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SHORT-TERM CHANGES IN SETTLEMENT OF MICRO- AND MACROFOULING ORGANISMS IN BRACKISH WATERS

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Colonization of test panels by micro- and macrofouling organisms was studied at two selected sites in the Warnow estuary. The stations differed substantially in terms of their physical and chemical parameters. Station 1 was situated in the Warnemünde marina and can be considered typical of the outer port area. The site selected for Station 2 was a floating shipyard dock about 10 km upstream. The water there had lower salinity and higher nutrient loads than at Station 1. The short, 14-day-long periods of exposure were intended primarily to yield information concerning the rate and variability of colonization. In addition, long-term exposure panels were deployed for the entire period of the experiment at both stations.

Species diverisity was lower in both the micro- and macrofouling communities at Station 2. Settlement of diatoms and ciliates proceeded throughout the whole season, its intensity being higher in spring at both stations. Domination of ciliates was more pronounced at Station 2 than at Station 1, diatoms being more abundant at Station 1. The macrofouling community at Station 1 was dominated by *Balanus improvisus, Laomedea loveni, Electra crustulenta, Mytilus edulis,* and *Fabricia sabella,* while the community at Station 2 was dominated by *Balanus improvisus, Cordylophora caspia,* and *Nais elinguis.*

INTRODUCTION

Practically all kinds of natural or artificial substrates immersed in natural waters will be, within a short time, colonized (fouled) by sessile organisms. The communities thus formed, comprising both auto- and heterotrophs, contain micro- and macrofouling organisms defined so in terms of their size.

Members of fouling assemblages are recruited from planktonic and benthic communities. In other words, fouling communities are more or less similar to the so-called

secondary hard bottom communities and often generally resemble the hard bottom communities.

The dual importance of fouling communities, i.e. firstly, in economic terms, as those organisms responsible for all kinds of biologically induced deterioration of man-made structures in the water, and secondly, as opportunist, fast-growing, and metabolically highly active communities in polluted waters, is a sufficient reason for intensive research (cf. Costlow and Tipper 1984).

In this paper, we discuss only one aspect of our studies on growth of biofouling communities along the German coastline, namely how (and why) the settlement of micro- and macrofouling organisms varies during the growth period.

The studies were performed at two stations in the estuary of the River Warnow and are based on detailed background information related to the development of planktonic populations (Bachor 1986; Jer jour in press; Nasev 1976), secondary hard bottom assemblages (Arndt et al. 1971; Sager and Eckert 1968; Strogies 1983; Subkiew 1970), and hydrography (Bachor 1987; Correns 1976; Freund 1977).

MATERIALS AND METHODS

The estuary of the River Warnow (the Unterwarnow) has a total length of about 15 km. With a total surface area of 12.5 km^3 and mean depth of 4.0 m, it belongs to the smallest estuaries in Germany, but, owing to the proximity of the city of Rostock, its port and the nearby industrial areas, it is one of the most intensively used.

Two stations differing substantially in terms of their physical and chemical parameters, despite a short geographic distance between them, were chosen for the present study. Station 1 was situated in the Warnemünde marina. Owing to the immediate proximity of the open Baltic, it can be considered typical of the outer port area. The site selected for Station 2 was a floating dock of the Neptunwerft shipyard, about 10 km upstream. The water there had low salinities varying within the oligohaline range, low O_2 contents in summer, and substantially higher organic and mineral nutrient loads throughout the year than those at Station 1. The location of the stations is shown in Fig. 1 together with the mean variations in the major hydrographic parameters.

To determine the rate of colonization by micro- and macrofouling organisms during the growth season, panels of various size, made of hard PVC, were suspended vertically at a depth of about 1 m and exposed within 14 April–29 September. The set of panels was replaced every fortnight. Additionally, long-term exposure panels were deployed for the entire period of the experiment at both stations. The panel sizes and methods used are summarized in Fig. 2.

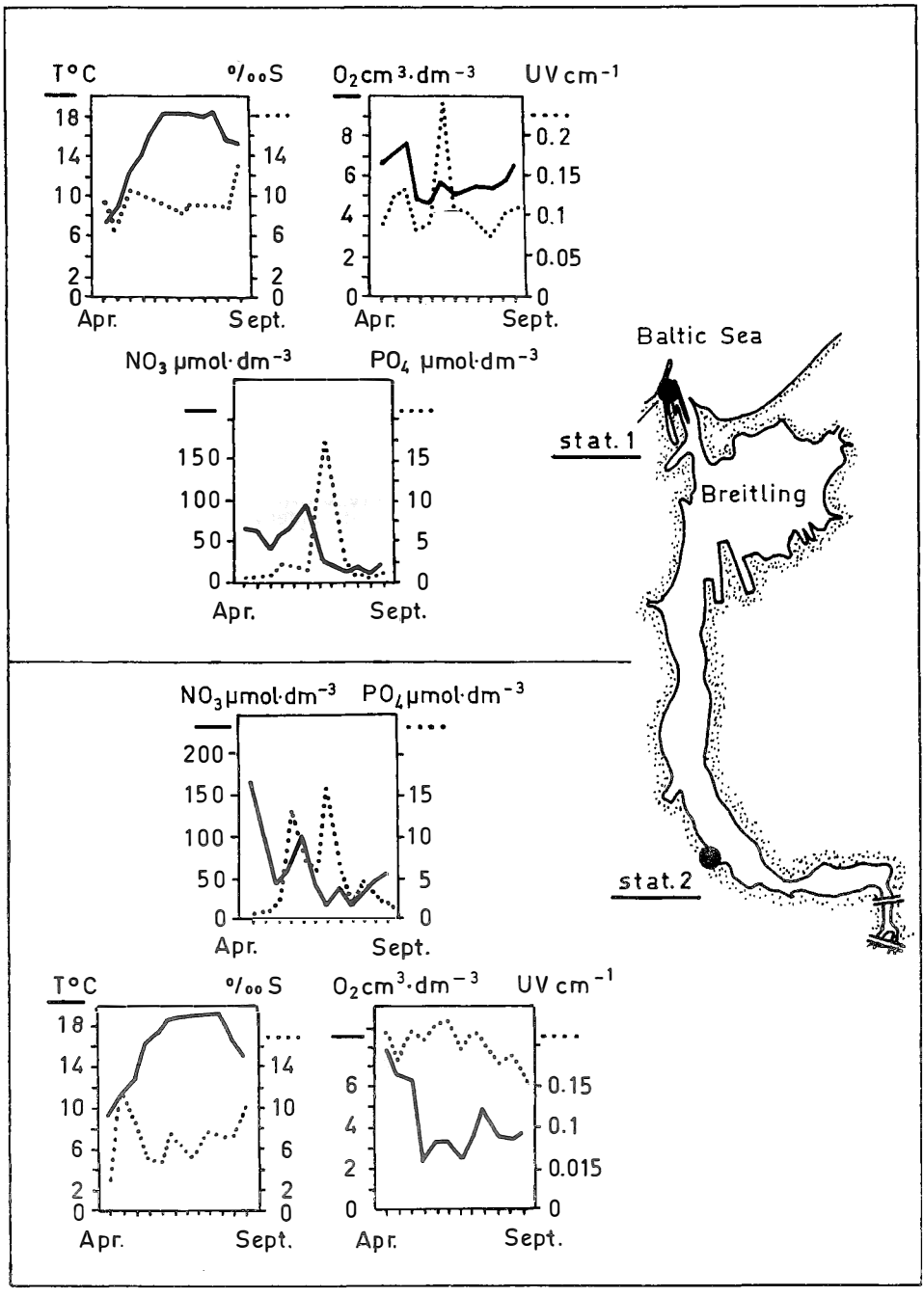
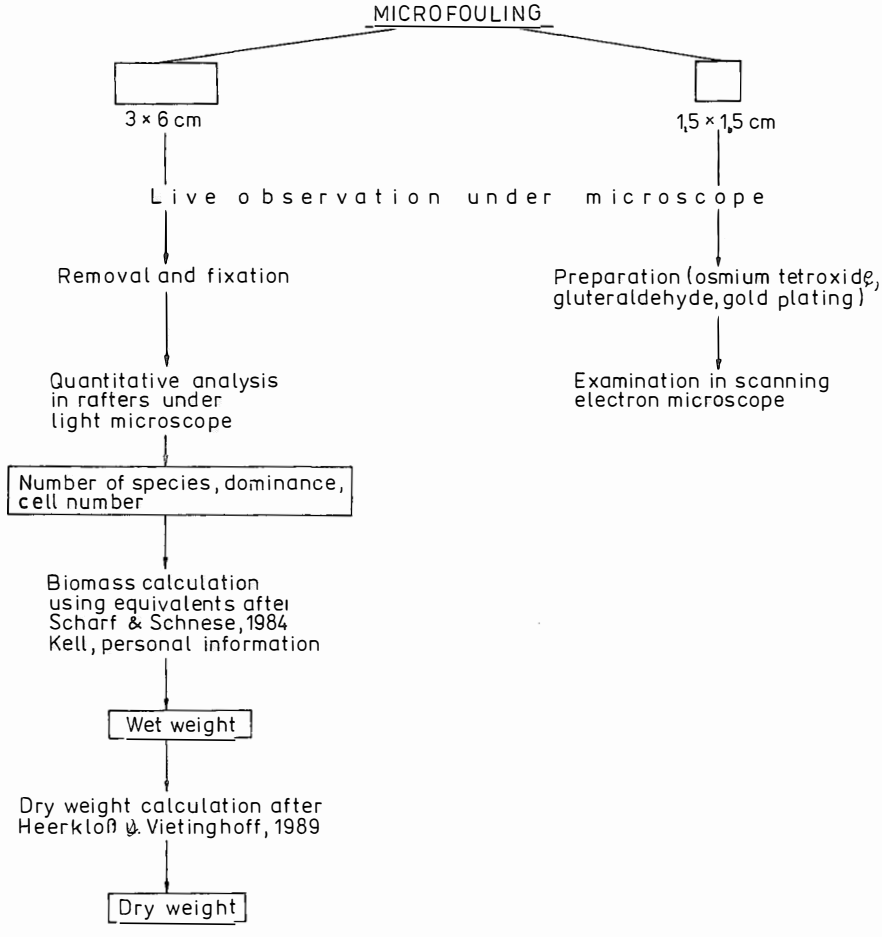


Fig. 1. Area of study and characteristic hydrographic data at the two stations

The abundance of larvae of the major macrofouling organisms in the plankton was recorded at times of panel change; additionally, the following abiotic parameters were measured: salinity (‰), temperature (°C), O_2 concentration (cm^3/dm^3), UV absorption at 254 nm as a measure of the organic load, and nutrients (PO_4, NO_3 and NO_2) ($\mu mol/dm^3$).



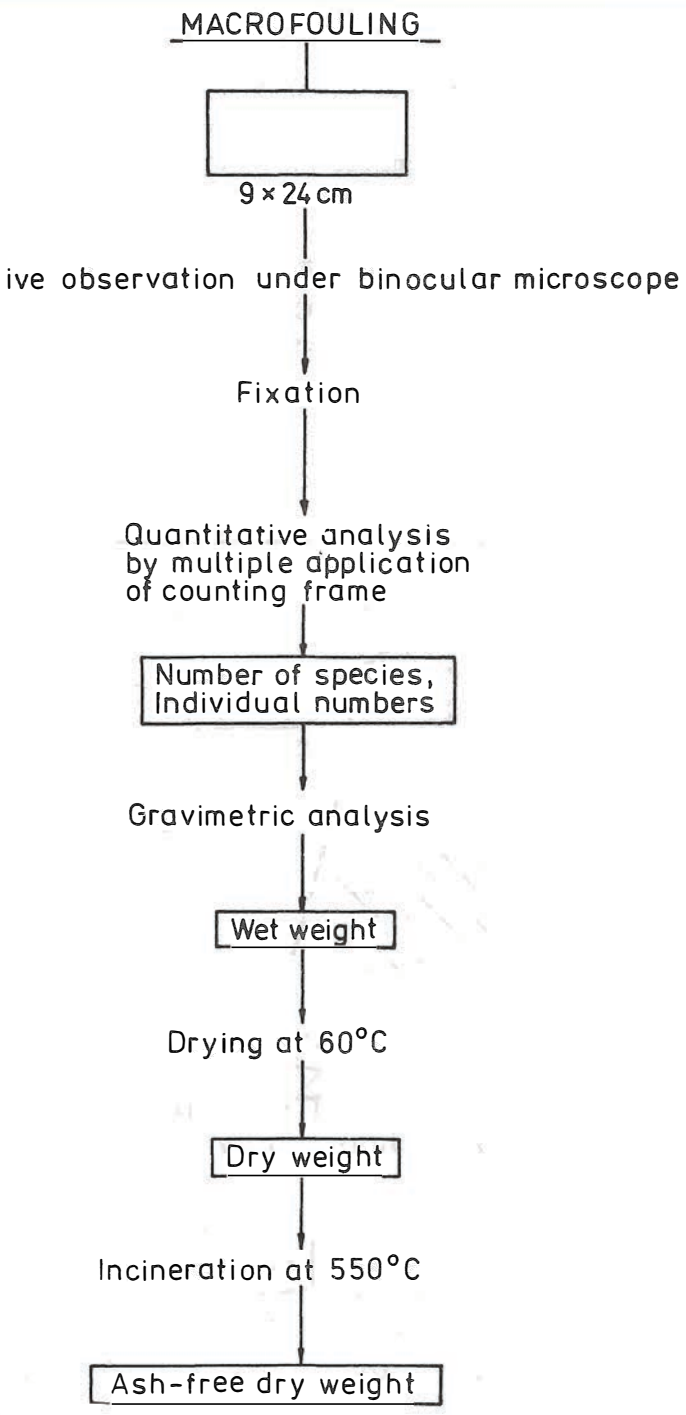


Fig. 2a, b. Procedures for quantitative and qualitative analyses of test panels (analysis of micro- and macrofouling)

RESULTS

The most striking result of the present study was a great heterogeneity in colonization of the artificial substrates by micro- and macrofouling organisms during the growth period. The rates and intensities with which the panels, exposed for 14 days, were colonized varied considerably not only during the growth season, but also between the two stations. The general pattern of test panel colonization at the two stations in terms of biomass is shown in Fig. 3. The 14-day differences between the fouling layers on the panels, formed during the experiment, were apparent on visual inspection, the low summer biomass values differing from the high spring values at

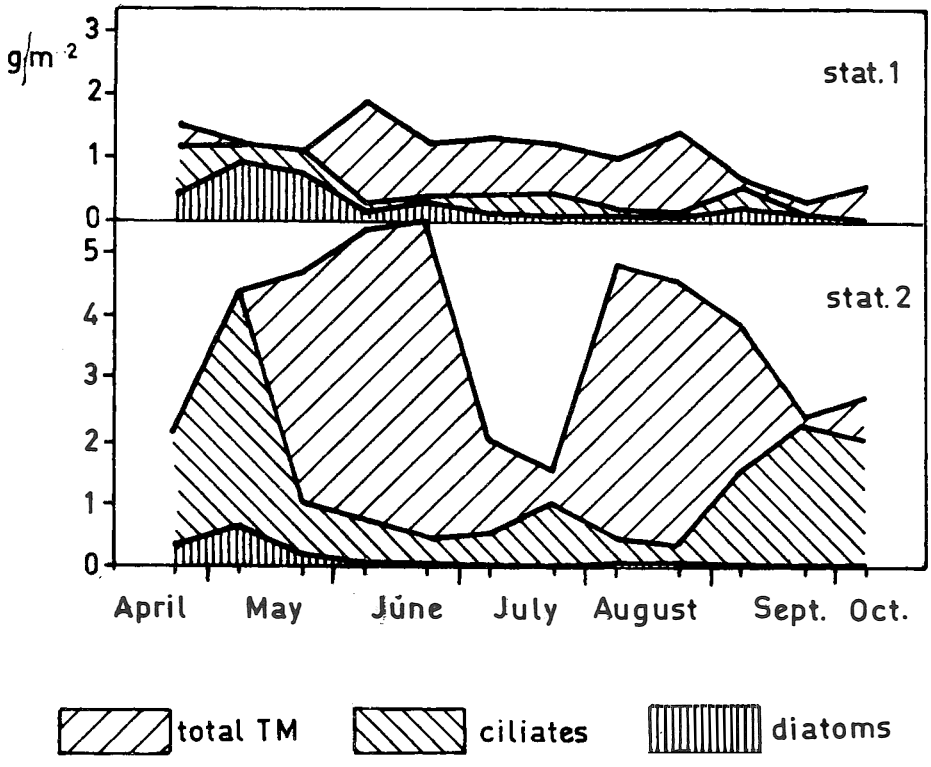


Fig. 3. Biomass (TM) development on test panels during the period of study

Station 2 by the factor of 3.5, and the spring and summer values differing from the autumn ones at Station 1 by the factor of 4.5.

Microfouling

The microfouling community consisted of bacteria, cyanobacteria, diatoms, green algae, and protozoans. Owing to the exposure depth of 1 m and the relatively high turbidity in the area of study, abundances of blue-green and green algae were remarkably low (less than 1% during the whole experiment) and will therefore not be discussed in more detail at this point.

No quantitative estimation of bacterial abundances on the test panels was made for methodological reasons. However, examination of the panels under a scanning electron microscope showed no sign of seasonal variation in density of bacterial colonization at either station.

Diatoms. Variation in diatom colonization at Stations 1 and 2 is shown in Fig. 4. A distinct spring maximum was observed at both stations, but in summer the abundances were very low, the diatoms virtually vanishing from Station 2 in July and August. Variation in domination and abundance differences during the experiment can be seen in Fig. 5. 5a and 5b. For the sake of clarity, only the major species of the fouling community are shown. Centric diatoms were present throughout the year at Station 2 owing to the freshwater influence, but were present only sporadically at

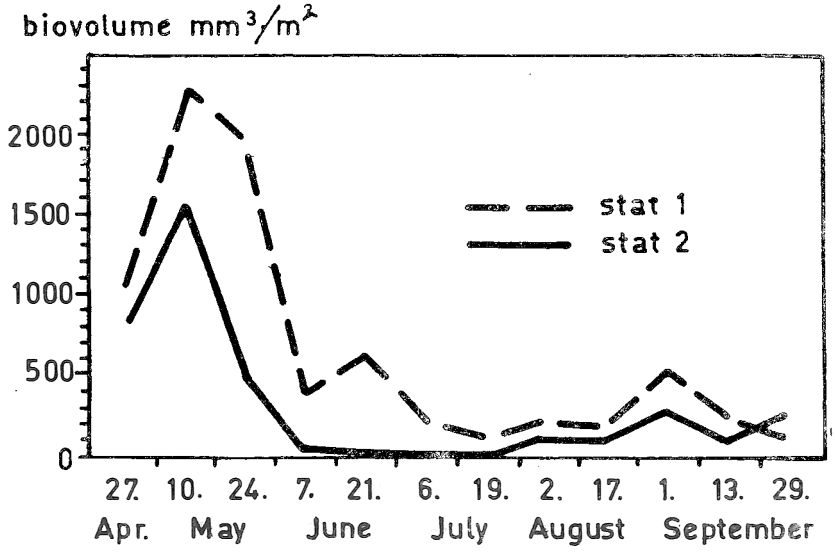


Fig. 4. Colonization of test panels by diatoms at Stations 1 and 2

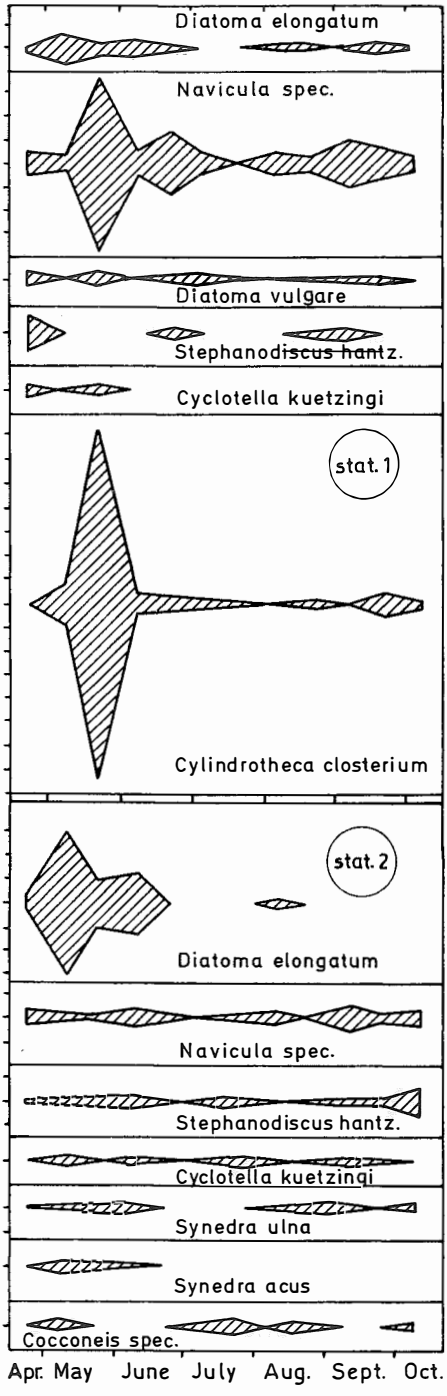


Fig. 5. Abundances of colony-forming diatoms at Stations 1 and 2 (one unit on y-axis = 10.000 ind./cm^2)

Station 1. No mass occurrence of *Cylindrotheca closterium*, similar to that at Station 1, was recorded at Station 2; owing to the size of the species, its occurrence had little effect on the biomass. The domination of diatoms was altogether higher at Station 1 in terms of both quantity and diversity.

Sessile ciliates. Sessile ciliates dominated the communities in general throughout the whole growth season (Fig. 6). As can be seen in Fig. 7, the abundances were much higher at Station 2 than at Station 1. The pattern of seasonal variations at Station 2 involved major peaks in spring and autumn and a distinct decline in summer, whereas only a spring maximum was recorded at Station 1, with substantially lower values in summer and autumn. As with the diatoms, diversity of the sessile ciliate community was markedly higher at Station 1 than at Station 2. *Epistylis* and *Zoothamnium* were the dominant genera at the latter, *Vorticella* and, from July until mid-August, *Pyxicola operculigera* being also fairly abundant. Very large numbers of *Stentor coeruleus*

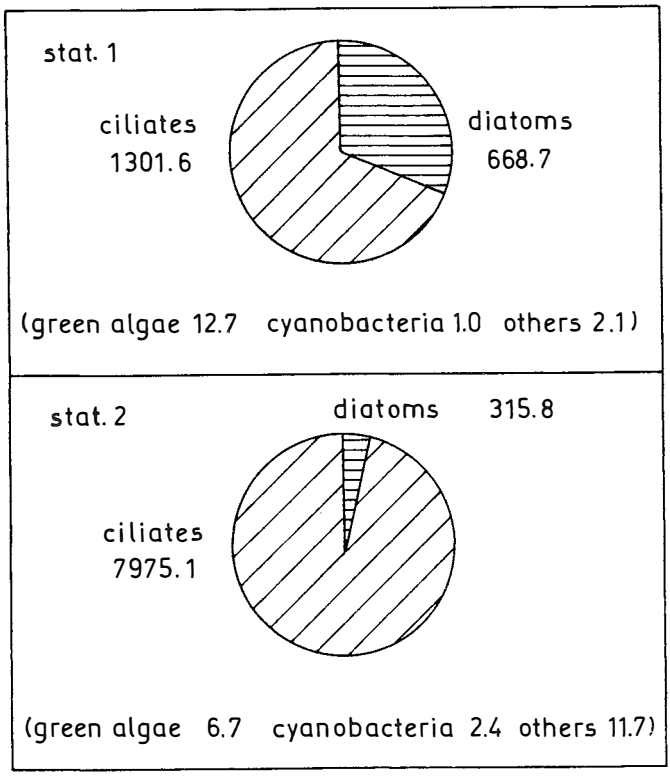


Fig. 6. Percentages of diatoms and sessile ciliates among microfouling organisms (mean biovolume in mm^3/m^2 on 14-day exposure panels)

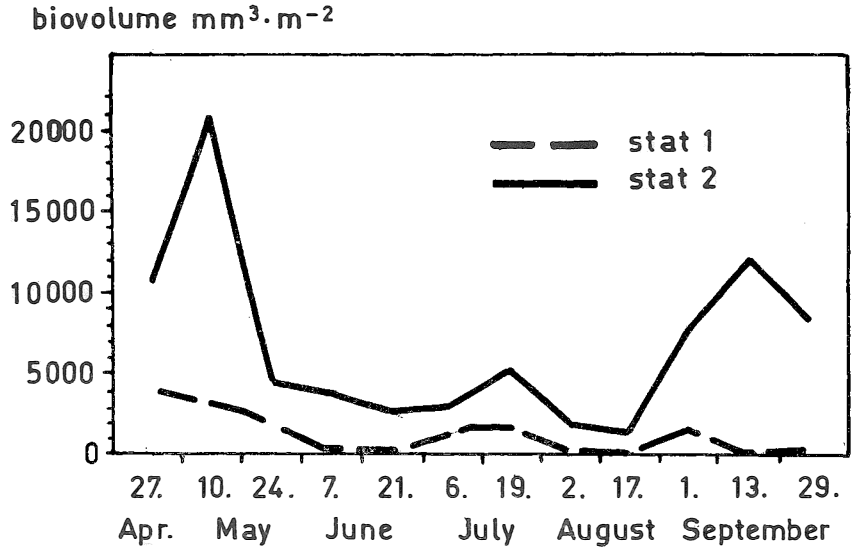


Fig. 7. Biomass growth of sessile ciliates at Stations 1 and 2

were found in May (it should be noted that the species was much more common on the long-term than on the short-term panels since the already existing assemblages on the former afforded more protection from the water current). The genera *Cothurnia, Acineta, Carchesium,* and *Vaginicola* were also found among the sessile ciliates colonizing the panels at Stations 1, but *Pyxicola* was not present at that station. The huge numbers of vagile ciliates inhabiting the panels are not considered in the analysis.

Macrofouling organisms

The times ar which the major macrofouling organisms colonized the short-term panels and the densities of their assemblages are summarized in Fig. 8.

Hydroids. The Station 1 panels were colonized by *Laomedea loveni,* the colonization rate being highest from early June until early July. The species was absent at Station 2 where the panels were colonized by *Cordylophora caspia* from June until the end of September, with a distinct maximum in July.

Bryozoans. Colonization by *Electra crustulenta* was recorded only at Station 1. Settlement of the species on the long-term panels was observed in August and September, but *E. crustulenta* was recorded only once (the second half of September) on the short-term panels.

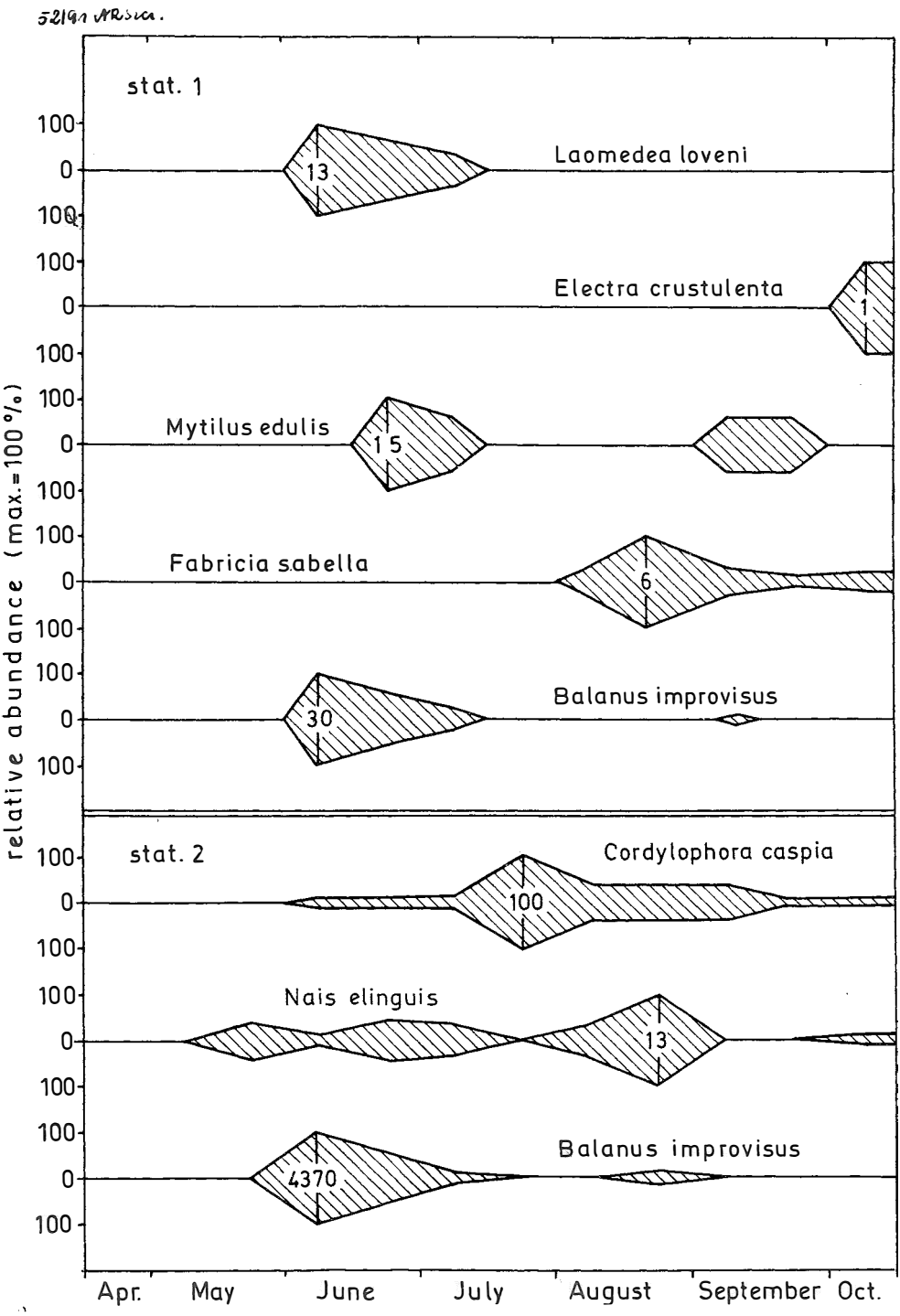


Fig. 8. Summary of colonization times and relative abundances of the major macrofouling organisms. Numbers represent maximum densities (ind./dm^2)

Molluscs. *Mytilus edulis* larvae were settling from June until early July and from mid-August until mid-September. *Embletonia pallida* was regularly found grazing on *Laomedea loveni* on the long-term panels at Station 1. No molluscs were found at Station 2.

Polychaetes. *Fabricia sabella* which builds mud tubes was present on the short-term panels at Station 1 from mid-July onwards and reached its maximum abundance during the first half of August. *Polydora ligni* was found only occasionally on the long-term panels at both stations. No new colonization of the short-term panels was recorded.

Oligochaetes. Although present on the long-term panels at both stations, oligochaetes on the short-term panels were observed only at Station 2. Colonization began in May and reached its maximum in August. *Nais elinguis* was present in densities of up to 420 ind./dm^3 on Station 2 long-term panels collected in September.

Crustaceans. The settlement pattern of the barnacle *Balanus improvisus*, which dominated the fouling communities at both stations, was bimodal. The main colonization occurred within early to mid-June, another, less-pronounced peak of colonization being observed in August and September. Barnacle densities reached 4370 ind./dm^3 at Station 1, and were thus far higher than those at Station 2. Newly settled cypris larvae and juvenile balanids were also recorded. *Corophium insidiosum* was found at both stations, but never colonized the short-term panels.

By the time the experiment ended on 29 September 1988, a diversified fouling community dominated by *Balanus improvisus, Laomedea loveni,* and *Corophium insidiosum* had developed on the long-term panels at Station 1. At the end of the 168-day exposure period, a dry weight of 687 g/m^2 was recorded. The long-term panels at Station 2 were covered by a continuous, 12.5 cm thick balanid crust of 3006 g/m^2 dry weight. Apart from *Balanus improvisus*, the major components of the low-diversity fouling community at this station were *Cordylophora caspia* and the oligochaete *Nais eliguis*.

DISCUSSION

Fouling on natural and artificial substratres reflects the potential of colonizing organisms (larvae and swarmers among the plankton) as well as biotic and abiotic conditions of the water body which determine whether the organisms can settle and grow. The considerable variability in the colonization of the panels exposed for 14 days by both micro- and macrofouling organisms must be viewed in this light. For instance, the mass growth of diatoms on the test panels (maximum in spring, decline in summer, another maximum in autumn) corresponds to the normal seasonal diatom

periodicity in the phytoplankton as well as in the microphytobenthos as reported by several authors both for the Unterwarnow (Bachor 1986; Jer jour in press) and other brackish waters (Nasev 1976; Schiewer et al. 1988; Täuscher 1976). Turbidity of the water at the exposure depth of 1 m explains several of the differences between our results and those reported by the authors quoted above, including the fact that the summer decline in diatoms was not accompanied by the development of the typical "summer" algae (cyanobacteria and green algae), the very slight autumn maximum, and the pronounced differences between Stations 1 and 2 in terms of algal growth. Nevertheless, Cooksey et al. (1984) report that diatoms are the dominant microfouling organisms (90%) on hard substrates anyway and, under the exposure conditions we selected, could possibly use the ability, as reported by the authors quoted, to actively adhere to substrates under poor light conditions or even in darkness. The considerable thickness of microfouling layers on the panels exposed for periods longer than 14 days, despite slow colonization of the panels exposed for only 14 days, supports the contention of Little (1984) that microfouling films are formed predominantly by the development of organisms that have become established rather than by continuous colonization by new organisms.

The relatively poor light conditions at the exposure depth also explain the domination of microfouling fauna among the colonizers at both stations. The "summer lack" of sessile ciliates is difficult to explain, however. No similar phenomenon has been observed among either benthic ciliates (Scharf and Schnese 1984) or other fouling communities dominated by sessile ciliates (Riedel-Lor jé 1980). The highest abundances and biomasses have always been observed during the warmest months. It was only Arndt (1986) who described an abundance minimum in May among planktonic ciliates in the Darss-Zingst Boddens and explained it by invoking the grazing pressure. Although the clearly higher abundances of sessile ciliates at Station 2 corresponded with the higher numbers of bacteria recorded in the water there at all times (Freund 1977), it is not clear why the almost optimal conditions for ciliates during the summer months were not reflected in either the colonization of new panels or rapid growth during the 14-day exposure intervals.

In April and May, the test panels were colonized exclusively by microfouling organisms (Fig. 3), but, as expected, initial colonization by macrofouling organisms started in early June and could be observed as a distinct increase in the biomass. Balanus improvisus were the first colonizers at both stations in June, as already reported by Subklew (1970) who also exposed test panels in the Unterwarnow.

The differences in composition of the macrofouling communities at the two stations conform largely to those already described in several works (Arndt et al. 1971; Gosselck 1966; Sager and Eckert 1968; Strogies 1983) and reflect the zonation of the environmental parameters in the Warnow estuary. Except for *B. improvisus*, colonization proceeded in a different order and led to different species compositions at each

station. *Mytilus edulis* and the marine euryhaline *Electra crustulenta* were found only at Station 1. The colonization by *Mytilus* in June and August correlates well with large numbers of the bivalve's larvae observed in the plankton in June, as described by Arndt and Heidecke (1973). *M. edulis* abundances were considerably higher on the long-term panels that had already been colonized by other macroorganisms. Dunstan (1984) believes that this is due to *Mytilus* avoiding unstructured substrates. *Electra crustulenta* colonized the panels later than the species mentioned above and was also more numerous on panels exposed for a longer period.

Colonization at Station 2 was dominated by *Balanus improvisus* and *Cordylophora caspia*. The high density of cypris larvae (up to 4370 ind./dm^2) and the rapid growth of adult *Balanus* show that the species has a preference for organically loaded eutrophic sites in ports (Igic 1984; Vuorinen et al. 1986). These growth conditions were also optimal for *Cordylophora caspia* (Arndt 1984).

Species diversity was lower at Station 2 in both the macro- and microfouling assemblages. On the other hand, the fouling communities at that station attained much higher biomasses during the growth season, thus allowing to treat the site as an extreme biotope.

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