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MICROPHYTOBENTHOS — A PART OF THE ECOSYSTEM OF HAAPSALU BAY, THE BALTIC SEA

Abstract. The structure of the microphytobenthos community and its spatial and seasonal variations were investigated in Haapsalu Bay, Estonia. The number of the taxa of microalgae found was 239, about 80% of them are diatoms. The Shannon diversity index (H') and the evenness index (I') were calculated from diatom assemblages. They both are high and stable throughout the period investigated ($\bar{H}'=4.3$, $\bar{I}'=0.82$). The number of microphytobenthic algae varied from 0.1 to $8.0 \cdot 10^6$ cells/10 cm², the biomass from 0.1 to 23.6 mg/10 cm², the concentration of chl *a* from 64 to 715 µg/10 cm², and the pheopigments content from 34 to 1064 µg/10 cm². The amount of benthic microalgae increases during the vegetation period and reaches its maximum in August or September.

Key words: Baltic Sea, biomass, microphytobenthos, species composition.

Introduction

Haapsalu Bay has been an intensively exploited recreation zone for a long time. The curative mud from the bay has been used in the sanatoria of Haapsalu since the first half of the 19th century.

Although the earlier data on microscopic algae from the sea bottom (from curative mud) of the bay were reported in the mid-19th century (Eichwald, 1852; Weisse, 1861), there are very few investigations about the benthic microalgae of the Gulf of Riga as a whole. The comprehensive study by Mölder (1938) of the diatoms of Estonia contains some references to Haapsalu Bay; an article by Rudzroga (Рудзрога, 1982) deals with the benthic diatoms of the Gulf of Riga. The author of the present paper has carried out several investigations about the microphytobenthos in the Väinameri area (Вильбасте, 1982, 1984, 1987, 1989, 1990).

This paper presents the results of the study of microphytobenthos in Haapsalu Bay during the period from 1976 to 1989. The aim of the research was to describe the structure of the microphytobenthos community and to investigate the spatial and seasonal variations of microphytobenthos.

Study Area

The investigations took place in the non-tidal, narrow and shallow Haapsalu Bay, which lies near the western coast of continental Estonia, in the northern part of the Gulf of Riga, in the Väinameri (Moonsund) area (Fig. 1). The bay is divided into three parts. The inner part is separated from the half-closed central part by several small isles. The outer part is a relatively open sea area. The water turnover is hindered in the inner and central parts.

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The maximum depth in the outer part is 4.5 m, it decreases towards the east and reaches 1—2 m in the central and inner parts of the bay. Because of its small depth, the water warms up relatively quickly and its temperature sometimes rises up to 20 °C in summer. The transparency of water is low and the salinity is variable both spatially and seasonally: it is higher and more stable (5—7.5‰) in the outer part than in the central and inner parts. For greater detail about the hydrological and hydrochemical conditions, see the article by Porgasaar (Поргасаар, 1984).

Several rivers, rich in biogens running through the intensively exploited agricultural landscape, discharge into the inner part of the bay. The central part is affected by sewage and waste waters from the food-processing and light industries of the town of Haapsalu.

A soft bottom is prevailing in the bay. It is chiefly muddy in the inner and central parts and sandy-clayey with various amounts of mud in the outer part.

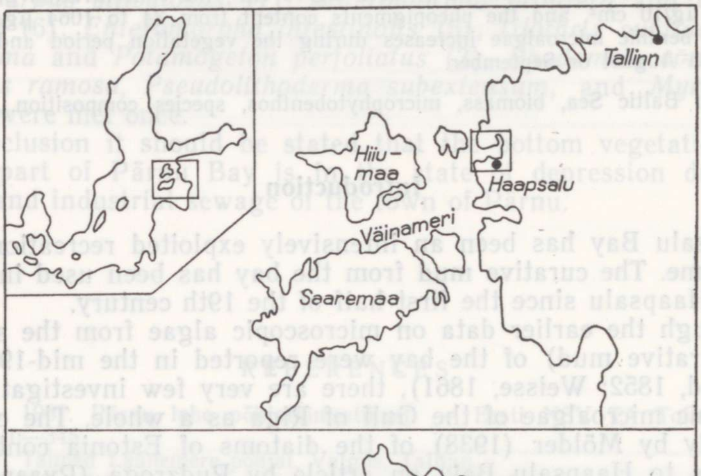

Fig. 1. Study area; division of Haapsalu Bay into inner (*I*), central (*II*), and outer (*III*) parts; and the location of sampling stations.

Material and Methods

The investigations were carried out on 18 occasions during 1976 through 1979 (4—6 times a year), in August 1985, and in June and August 1989. The inner part of the bay was studied only in 1985 and 1989 and the content of chl *a* was also measured only in 1985 and 1989.

The samples of microphytobenthos were taken with the Elmgren piston corer for meiobenthos. The area of each sample was 4.52 cm^2. The samples were preserved in the 4% formalin solution. The number of algal cells was counted using the Goryaev chamber (0.0009 cm^3) under a MBI-15 microscope at 400× magnification.

The biomass of microphytobenthos was calculated using the list of mean volumes af algal cells after Melvasalo et al. (1973).

The chl *a* content in microphytobenthos was measured according to Strickland and Parsons (1960) and Lorenzen (1967) after the extraction of freeze-dry samples with acetone.

All algal species except diatoms were determined in water preparations. To identify the diatoms, permanent microscope slides were used. The organic cell content was removed by oxidation in hot H_2SO_4. The slides were prepared by using Hyrax. About 200 diatom valves were identified in each sample. The Shannon diversity index (H') and the evenness index (I') were calculated from diatom assemblages.

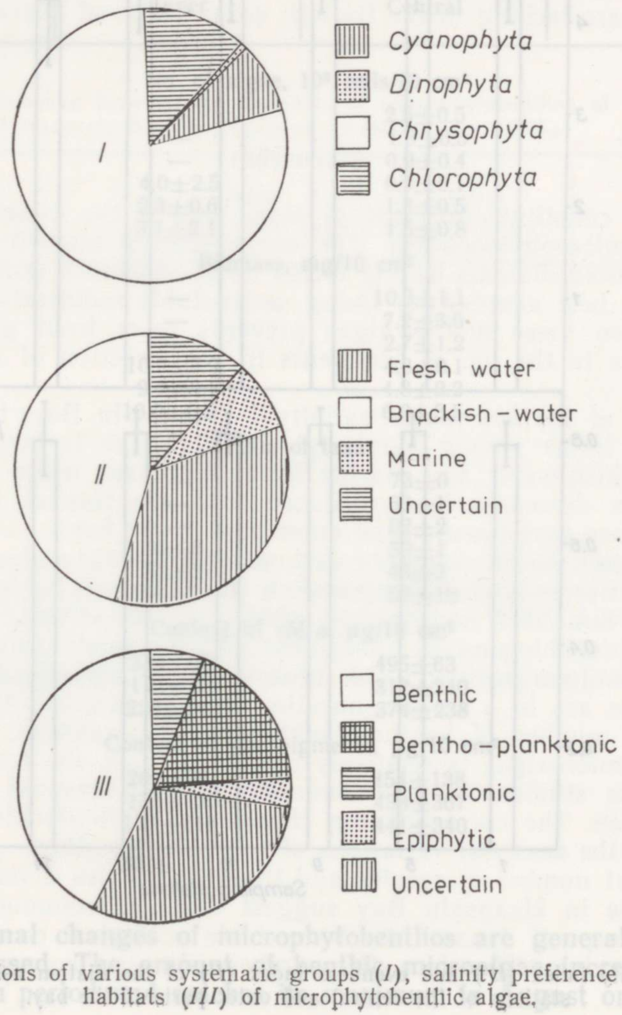

Fig. 2. Proportions of various systematic groups (*I*), salinity preference (*II*), and main habitats (*III*) of microphytobenthic algae.

Results

1. Structure of the Microphytobenthos Community

All in all 239 taxa of microalgae were registered from the material studied. The most numerous are diatoms — 188. The most frequent are *Amphora ovalis*, *Rhoicosphenia abbreviata*, and some species of the genera *Cocconeis*, *Epithemia*, *Mastogloia*, *Navicula*, *Nitzschia*, and *Sunedra*. All the other systematic groups of algae were represented by considerably smaller numbers: Chlorophyta — 30, Cyanophyta — 20, and Dinophyta — 1 (Fig. 2 *I*).

The proportion of fresh-water forms among the bottom microalgae is large (36%). Brackish-water forms constitute 45% and marine forms only 8% of the total number of taxa of microphytobenthos (Fig. 2 *II*).

Of all the taxa 103 are real benthic and 43 bentho-planktonic forms, 14 are planktonic, and 7 epiphytic ones. The habitat preference of 72 taxa is uncertain (Fig. 2 *III*).

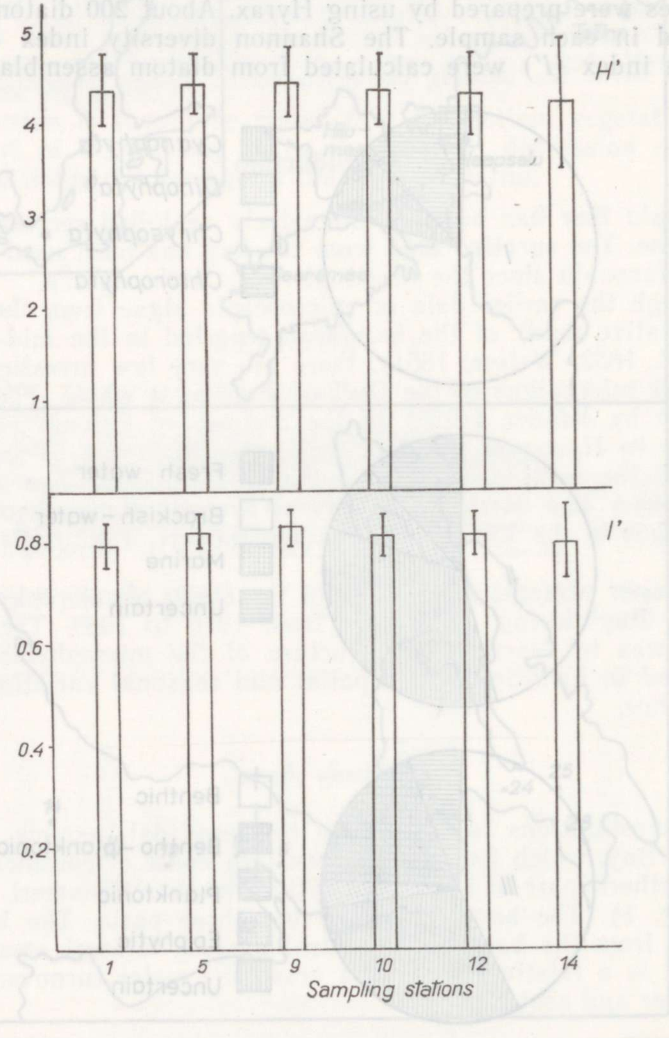

Fig. 3. Diversity index (*H'*) and evenness index (*I'*) of the diatom assemblages at the stations of the central and outer parts of the bay.

More than half of the microphytobenthos species are rare and occasional; only 6 species are very common (occurrence $>80\%$ of the samples): *Cocconeis pediculus, Epithemia sorex, E. turgida, Navicula salinarium, Rhoicosphenia abbreviata*, and *Synedra pulchella*. The diversity and evenness of the diatom assemblages are high and stable throughout the investigated period ($\bar{H}'=4.3$; $\bar{I}'=0.82$) (Fig. 3).

2. Spatial and Seasonal Variations of Microphytobenthos

The number of microphytobenthic algae varied from 0.1 to $8.0 \cdot 10^6$ cells/10 cm², the biomass from 0.1 to 23.6 mg/10 cm², the concentration of chl *a* of microphytobenthos from 64 to 715 µg/10 cm², and the pheopigments content from 34 to 1064 µg/10 cm². The annual variations of these indices are notable and they are higher in the central part of the bay than in the outer part (Table 1).

Table 1

Characteristics of microphytobenthos in different parts of Haapsalu Bay in August in different years

Years	Inner	Central	Outer
	No. of algae, 10^6 cells/10 cm²		
1976	—	2.5±0.5	1.4±0.8
1977	—	1.8±0.5	0.8±0.6
1978	—	0.9±0.4	0.3±0.3
1985	4.0±2.5	0.9±0.1	0.1±0
1989	2.3±0.6	1.3±0.5	1.4±0.8
Σ	3.1±2.1	1.5±0.8	0.7±0.9
	Biomass, mg/10 cm²		
1976	—	10.3±1.1	4.1±2.4
1977	—	7.2±3.6	1.2±0.9
1978	—	2.7±1.2	0.7±0.3
1985	10.9±7.9	4.8±0.1	0.3±0.2
1989	9.1±3.1	4.8±2.2	4.7±2.4
Σ	10.0±6.5	6.0±3.5	1.9±2.3
	No. of taxa		
1976	—	73±0	54±10
1977	—	63±1	51±2
1978	—	62±2	55±6
1985	61±6	59±1	38±9
1989	51±2	43±2	46±11
Σ	56±7	58±10	49±11
	Content of chl *a*, µg/10 cm²		
1985	339±95	496±63	203±64
1989	113±28	312±240	166±103
Σ	226±142	374±238	179±103
	Content of pheopigments, µg/10 cm²		
1985	209±59	454±138	118±54
1989	134±135	433±367	387±150
Σ	171±118	441±340	297±196

The seasonal changes of microphytobenthos are generally not very clearly expressed. The amount of benthic microalgae increases during the vegetation period and reaches its maximum in August or September.

In spring, when the vernal bloom of phytoplankton takes place, there are plenty of arctic planktonic diatoms in the composition of microphytobenthos. At that time the large biomass and especially the high number of algae are due to the presence of planktonic algae, such as *Achnanthes taeniata* and *Diatoma elongatum.*

In summer an extensive development of microscopic bottom algae takes place. The number of algal cells grows and also the biomass of microphytobenthos increases. Besides diatoms, the occurrence of blue-green and green algae is high, especially in the central and inner parts of the bay. The most frequent representatives are from the genera *Gomphosphaeria*, *Merismopedia*, *Pediastrum*, and *Scenedesmus*.

In autumn, as the temperature of water falls and solar radiation decreases, the development of microphytobenthic algae ceases. Blue-green and green algae decay before diatoms. However, when the maximum of phytoplankton occurs in October or November, a large number of planktonic diatoms are again found among benthic microalgae.

In winter microphytobenthos is underdeveloped. Although there exist some occasional microalgae that can live also in winter, typical winter inhabitants are lacking in the floristic composition of microphytobenthos.

Discussion

Diatoms constitute the part of algae that is the most characteristic of marine microphytobenthos. The overwhelming majority (over 90%) of the identified diatoms belong to the order Pennales. Most of them are single cells, best adapted for living on unstable sediments. The positive phototaxis on these motile algae prevents them from getting buried: they migrate to the top of sediments in the direction of light (Harper, 1977).

Because of the low water salinity in Haapsalu Bay, the number of fresh-water forms among microphytobenthic algae is large. The quantity of brackish-water and marine forms increases while that of fresh-water forms decreases in accordance with the rise of water salinity from the inner part towards the outer part of the bay.

It has often been suggested that sediment-associated microalgae influence the nutrient dynamics between the sediments and water (Sundbäck, 1986; Sundbäck and Granéli, 1988; Hansson, 1989), thus affecting the amount of biogens available for phytoplankton (Hansson, 1990). Nevertheless, in a coastal water ecosystem phytoplankton and microphytobenthos are in a close connection (Пийрсоо, 1984, 1986) and that is why the number of bentho-planktonic and planktonic forms among the bottom microalgae is relatively large. Likewise, the results of microphytobenthos studies are overshadowed by the seasonal variations of phytoplankton. The corresponding changes of phytoplankton are clearly reflected in the seasonal variations of microphytobenthos.

The great number of species and the high species diversity of microphytobenthos in Haapsalu Bay suggest that the community of microalgae can respond dynamically to variable ecological conditions typical of coastal waters. Therefore, the number of very common species is small.

Although the measurements of chl *a* content of microphytobenthos in Haapsalu Bay are not numerous, the data obtained (Table 1) indicate a high level of microphytobenthos compared with that in the Danish Wadden Sea tidal areas (Rasmusen et al., 1983), in the northern Baltic Proper (Kautsky et al., 1984) and in Öresund (Sundbäck, 1984; Granéli and Sundbäck, 1985).

It was shown that as much as 70% of the gross primary production of the community of a shallow inlet originates from bottom macro- and microphytes (Вильбасте К., 1987). On a hard and stable bottom macroalgae are responsible for the greater part of primary production; on an unstable sediment, however, the role of microphytobenthos increases considerably.

The number of algal cells and the biomass of microphytobenthos is higher in the eutrophic central part, which is influenced by the sewage from the town, than in the outer part (Tables 1 and 2). In a shallow bay moderate eutrophication creates favourable ecological conditions for the growth of microphytobenthos. The abundance of nutrients accompanied by opportune light conditions, a relatively high temperature, and low salinity contribute to the flourishing of the bottom microalgae.

It can be concluded that microphytobenthos is a well developed part of the ecosystem of Haapsalu Bay.

Table 2

The average differences between the variables of microphytobenthos of different parts of Haapsalu Bay by means of *t*-statistic ($p > 0.95$)

Variable	Inner Central	Central Outer	Inner Outer
No. of algae	+	+	+
Biomass	—	+	+
No. of taxa	—	—	—
chl *a*	—	—	—
Pheopigments	—	—	—

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