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## **Seasonal variation in bacterial activity in the near-bottom water layer of Kiel Bight (Western Baltic Sea)**

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### **Abstract**

The near-bottom water layer is influenced by events in the sediment and by sedimentation from the productive surface layer. Microbial activity in this layer shows occasionally strong gradients from the pycnocline down to the sediment and it reacts to seasonal variations in oxygen content in the adjacent to the sediment. Comparison of mean values of bacterial stock and activity parameters in the productive surface layer and in the near-bottom layer shows, that despite of similar patterns of bacterial biomass and bacterial production in both layers, uptake velocity of leucine, peptidase activity, as well as turnover rates of leucine and hydrolysis rates of peptides are considerably lower in the near-bottom water layer. This is explained by effects of temperature, nutrient quality and oxygen depletion.

### **Introduction**

In coastal areas not much scientific interest has focussed on bacterial activity in the near-bottom water. Bacterial populations in this part of the water column were thought to be too small to be of major importance in the turnover of organic material. However, in Kiel Bight, a relatively shallow part of the Baltic Sea, large inputs of organic material occur during spring and fall via rapid sedimentation of phytoplankton blooms and resuspension of organic compounds from the sediments. These processes could provide enough food for a considerable near-bottom bacterial community. Another interesting feature of this water layer are strong seasonal variations in the oxygen content, usually leading to anoxic conditions in deeper parts of the Kiel Bight area during late summer. The present study investigated activity, production and standing stock of bacteria in the near-bottom water in comparison to the upper part of the water column.

### **Materials and methods**

An investigation of bacterial activity was performed in the Kiel Bight channel system at Boknis Eck (28 m depth) (Fig. 1) from August 88 to April 90. In bi-weekly or monthly intervals water samples were taken above, in, and below the pycnocline as close as 20 cm to the sediment. For samples from below the pyc-

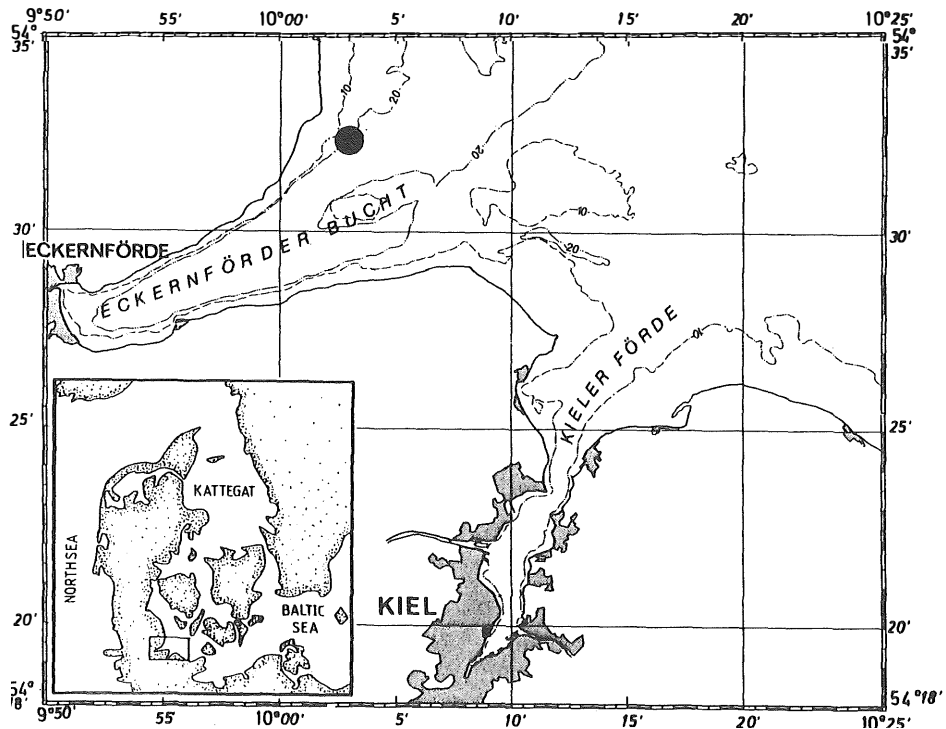


Fig. 1. Location of the study site Boknis Eck (28 m) in the Kiel Bight channel system.

nocline a special bottom-water sampler was used. The water layer below the pycnocline (around 20 m depth) was defined as near-bottom water.

Bacteriological measurements included enumeration of bacteria and cell size determination by acridine orange (AO) staining and epifluorescence microscopy (HOBBIE et al. 1977, ZIMMERMANN 1977) using a New Porton G12 grid (Graticules Ltd. U.K.). Bacterial production was determined by measuring the incorporation of  $^3\text{H}$ -Thymidine according to FUHRMAN and AZAM (1982) with a final concentration of 10 nM. Heterotrophic uptake of  $^3\text{H}$  labelled leucine was measured as described by GOCKE (1977). The determination of extracellular enzyme activity of peptidases by means of the fluorogenic model substrate leucine-methylcoumarinylamide (Leu-MCA) followed the procedures of HOPPE (1983). The hydrolysis rate ( $H_R$ ) of peptides was calculated from the hydrolysis of a very low Leu-MCA addition (0.1  $\mu\text{M}$ ) by the natural bacterial population. Then the parameter  $H_R$  corresponds to the turnover rate of monomers ( $T_R$ ) as it is determined by uptake studies. Samples collected on Whatman GF/F filters were used for measurement of particulate organic carbon with a CHN-analyser (Heraeus, CHN-O-rapid).

## Results and discussion

Seasonal bacterial activity varied as much in the near-bottom water layer as in the surface layer. During most of the year, near-bottom activity was low compared to the upper part of the water column. Special events, e.g. rapid sedimentation of phytoplankton blooms in spring and fall or the development of anoxic conditions in fall resulted in significant changes.

Above the pycnocline activities and production of bacteria showed immediate reaction to the carbon input by phytoplankton in spring. Bacteria standing stock at first reacted by increases in cell volume and later in bacterial numbers. The near-bottom community (Fig. 2a, b) responded in the same manner but with a lag time of a few days as sedimentation of the bloom progressed.

The more drastic increase in the hydrolysis rate of Leu-MCA ( $H_R$ ) than in the turnover rate of leucine ( $T_R$ ) resulted in low  $T_R/H_R$  ratios during the bloom (March/April). The quotient  $T_R/H_R$  can be interpreted as an indirect measurement of the pool size ratio between polymers and monomers (HOPPE et al. 1988) and describes the hydrolysis-uptake coupling in bacterial utilisation of dissolved protein.  $T_R/H_R$  ratios of  $\approx 1$  imply that usage and pool sizes of both monomers and polymers were almost equal. In late spring a high  $T_R/H_R$  ratio reflected the instantaneous uptake of monomers by a growing bacterial population and the existence of a large pool of decomposable material. Consequently  $T_R/H_R$  ratios decreased towards fall.

During a period of microaerobic conditions in the near-bottom water layer high nitrate and ammonia values (not shown) indicated possibly the development of an autotrophic bacterial population. Furthermore, this coincided with high heterotrophic activities and a significant increase in biomass due to changes in cell volume (Fig. 2c, d). These findings agree well with observations made by GAST and GOCKE (1988) and RHEINHEIMER et al. (1989) studying processes at the permanent chemocline in the Gotland-Basin (Central Baltic). FENCHEL et al. (1990) found that high bacterial activity and biomass in the oxycline were reflected by a biomass maximum of both ciliates and heterotrophic flagellates.

In October 89 oxygen was depleted in the near-bottom water and high amounts of phosphate and ammonia (data not shown) were released from the sediment.  $H_2S$  was detected in the lowest sample. Again relatively high values were measured in the microaerobic layer overlying the  $H_2S$  zone (Fig. 2e, f). While  $H_R$  seemed not to be affected by  $H_2S$  there was a sharp decrease in  $T_R$ . The uncoupling of uptake and hydrolysis at the presence of  $H_2S$  (HOPPE et al. 1990) might lead to a temporary accumulation of monomers in occasionally anoxic waters which can stimulate uptake and growth after reoxygenation of the water. This effect might also help to explain the observed high values of activity and biomass in microaerobic water: Diffusion of monomers together with end products of anaerobic metabolism could provide additional food for the microaerobic bacterial population. In addition SEKI et al. (1984) reported low transport constants of microaerophilic microorganisms.

Fig. 2. Vertical profiles of POC and bacteriological measurements during spring bloom (03.04.89) (a, b), microaerobic conditions below the pycnocline (22.08.89) (c, d) and anoxic conditions in the deepest sample (20.10.89) (e, f). POC: particulate organic carbon,  $T_R$ : turnover rate of  $^3H$ -leucine,  $H_R$ : hydrolysis rate of Leu-MCA (peptide model substrate),  $V_{max}$ : max. uptake velocity of leucine,  $H_{max}$ : max. hydrolysis of Leu-MCA.

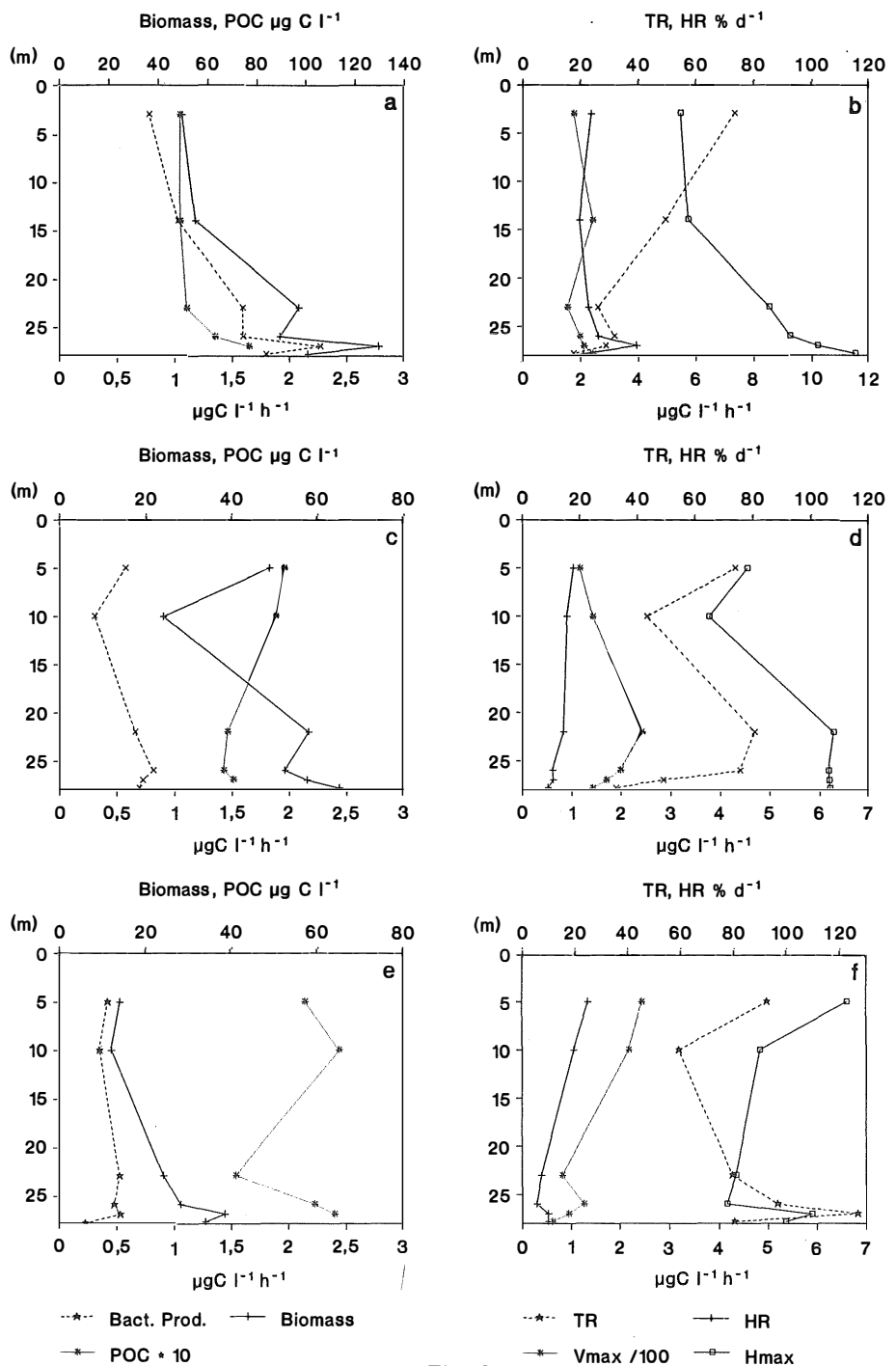


Fig. 2

Table 1. Mean values of bacteriological data for the whole investigation period (station Boknis Eck, 28 m) above (A) and below the pycnocline (B). Prod: bact. production, TBN: total bacterial number, TBB: total bacterial biomass, Vmax: max. uptake velocity of  $^3\text{H}$ -leucine, Hmax: max. hydrolysis of Leu-MCA,  $T_R$ ,  $H_R$ : turnover and hydrolysis rate respectively.

	Prod $\mu\text{gC l}^{-1}\text{h}^{-1}$	TBN $10^6\text{ml}^{-1}$	TBB $\mu\text{gC l}^{-1}$	Vmax $\text{ngC l}^{-1}\text{h}^{-1}$	Hmax $\mu\text{gC l}^{-1}\text{h}^{-1}$	$T_R$ $\%d^{-1}$	$H_R$ $\%d^{-1}$	$T_R/H_R$
A	0.13	1.69	24.66	13.55	4.61	48.35	14.76	3.87
B	0.13	1.60	25.12	8.62	2.69	27.87	8.06	5.09

Mean values of bacteriological measurements for the whole investigation period showed no difference between the upper part of the water column and the near-bottom water (Table 1) except for activities. Equally high production and biomass but different levels of activities imply different limiting factors for bacterial populations above and below the pycnocline: The former seemed to be limited by substrate and nutrients whereas the latter for temperature and changes in the oxygen conditions may play an important role. Although near-bottom bacteria show lesser activity they might be able to work closer to maximum potential uptake velocity. The high  $T_R/H_R$  ratio in the lower part of the water column implies a larger pool of decomposable material than in the surface layer. The results suggest that in shallow coastal areas - particularly those with oxygen deficiency - bacterial production and biomass should be measured throughout the water column, especially when budgeting carbon flows of the system in question.

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