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Colonization of artificial substrates by Foraminifera*

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Summary: From June 1972 to October 1974 colonization experiments were carried out off Boknis Eck (Eckernförder Bay, Western Baltic Sea) with artificial substrates (gravel, sand and clay) in 3 different water depths, 19 m (1.5 m above the bottom), 15 m (4.5 m) and 11 m (5.0 m).

The first Foraminifera appeared in spring 1973. With few exceptions only *Elphidium excavatum clavatum* (Cushman 1930) was present. It is assumed that *E. excavatum clavatum* has an especially good passive distribution capability by advection. This explains why this sub-species rapidly recolonizes the deeper areas of the Baltic after reestablishment of aerobic conditions.

Besiedlung von künstlichen Substraten durch Foraminiferen (Zusammenfassung): Von Juni 1972 bis Oktober 1974 wurden Erstbesiedlungsversuche mit sterilen Substraten (Kies, Sand und Ton) in 3 Wassertiefen: 19 m (1,5 m oberhalb des Bodens, 15 m (4,5 m) und 11 m (5,0 m) vor Boknis-Eck (Eckernförder Bucht, Westliche Ostsee) durchgeführt.

Die ersten Foraminiferen wurden im Frühjahr 1973, 8 Monate nach Installation dieser Substratflächen gefunden. Nach vereinzelten Funden folgten juvenile Exemplare in großer Zahl (bis zu 50 Ex./10 cm^2). Mit geringen Ausnahmen ist nur eine Unterart, *Elphidium excavatum clavatum* (Cushman 1930), vertreten.

Alle Sedimenttypen wurden besiedelt, eine Sedimentpräferenz konnte also nicht festgestellt werden. Da bisher kein echtes planktisches Stadium beschrieben wurde, ist es wahrscheinlich, daß *Elphidium excavatum clavatum* bei stärkerer Wasserbewegung, z.B. Einstrom- oder Ausstromlagen, aufgewirbelt und auf die künstlich angelegten Sedimente transportiert wurde.

Diese Befunde sprechen für eine besonders gute passive Verbreitungsmöglichkeit für diese Unterart, die durch eine Lebensweise auf der Sedimentoberoberfläche begünstigt wird. Zudem scheint die Unterart gegen niedrige O_2-Gehalte besonders resistent zu sein. Dieses mögen die Gründe dafür sein, daß die Becken in der mittleren und östlichen Ostsee nach anoxischen Bedingungen schnell wieder durch gerade diese Unterart besiedelt werden.

Introduction

Recolonization by benthos of areas subject to mass mortality due to periodic oxygen depletion has not received much attention. In the deeper basins of the Baltic, a good example of such an environment, recolonization occurs when lateral advection replenishes the oxygen supply (Leppäkoski 1973).

Lutze (1965) suggested that for benthic Foraminifera this process must take place rapidly, although the mode of recolonization was unknown. As so far no cyst formation has been described for the species in question, lateral transport remains the most likely mechanism to account for this process. Planktonic intermediate stages in the species concerned are also unknown and transport of gametes over greater distances is highly unlikely (Röttger, personal communication). Therefore, recolonization is most probably due to suspension and lateral transport of individuals from other areas.

This assumption was supported by the results of colonization experiments using submerged platforms carrying substrate containers. This experiment was conducted in the restricted research area "Hausgarten" of the SFB 95 in Kiel Bight.

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This paper presents results of this experiment giving the species composition, the size and number of the Foraminifera transported onto the platforms, as well as time of transportation and the development of the new population.

Methods

Sediment samples were collected monthly by divers from July 1972 until March 1974 on three submerged substrate platforms at 19, 15 and 11 m water depth. For technical details about the platforms see SARNTHEIN and RICHTER, 1974. In order to gain representative samples despite the patchy settlement of the Foraminifera, a 20 cm² sampling cylinder was used three times on each platform and sampling date. The samples were stained with Rose Bengal to identify the living specimens. After washing through a 63 µ sieve and concentrating, the species composition was determined and the diameter of tests of *Elphidium excavatum ctavatum* (CUSHMAN 1930) were measured. From size distribution curves of the tests, the reproduction periods and the growth of the individual populations can be ascertained (WEFER 1976).

Observations

After installation of the substrates in July/August 1972 Foraminifera were found only occasionally until January 1973 (less than 1 specimen/10 cm²: fig. 1). Later on higher numbers of *Elphidium excavatum clavatum* (CUSHMAN 1930) and *Elphidium incertum* (WILLIAMSON 1858) were found (up to 5 specimens/10 cm²) on all platforms. Other species of the Western Baltic (e. g. *Milliammina fusca* (BRADY 1870) or *Reophax dentaliniformis regularis* HÖGLUND 1947) occurred only sporadically.

Among the first living individuals to appear, only intermediate forms but no juveniles or fully adult specimens were present. Tests with a diameter of 200 µ were predominant among the calcareous Foraminifera, generally *Elphidium*. The living arenaceous species (*R. dentaliniformis regularis*, *Ammotium cassis* (PARKER 1870) and *M. fusca*) had several chambers and were all of medium size. Dead specimens were found rarely and were always adults. In the course of colonization, *E. excavatum clavatum* reached densities over 200 specimens/10 cm². The only other species with relatively higher numbers was *Ophthalmina kilianensis* (RHUMBLER 1936) with up to 10 specimens/10 cm², though only for a limited period.

The population density of the three platforms varied. The highest density was recorded on the 15 m platform (up to 45 specimens/10 cm²) and lowest density on the 11 m platform (not shown in fig. 1) with up to 15 specimens/10 cm².

Sediment type on the 19 m platform apparently did not influence settlement. Local variations in population density on the substrate are probably due to patchiness, also observed under natural conditions. With the exception of the clay substrate at 15 m, no densities approaching those of natural environments were recorded during the experiment. The clayey substrate of the 15 m platform produced densities approaching those in the natural environment only after 13 months (July 1973).

Size distribution curves of *Elphidium excavatum clavatum* tests demonstrating the changes in population, are shown in fig. 2 for two substrates (19 m sand and 16 m clay). For comparison, the size distribution curves for *E. excavatum clavatum* under natural conditions are given using data from WEFER (1976, fig. 2). Only occasional individuals were recorded until April 1973, however, after May 1973, an adult population was established (fig. 2). Reproduction occurred at the end of May (at 16 m) and the beginning of July

(at 19 m); this is demonstrated by the high proportion of juvenile (2—4 chambered) specimens. At the end of August the size distribution again showed the presence of a completely adult population. In December 1973 and January 1974 *Elphidium excavatum clavatum* was found only occasionally but in contrast to January—April 1973, specimens larger than 400 μ were observed. These were probably part of the original population. A reproduction at both depths was again observed in January/February 1974, as well as under natural conditions in 27 m water depth.

Discussion

It is difficult to explain the almost total absence of Foraminifera on the substrates in the seven months from beginning of the experiment in July 1972 until January 1973. The probable absence of strong water movements during this period and/or the lack of smaller specimens on the bottom (only smaller ones are transported onto the substrates) could explain this lack.

The first specimens reaching the substrates were of small and medium size. They apparently had the necessary hydrodynamic qualities to be suspended and carried onto the substrates by water movement. Therefore, a recent reproduction in the source area, supplying small and medium sized shells for transport, is a prerequisite for this type of colonization.

This form of migration differs from that observed in nematodes and harpacticoids. These were reported to colonize the substrates by migrating up the lines securing the substrate platforms (SCHEIBEL 1974). The restricted mobility of the Foraminifera precludes use of the same migration route.

That benthic Foraminifera can be transported from the seabed into the water column is confirmed by MURRAY (1965), LOOSE (1970) and others, who described finds of benthic Foraminifera in plankton nets; the SFB 95 Plankton Group reported similar observations (MARTENS, personal communication) for Kiel Bight. Generally, only small and medium sizes between 150 and 200 μ were found. This form of transport is further substantiated by the following observation. Divers watching the lowering of a van Veen grab reported that the upper sediment layers were already whirled up before the grab touched the bottom. Water samples collected by divers from this suspension cloud contained 4 *E. excavatum clavatum* (size: 2 × 200 μ and 2 × 125 μ) in 0.8 liters. Only this species was suspended, although other species present at the same locality had higher population densities. Therefore, the fact that only *E. excavatum clavatum* colonized the substrates may be explained by:

1) this species having an easily suspendable test,
2) its habitat on the sediment surface (WEFER 1976, fig. 7), making it more susceptible to water movement as opposed to infauna species such as *E. incertum*,
3) a greater resistance to unfavourable environmental factors, especially low oxygen concentrations (WEFER 1976).

Conclusions

The observations presented here indicate how recolonization of the Baltic Basins after destruction of the bottom fauna by oxygen depletion could take place. Accordingly, recolonization occurs by lateral transport of individuals during inflow conditions. If the species finds favourable environmental conditions, reproduction occurs and after a few

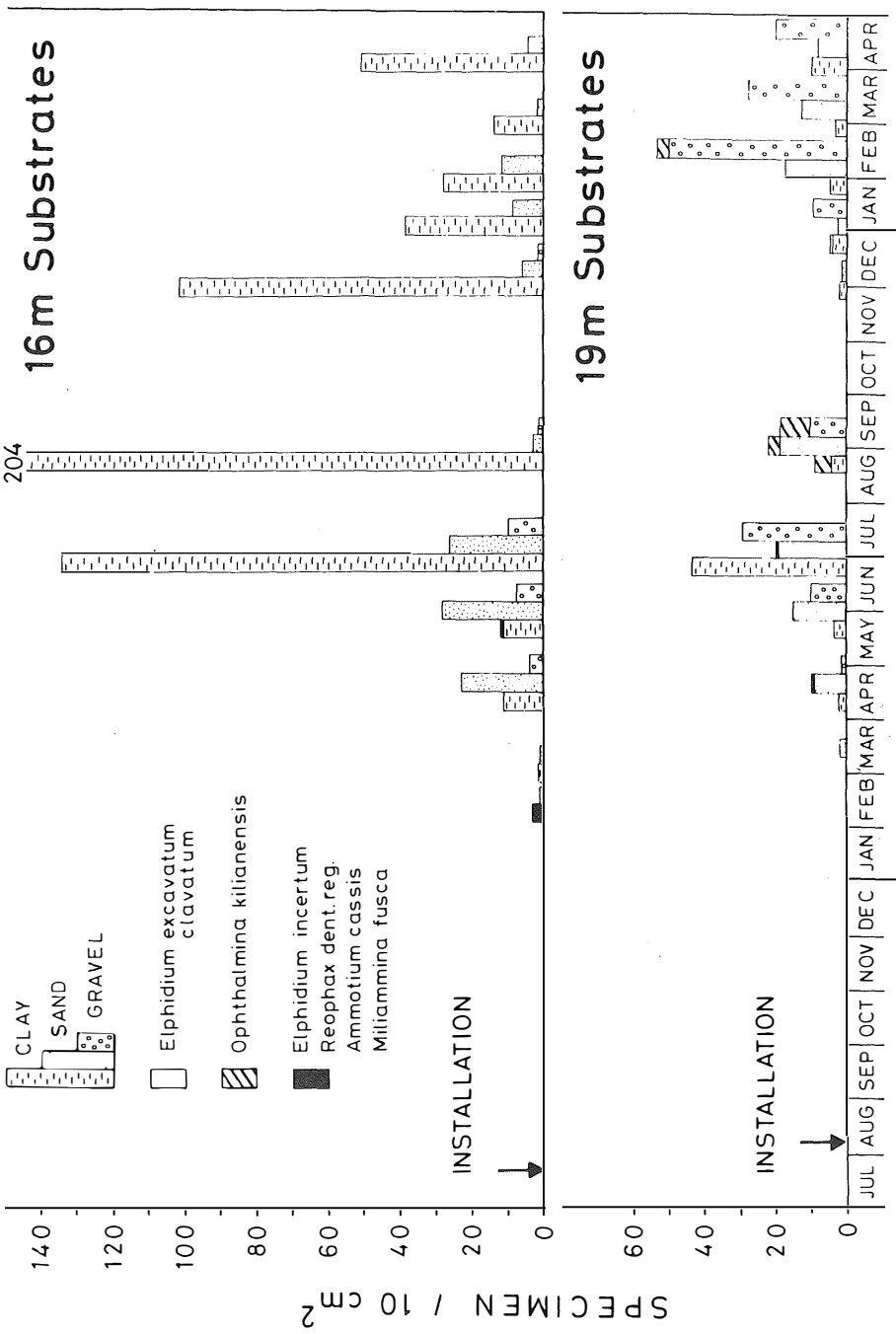
16m Substrates
19m Substrates
204
CLAY
SAND
GRAVEL
Elphidium excavatum clavatum
Ophthalmina kilianensis
Elphidium incertum
Reophax dent.reg.
Ammotium cassis
Miliammina fusca
INSTALLATION
SPECIMEN / 10 cm²
0
20
40
60
80
100
120
140
JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR
1972
1973
1974

Fig. 1

Tafel 2 (zu WEFER/RICHTER)

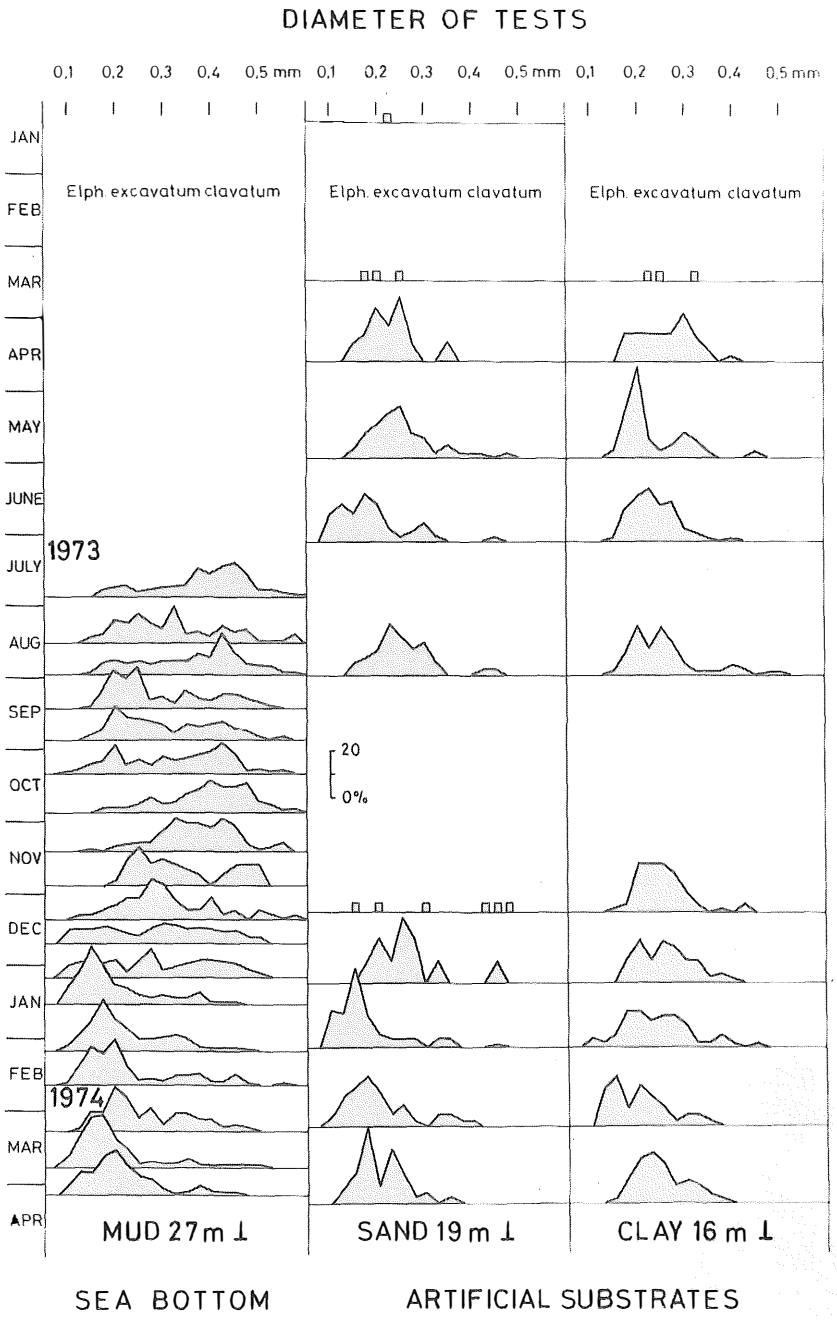

Fig. 2

months population densities comparable to unaffected areas can again be established. It also appears that *E. excavatum clavatum* preferentially recolonizes these basins, due to the same reasons presented in the discussion on artifical substrate colonization.

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