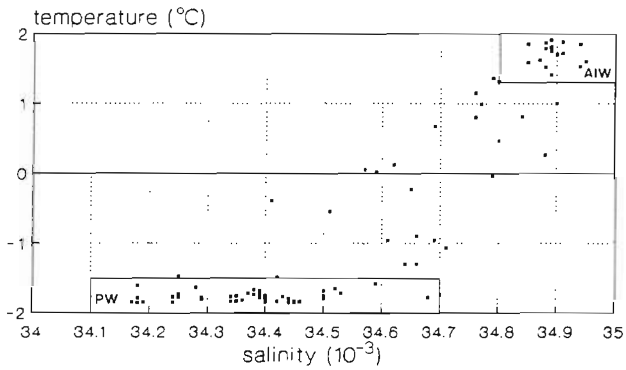

Fig. 2. T/S-diagram of all samples analysed with the cores of 2 water masses, Polar Water (PW) and Atlantic Intermediate Water (AIW)

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

Parameter	Water mass PW	MW	AIW
n	42	20	18
p	16.6	90.0	100.0
r	0–7	0–12	5–22
$\bar{x}$	0.4	6.2	12.9
SD	1.3	4.1	5.9

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

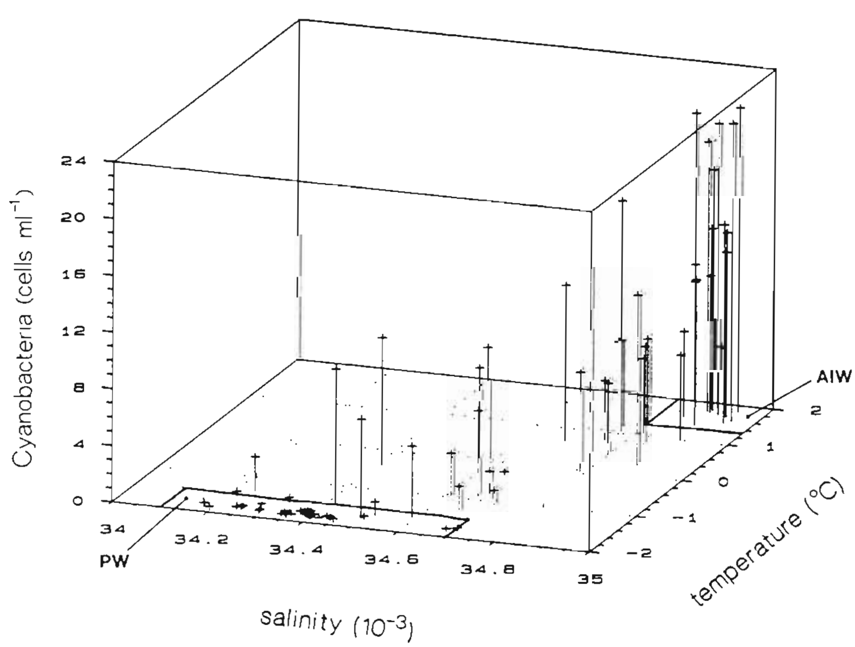

Fig. 3. Abundance of cyanobacteria (cells ml^{-1}) in relation to temperature (°C) and salinity

in sea surface temperature. This also holds true for the East Greenland Current area. The abundance of cyanobacteria was extremely low and eucaryotic phytoplankters constituted the main fraction in the picoplankton size class in all samples analyzed (Gradinger unpubl.). The cell numbers of the latter were generally in the range 10^2 to 10^3 ml^{-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 pattern.

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 organisms 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 dynamics.

This note was submitted to the editor

Acknowledgements. We are indebted to the crew of RV 'Polarstern' and the staff of the Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, for their extensive assistence. Helpful comments and additional information from 2 anonymous referees are gratefully acknowledged. The work was supported by the Deutsche Forschungsgemeinschaft (Le 232/15).

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Manuscript received: October 14, 1988
Revised version accepted: December 9, 1988