

Successful establishment of the spionid polychaete, *Marenzelleria viridis* (Verrill, 1873), in the Darss-Zingst estuary (southern Baltic) and its influence on the indigenous macrozoobenthos

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Abstract

Marenzelleria viridis (Verrill, 1873), a North American spionid polychaete that immigrated to brackish water ecosystems of the North Sea and Baltic Sea in the early eighties, has spread rapidly in its European biotopes and is now a dominant element of the fauna in some regions. It was first found in the Darss-Zingst bodden chain, an estuary on the southern Baltic coast, in 1985. Continuous monitoring from 1991 to 1994 showed that *M. viridis* has continuously spread in these waters and has revealed the effects of its introduction on the indigenous fauna. The highest abundances and biomasses (about 30,000 ind.·m⁻² and 400 g wet weight·m⁻²) were found in the inner part of the estuary (S = 3-5 PSU). Significant positive correlations (abundance and rank correlations) existed between the adult and juvenile subpopulations of *M. viridis* and between juvenile *M. viridis* and chironomids (larvae of the *Chironomus plumosus* and *Ch. halophilus* types). Negative correlations were found between the spionid and both *Corophium volutator* and the naidids. The abundance and biomass data collected for various macrozoobenthos representatives (*Hediste diversicolor*, *Corophium volutator*, *Hydrobia* spp., chironomids and oligochaetes) during the present study are compared with those available in the literature to assess the impact of the new species.

Kurzfassung

Erfolgreiche Ansiedlung des spioniden Polychaeten *Marenzelleria viridis* (Verrill, 1873) in der Darß-Zingster Boddenkette (südliche Ostsee) und sein Einfluß auf das einheimische Makrozoobenthos

Zu Beginn der 80er Jahre wanderte der nordamerikanische Polychaet *Marenzelleria viridis* (Verrill, 1873) in die Brackwasser-Ökosysteme der Nord- und Ostsee ein. Es folgte eine rasche Ausbreitung in den europäischen Biotopen, und der Spionide stellt heute in einigen Regionen das dominierende Faunenelement dar. In der Darß-Zingster Boddenkette, einem Küstengewässer der südlichen Ostsee, wurde *M. viridis* 1985 das erste Mal gefunden. Die Auswertung des Monitorings von 1991 bis 1994 zeigte eine kontinuierliche Ausbreitung in diesem Gewässer und macht Einflüsse auf die einheimische Fauna deutlich. Die höchsten Abundanzen und Biomassen (über 30 000 Ind.·m⁻² und 400 g Feuchtmasse·m⁻²) wurden in

den inneren Teilen des Ästuars (S = 3-5 PSU) gefunden. Signifikant positive Korrelationen (Abundanz- und Rangkorrelationen) bestehen zwischen den adulten und juvenilen Subpopulationen von *M. viridis* und zwischen juvenilen *M. viridis* und den Chironomidae (Larven des *Chironomus plumosus* und *Ch. halophilus* Typs). Negative Korrelationen wurden zwischen der Spionide und *Corophium volutator* sowie den Naididae gefunden. Die Abundanz- und Biomasse-Daten verschiedener makrobenthischer Vertreter (*Hediste diversicolor*, *Corophium volutator*, *Hydrobia* spp., Chironomidae und Oligochaeta) der eigenen Untersuchungen wurden mit denen aus der Literatur verglichen, um daraus Rückschlüsse auf den Einfluß dieser neuen Art ziehen zu können. In einer Langzeitstudie (1969-94) wird die Entwicklung der Taxa verfolgt.

Résumé

Immigration avec succès du polychète spionide *Marenzelleria viridis* (Verrill, 1873) dans l'estuaire du Darss-Zingst (Baltique du sud) et son influence sur le macrozoobenthos indigène local

Au début des années 80 le *Marenzelleria viridis* (Verrill, 1873), polychète nord américain, immigrait dans les écosystèmes des eaux croupies de la Mer du Nord et de la Baltique. Il s'en est suivi une propagation dans les biotopes européens et le spionide représente aujourd'hui un élément dominant de la faune dans certaines régions. Le *M. viridis* a été trouvé dans la chaîne des étangs côtiers du Darss-Zingst, des eaux au sud de la Baltique, pour la première fois en 1985. L'évaluation du monitoring de 1991 à 1994 montre une expansion continuée dans ces eaux et un influence importante sur la faune locale. Les plus fortes abondances et biomasses (plus de 30 000 indiv.·m⁻² et 400g de masse humide·m⁻²) ont été rencontrées dans les parties intérieures de l'estuaire (S = 4-3 USP). Des corrélations positives significantes (relation abondance et rang) se trouvent entre souspopulations adultes et juvéniles de *M. viridis* ainsi qu'entre les *M. viridis* juvéniles et les Chironomidae (larves du type de *Chironomus plumosus* et *Ch. halophilus*). Des corrélations négatives ont été constatées entre les spionides et *Corophium volutator* ainsi que les Naididae. Les données sur les abondances et la biomasse de différents représentants macrobenthiques (*Hediste diversicolor*, *Corophium volutator*, *Hydrobia* spp, Chironomidae et Oligachidae) des propres analyses ont été comparées avec celles de la littérature afin d'en venir aux déductions sur l'influence de ces nouvelles espèces. Le développement des taxons seront suivis dans une étude à long terme (1969-94).

Introduction

The immigration or introduction of a new species can have both direct and indirect effects on the indigenous community, with potential economic benefits or losses. The main risks are possible degradation of the environment, disturbance of existing communities, genetic influences and possible introduction of new diseases and parasites (Hedgpeth 1980, Reise 1993, Welcomme 1988). Many present day European invertebrates immigrated during the past 100 years, including the molluscs *Dreissena polymorpha*, *Potamopyrgus antipodarum*, *Crepidula fornicata*, *Ensis directus*, *Corbicula fluminea* and *Petricola pholadiformis* and the crustaceans *Eriocheir sinensis*, *Rhithropanopeus harrisi* and *Orconectes limosus*. The muskrat (*Ondatra zibethica*) is one the best known example among the mammals, and over 100 fish species have been introduced to Europe (Welcomme 1991).

The spionid *M. viridis* (syn. *Scolecopides viridis*) originates from estuaries along the North American east coast (Zettler *et al.* 1995, for references). The first specimen in a European brackish water (Forth estuary in Scotland) was found by McLusky *et al.* (1993) in 1982, and it has spread rapidly in the North Sea. Essink and Kleef (1988) found it in the Ems estuary (The Netherlands) in 1983, and Kirkegaard (1990) in Ringkøbing Fjord (Denmark) in 1990. The first specimens in the Baltic Sea were found in the boddens south of the Darss-Zingst Peninsula in 1985 by Bick and Burckhardt (1989). In the Baltic Sea, the worm also spread relatively rapidly, being found in Poland during 1988 (Gruszka 1991), Sweden in 1990 (Persson 1990) and Finland in 1990 (Andersin, pers. comm.).

The purpose of this present study was to investigate the establishment of *Marenzelleria viridis* (Verrill, 1873) in the semi-enclosed Darss-Zingst estuary. Hydrographic and ecological studies have been performed continuously in the Darss-Zingst bodden chain for over 30 years, and the measurements have been presented in numerous publications, diploma and doctoral theses (Arndt 1988, 1989, 1994; Möller 1984; Thiel 1990; Zettler 1993; Zettler *et al.* 1995). These data have been analysed and compared with the results of this study to obtain a fairly comprehensive reconstruction of the development and dynamics of the macrozoobenthos, providing information about the effects of this new species on the indigenous macrobenthos.

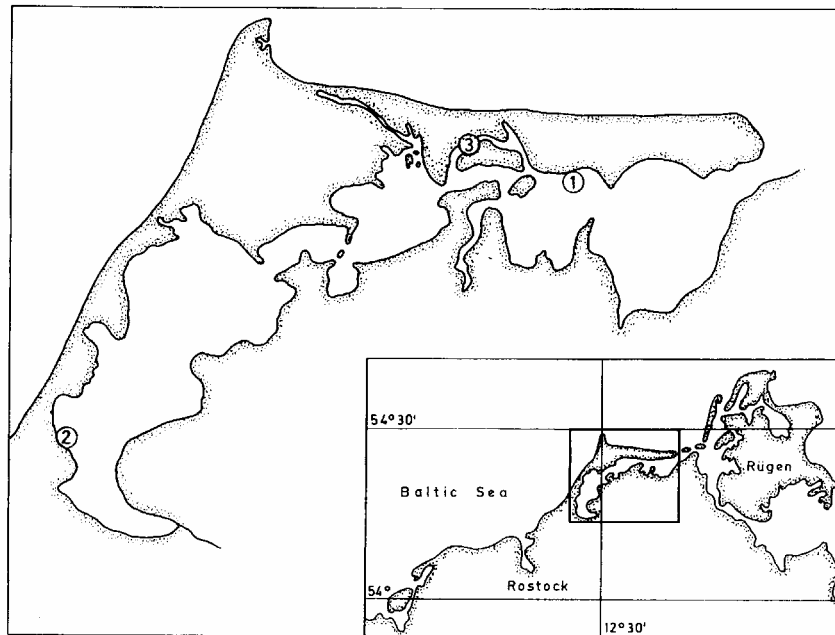


Figure 1: Area of investigation, the bodden chain south of the Darss-Zingst Peninsula, with stations 1-3

Area of investigation

The investigated area (Fig. 1), the bodden chain south of the Darss-Zingst Peninsula (north east of Rostock), is about 40 km long covering an area of 196.7 km² (Correns 1976). The mean depth is 2 m. Salinity is relatively low (1-10 PSU) and is subject to seasonal and interannual fluctuations owing to freshwater inflows and irregular exchange with the open Baltic Sea (Zettler *et al.* 1995). The salinity decreases from east to west, the lowest salinities (1 – 5 PSU) being measured in the inner parts (e.g. station 2) of the bodden chain. At station 1 salinity fluctuates between 6 and 10 PSU, and at station 3 it varies between these extremes. Some other abiotic parameters measured at station 1 and 2 are given in table 1 .

Table 1: Survey of the abiotic parameters at station 1 and 2. Means of the monthly measurement in 1993, with maximum values in parentheses. Chl *a* values for station 1 from Gewässergütebericht 1993 (Umweltminister des Landes Mecklenburg-Vorpommern 1994), Chl *a* values (1992) for station 2 from Schiewer *et al.* (1994)

| | Median grain size (mm) | Fraction < 0.063 mm (%) | Organic content (%) | Water content (%) | Chl <i>a</i> mg·m ⁻³ |
|--------|------------------------|-------------------------|---------------------|-------------------|---------------------------------|
| Stn. 1 | 0.3 (0.33) | 3.19 (12.26) | 1.25 (2.01) | 30.3 (36.83) | 126 (227) |
| Stn. 2 | 0.27 (0.33) | 1.28 (4.04) | 0.49 (1.14) | 23.68 (25.71) | 56.7 (83.9) |



Figure 2: Mean annual salinity (daily measurement) at station 3 from 1969 to 1994; the deviations are the maxima and minima

Methods

From 1969 to 1991, samples were collected only twice a year (spring and autumn) using Ekman-Birge (225 cm²), Hydrobios (250 cm²) and van Veen (600 cm²) grabs penetrating down to 10 cm, and the sieve mesh size was 0.5 mm. Between 1992 and 1994 monthly samples were collected using a corer with a cross section of 78.5 cm² penetrating down to 40 cm, thereby accounting for the vertical distribution of *M. viridis* which has burrows extending down to 35 cm (Zettler *et al.*, 1994). A 0.5 mm mesh sieve was again employed. Three samples per station (1 and 2) were collected, fixed in 4 % borax-buffered formaldehyde and counted in the laboratory under a dissecting microscope (magnification: x10). The biomass of all endobenthic species in each sample was measured to the nearest 0.1 g wet weight and the data expressed per m².

For investigating interspecific interactions Spearman's rank correlations (*r_s*) were calculated for abundances of *M. viridis*, *Hydrobia ventrosa*, *Corophium volutator*, *Hediste diversicolor*, naidids and chironomids. Due to different spatial distributions (Zettler and Bick 1996) a distinction was made between juvenile (up to 70 segments) and adult (> 150 segments) *M. viridis*. Individuals in the range of 70 to 150 segments were classified as intermediate, and were not included in this study.

Results

Salinity

Between 1969 and 1994 the mean annual salinities varied between 3.5 and 8.2 PSU (Fig. 2). The salinity fluctuation patterns at stations 1 and 2 were similar, being 1–2 PSU higher at station 1, and 1–4 PSU lower at station 2. The lowest salinities (mean = 3 PSU) were recorded at the beginning of the 1980s (1979–1981).

Abundances and biomasses

Since the first appearance of *M. viridis* at station 1 in the mid 1980's, its abundance has steadily increased rising from a few hundred ind.·m⁻² to a mean density of 10 000 ind.·m⁻² and a wet weight of 400 g·m⁻² in 1994 (Fig. 3). The spionid now dominates in terms of individual abundance (50 %) and 85 % of biomass. However, this proliferation was not accompanied by a decrease in the numbers of indigenous macrozoobenthic species, and actually the abundances and biomasses of most macrobenthic organisms (*Hediste diversicolor*, *H. ventrosa* and oligochaetes) are now considerably higher than 10 to 20 years ago. *Corophium volutator* has been found at this station only since 1991 (Fig. 3).

The abundances of the polychaetes *M. viridis* and *H. diversicolor* have both increased since 1988, and the nereids have spread to the inner parts of the bodden chain. The numerical density and biomass of *H. diversicolor* has increased five to ten-fold since 1988: the mean individual densities and biomasses recorded for the period 1969 to 1988 were 200 ind.·m⁻² and 10 g·m⁻² respectively, compared to 2 000 ind.·m⁻² and 50 to 100 g·m⁻² respectively in 1994 (Fig. 3).

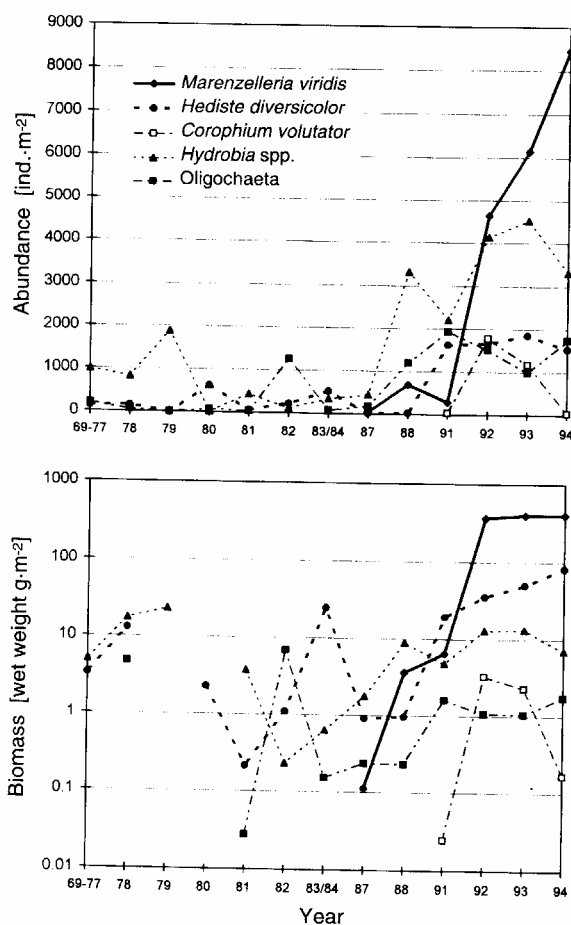


Figure 3: Mean annual abundance and biomass recorded at station 1 from 1969 to 1994 (logarithmic biomass scale); data from 1969-88 Arndt (1988, 1989), Möller (1984), Thiel (1990), for 1991-94 own data

Station 2 is situated in the inner part of the bodden chain (Fig. 1), and has a much lower salinity. *M. viridis* colonized this station 1 or 2 years later than station 1 (Fig. 4). The chironomids (*Chironomus plumosus* and *Ch. halophilus* types) dominated the fauna before the arrival of the spionid and achieved mean annual densities of 200 to 2000 ind. \cdot m $^{-2}$ (max. 6200 ind. \cdot m $^{-2}$) and biomasses of 3 to 10 g \cdot m $^{-2}$ (max. 80 g \cdot m $^{-2}$). Chironomid abundance has not decreased since *M. viridis* was found at the station. The spionid has proliferated since 1990 and, with a mean numerical density of ca. 30 000 ind. \cdot m $^{-2}$ and biomasses of between 350 and 400 g \cdot m $^{-2}$, has achieved a dominance of 95 % in terms of both individuals and biomass in 1993 to 1994.

The abundance values included both juvenile and adults of *M. viridis*. Due to the seasonal occurrence of reproduction in autumn, the abundance are subject to relatively large annual variations. The value at station 1 varied between 6 000 and 11 000 ind. \cdot m $^{-2}$, and at station 2 between 10 000 and 60 000 ind. \cdot m $^{-2}$. The spionid population dynamics at both stations from 1992 to 1993 have been described in detail by Zettler *et al.* (1995).

Marenzelleria viridis in the Darss-Zingst estuary

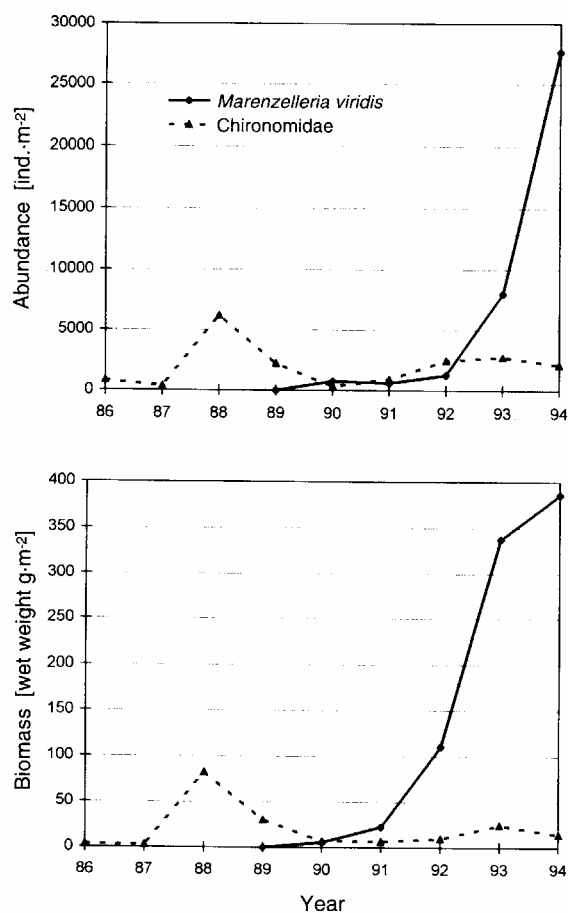


Figure 4: Mean annual abundance and biomass of *Marenzelleria viridis* and chironomids at station 2 from 1986 to 1994; data for 1986-90 from Arndt (1994 and unpubl. data), for 1991-94 own data

Interspecific relationships

Spearman's rank correlation coefficient was calculated using the abundances at station 1 for the summer months in 1992/93 as replicates ($n = 51$), and the results obtained during a study on dispersion patterns at station 2 ($n = 121$) on one day in March 1993 (Zettler and Bick 1996). The results of long term studies were confirmed by Spearman's rank correlation coefficient (r_s) between *M. viridis* (adults and juveniles) and representatives of the indigenous macrozoobenthos (Tab. 2). Significant negative correlations existed only between adult *M. viridis* and *Corophium volutator* and the naidids, respectively. The correlations between juvenile *M. viridis* (up to 70 segments) and the chironomids were significantly positive, whilst there was no significant correlation between *M. viridis* and *H. diversicolor*. Unlike adult *M. viridis*, which positively correlates with the nereid,

the correlation between juvenile *M. viridis* and *Hediste diversicolor* was negative, although neither correlation was significant.

Table 2: Spearman's rank correlation coefficient between adult (> 150 segments) and juvenile (< 70 segments) *Marenzelleria viridis* and other macrozoobenthos taxa (*Hediste diversicolor*, *Corophium volutator*, *Hydrobia ventrosa*, Chironomidae, Naididae). Level of significance: * p < 0.05, ** p < 0.01 and *** p < 0.001

| | adult <i>Marenzelleria viridis</i> n=121 | juvenile <i>Marenzelleria viridis</i> n=121 | <i>Hediste diversicolor</i> n=51 | <i>Coro- phium volutator</i> n=51 | <i>Hydrobia ventrosa</i> n=51 | Chiro- nomidae n=121 | Naididae n=51 |
|--|--|---|---|--|--------------------------------------|----------------------------|------------------|
| adult <i>Marenzelleria viridis</i> | - | 0.272** | 0.131 | -0.384** | -0.025 | 0.051 | -0.314* |
| juvenile <i>Marenzelleria viridis</i> | 0.272** | - | -0.142 | -0.239 | -0.185 | 0.424*** | -0.109 |

Discussion

Marenzelleria viridis has dispersed rapidly throughout the boddens south of the Darss-Zingst and is now the dominant faunistic element. It has colonized a range of habitats varying from almost limnic (0.5 PSU) to brackish water regions up to 10 PSU (Zettler 1993). In view of this rapid increase in terms of both abundance and biomass, a negative impact on the indigenous fauna was expected. However, comparison with pre-invasion data reveal no negative consequences, and on the contrary, colonisation of the substrate by the spionid appears to encourage the proliferation of other organisms. Burrowing organisms have a strong influence on the chemistry and physics of the sediment and water (Aller 1982; Kitlar 1991; Rhoads and Boyer 1982). The tube of *M. viridis* extends down to a depth of 35 cm in the substrate (Zettler *et al.* 1994), and increased bioturbation will certainly effect the chemistry of the substrate. Irrigation by *M. viridis* will increase nutrient supply to the benefit of other organisms (especially algae) in densely colonized regions. Since algae and faeces are important elements of the chironomid diet (Aller 1980; Johnson 1987; Kajak 1987), this might explain the significant positive correlation found between *M. viridis* and chironomids. Gallagher *et al.* (1983) and Woodin (1974) stated that the activity of burrowing organisms, in particular polychaetes, encouraged the settlement of soft substrates, and that inhibition of other taxonomic groups by burrowers was rarely observed. Sarda (pers. comm.), who investigated *M. viridis* in a salt marsh of southern New England, reported similar results and considers this species to be a cold-tolerant opportunist. Unlike Atkins *et al.* (1987), who observed negative correlations between *M. viridis* and *Hediste diversicolor*, we found no evidence for a decrease

in the abundance or biomass of nereids in the bodden chain. Essink and Kleef (1993) also reported reductions in the density of *H. diversicolor* following the appearance of the spionid. However, these were not statistically significant and, unfortunately, no separate data were presented for adults and juveniles. Kolbe (1993) observed no negative correlation between *M. viridis* and *H. diversicolor* in the Weser estuary, Germany. Competition and predation studies (Zettler unpubl.) have shown that adult *M. viridis* (>150 segments) and adult *H. diversicolor* (>80 segments) do not negatively affect each other. Although a negative correlation between adult *H. diversicolor* and juvenile *M. viridis* may be suspected (Tab. 2), the values were not significant and further studies are required.

Salinity measurements showed that periods of relatively high salinity (6-8 PSU) occurred frequently between 1969 and the mid-1980s. The increases in abundance and distribution recorded for many benthic organisms occurred only after the appearance of *M. viridis* at the end of the 1980s, and salinity, therefore, does not appear to be the principal factor explaining these changes.

Comparisons made between the grab and corer as sampling methods showed deviations only for the abundance of species found deeper than 10 cm in the sediment. This included the polychaetes *M. viridis* and *H. diversicolor*. As only the largest individuals of *H. diversicolor* have been found to penetrate deep into the sediment (Zettler *et al.* 1994), a bias in the biomass estimates is possible. The change in sampling technique may have therefore been responsible for the sudden increase in *M. viridis* abundance between 1991 and 1992, although it is unlikely that the long-term trends described here were influenced by changes of sampling methods.

Direct negative interactions are primarily competition (*e.g.* for nutrition and space) and predation. Woodin (1979) stated that tube builders often show spatial partitioning on the sediment surface as well as below the sediment surface, and this may explain the negative correlation between *M. viridis* and *C. volutator*. The latter is known to be prone to trouble through bioturbation (Olafsson and Persson 1986).

Particularly high abundances of *M. viridis* in recently colonized estuaries may be a result of a surplus of food (Dekker 1991; Gosselck *et al.* 1993; Norkko *et al.* 1993; Olenin and Chubarova 1992; Zmudzinsky *et al.* 1993), the native species being prevented from exploiting the available resources by adverse physical factors. The introduced *M. viridis* is evidently well adapted to, and even capable of modifying the local sediment to the benefit of itself as well to other species. It is likely that irrigation and bioturbation activity reduced toxic sulfide concentrations, enhanced nutrient fluxes to the sediment surface (which may promote benthic microalgae) and added fecal material to the sediment texture. It thus may act as an ecological engineer (*sensu* Lawton 1994).

Compared to other coastal regions, the post-glacial recolonization of the Baltic Sea by benthic species appears to be still unfinished (Leppäkoski 1984). This is reflected by an undersaturated species assemblage open to potential invaders such as *Marenzelleria viridis*.

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