

The introduction of *Marenzelleria viridis* (Polychaeta, Spionidae) into the Gulf of Finland and the Gulf of Bothnia (northern Baltic Sea)

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Received 14 August 1996, accepted 16 December 1996

The spionid polychaete *Marenzelleria viridis* (Verrill 1873) was for the first time observed in the Finnish coastal waters at the entrance of the Gulf of Finland in 1990. During 1990–1993 *M. viridis* expanded its distribution into the eastern parts of the Gulf of Finland and into the southern part of the Gulf of Bothnia. Its introduction into the Baltic Sea has probably occurred through ship transport, as all the first findings are connected to harbour areas. Although the abundance and biomass of *M. viridis* is comparatively low the species seems to have become a permanent member of the macrozoobenthos in the northern Baltic.

1. Introduction

During zoobenthos monitoring in 1990, an unidentified polychaete was observed in the samples from the Tvärminne area (NW Gulf of Finland). The specimen was determined as *Marenzelleria viridis* (Verrill 1873) (syn. *Scolecopelides viridis*), a species native of meso- and oligohaline estuaries on the northeastern coast of North America (cf. Maciolek 1984). The first observation of *M. viridis* in the Baltic Sea is from 1985 (Bick & Burckhardt 1989). A revision of species determination regarding spionid polychaetes in the monitoring material (1991–1993), from the area outside Helsinki,

revealed that *M. viridis* was present already in 1991. Since 1992, the species has also been found in the northeastern Gulf of Finland and in the southeastern Gulf of Bothnia.

The aim of the present study is to describe the introduction of *M. viridis* into the northern parts of the Baltic Sea.

2. Material and methods

Four areas in the Gulf of Finland, and one in the Gulf of Bothnia have been sampled (Fig. 1). Details regarding sampling and methods used are given in Table 1.

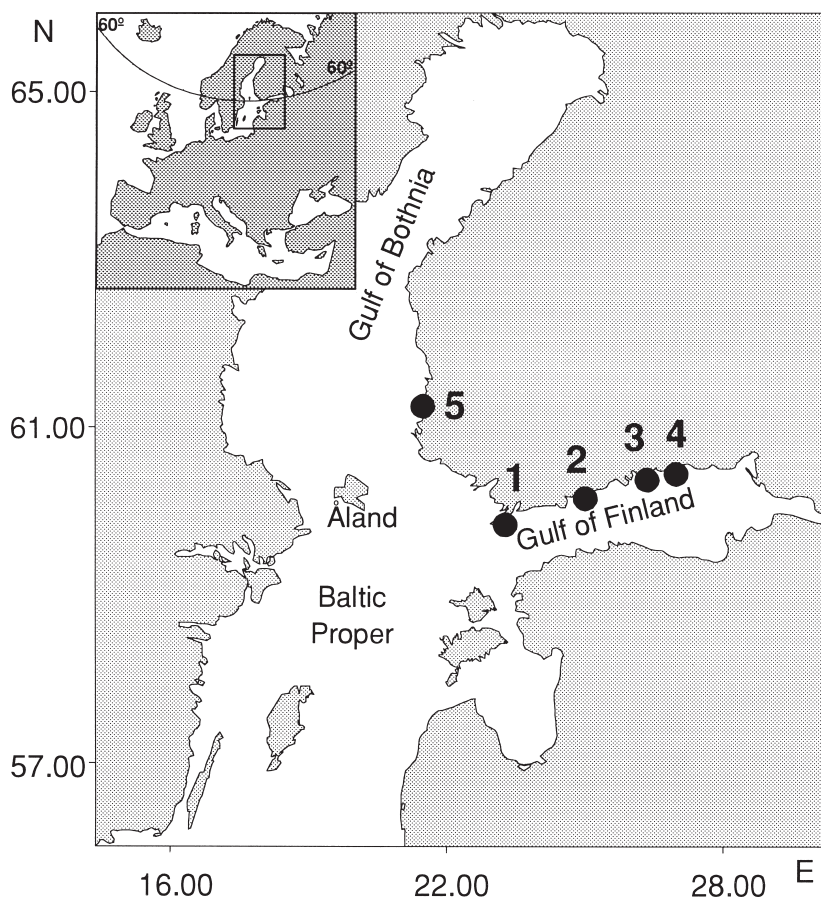


Fig. 1. Localities where *Marenzelleria viridis* has been found in the present study. 1 = Tvärminne, 2 = Helsinki, 3 = Loviisa, 4 = Kotka and 5 = Olkiluoto.

2.1. Tvärminne area

Tvärminne is situated at the entrance of the Gulf of Finland near the Koverhar harbour (Fig. 1). The sediment in the

study area is mainly soft mud, and bottom water salinity varies between 5 and 7‰. For a more detailed description, see Niemi (1975), Kuparinen *et al.* (1984) and Haapala (1995). The macrofauna in the area consists mainly of the lamelli-

Table 1. Summary of the sampling and methods. Sampling gear: V_1 = Van Veen (1 115 cm²), V_2 = Van Veen (1 110 cm²), T = Tube corer (64 cm²), B = Box corer (400 cm²), E = Ekman (250 cm²), E-B = Ekman-Birge (299 cm²). ¹ = samples fixed with formalin before sieving, ² = replicate samples pooled before sieving.

Research area and study	Number of stations	Depth (m)	Sampling gear	Number of replicates	Mesh (mm)	Biomass
Tvärminne						
Monitoring	2	20, 35	V_1	2–5	1 + 0.5	Formalin ww
Case study 1990 ¹	44	3–30	T	1	0.5	None
Case study 1992 ¹	123	3–61	T	1	0.5	None
Case study 1993 ¹						
July	4	9–35	E, B	1	0.5	None
August	36	3–56	T	1	0.5	None
August	3	20	T, B, V_1	20/10/5	0.5	None
Helsinki 1991–1993	10–30	2–60	E, V_2	10/5	0.5	Formalin ww
Kotka 1993	25	12–62	B	1	0.5	None
Loviisa ² 1992–1993	10	7–33	E-B	3–5	0.6	Alcohol ww
Olkiluoto ² 1992–1993	7	6–16	E-B	3–5	0.6	Alcohol ww

branch *Macoma balthica* (L.) and the crustacean *Monoporeia affinis* (Lindström) (Karjala & Lassig 1985). Results from several different soft-bottom macrozoobenthos studies done in the Tvärminne area are included in this report.

Regular monitoring of the soft-bottom zoobenthos in the area has been carried out since 1964 by the Finnish Institute of Marine Research (1964–1986) and by the Finnish Environment Agency (1987 onwards). Samples are taken twice a year from two stations (20 and 35 m) situated in the outer archipelagic zone. During 1990 and 1992 especially the distribution of the macrofauna was studied at locations situated in the middle archipelago (August 1990) and in the outer archipelagic zone (August–September 1992). The samples were taken with 1-m vertical intervals, from 3 to 30 m and from 3 to 61 m, respectively. One sample was taken randomly from each depth zone. The vertical distribution of macrofauna was also studied in 1993, during field courses arranged by the University of Helsinki. The samples were taken with 1- to 2-m intervals in the depth range 2.5–56 m.

2.2. Helsinki area

In the Helsinki area (Fig. 1), zoobenthos has been monitored since the 1960s at ca. 90 stations, of which 15 have been sampled annually from 1989 to 1993 (e.g. Varmo 1988, 1994). The sampling area covers soft bottoms in the depth range 2–60 m, including sand, clay and mud bottoms containing hydrogen sulphide. Salinity varies between 3 and 7‰. In the inner bays the dominant macrofaunal groups are oligochaetes and chironomid larvae, whereas *Monoporeia affinis* and *Macoma balthica* predominate in the outer archipelago (Varmo 1994).

Small individuals of the *Marenzelleria viridis* were at first determined as other polychaete species, mainly *Polydora redeki* Horst. In 1993, however, a revision of the available material (1991–1993) was made. All of the material from 1993 was checked, but only 80 and 55% of the 1991 and 1992 material, respectively, could be controlled.

2.3. Loviisa and Olkiluoto

Macrozoobenthos in the sea areas outside the two Finnish nuclear power plants, Loviisa in the northeastern Gulf of Finland, and Olkiluoto in the southern part of the Gulf of Bothnia (Fig. 1), has been monitored by the Finnish Centre for Radiation and Nuclear Safety since 1967 and 1972, respectively. Samples have been taken twice a year, the number of permanent sampling stations being 10 in Loviisa and 7 in Olkiluoto.

In the Loviisa area the salinity of the near-bottom water has ranged from 3.3 to 5.9‰. The dominant type of bottom sediment is soft sulphide clay or mud. Owing to limited exchange of water in the semi-enclosed basins of the archipelagic zone, the hypolimnic oxygen supply has fre-

quently been exhausted during late-summer (Bagge & Voipio 1967). Due to the low oxygen levels and salinity the bottom fauna is poor in number and consists of only a few species. The tubificid oligochaete *Potamothrix hammoniensis* (Michaelsen) and the midge larvae of the *Chironomus plumosus* L.-group predominate in the benthic communities (Ilus & Keskkitalo 1980).

In the Olkiluoto area the mean salinity is approximately 6‰ (Keskkitalo & Ilus 1987). Due to the narrow archipelago zone, the area is characterised by an effective exchange of water, and the bottom type varies from sulphide clay to sand. The macrofauna consists mainly of *Macoma balthica*.

2.4. Eastern Gulf of Finland

In September 1993, 25 stations in the eastern Gulf of Finland were sampled (Rissanen *et al.* 1995) during a field course arranged by the University of Helsinki. The study area covered ca. 60 km of the coast east of the city of Loviisa (Fig. 1), and extended from the inner bays to the outer parts of the archipelago. Only soft mud bottoms were included in the study. Bottom water salinity ranged from 4 to 6.5‰.

3. Results

3.1. Tvärminne area (western Gulf of Finland)

The first observations of *M. viridis* in the Finnish coastal waters were made in the Tvärminne area in August 1990 (Table 2). The polychaete was found at 3 of the 44 sampled stations, all in the vicinity of the harbour of Koverhar, at the depth of 6–10 m (Fig. 2). The mean abundance was 11 ind./m², which corresponded to 0.3% of the total abundance of the benthic macrofauna in this case study. Monitoring samples taken the same autumn showed that *M. viridis* also occurred at the 20-m deep station (Fig. 3). During the following two years (1991–92) the abundance was low (3–15 ind./m²) at both monitoring stations. This corresponded to 0.3–0.8% of the total abundance. The results from the case study in 1992 showed that *Marenzelleria viridis* had expanded its distribution covering the whole studied depth range from 3 to 60 m. *M. viridis* was found in 36% of the samples and the densities were higher, on average 91 ind./m², corresponding to 2.2% of the total abundance. In the 1993 monitoring samples the abundance of *M. viridis* had increased further to 6–148 ind./m², which corresponded to 0.3 to 8.2% of the total abundance.

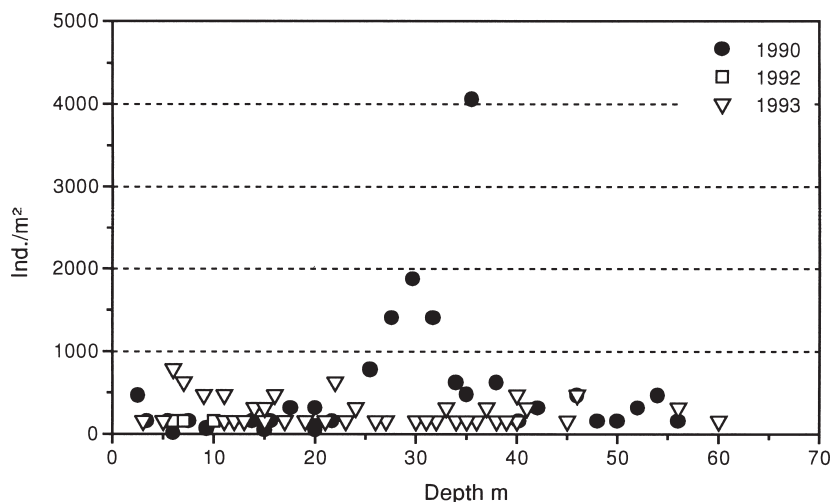


Fig. 2. Abundance (ind./m²) and depth distribution of *Marenzelleria viridis* in the Tvärminne area in the case studies of 1990, 1992 and 1993.

In July–August 1993, *M. viridis* was found between the depths of 2.5 and 56 m, and considerably higher numbers were recorded than in the previous studies. In the 20–40-m depth zone the abundance values exceeded 1 000 ind./m² at 4 of the 14 sampled sites (Fig. 2). The numbers may have been overestimated since it is possible that fragmented parts of animals may have been counted as different individuals by the students. However, fixing of the samples before sieving may

decrease the loss of small individuals and thus cause discernible differences compared with the monitoring results.

3.2. Helsinki area (Central Gulf of Finland)

M. viridis has occurred in the Helsinki sea area since 1991. As the species was first incorrectly determined as *Polydora redeki* it is probable that

Table 2. The distribution of *Marenzelleria viridis* at the localities sampled in 1990–1993. Frequency of occurrence indicates the presence of *M. viridis* in the total number of the sampled sites. Salinity is given for the sites and depths where *M. viridis* were found. ¹ = Tvärminne monitoring sampling, ² = Tvärminne case studies, ³ = Courses arranged by the University of Helsinki.

Sea area and location	Date	Abundance (ind./m ²)		Biomass ww (g/m ²)		Depth of occurrence	Freq. of occurrence	Salinity (psu)
		avg ± 95% <i>c.i.</i>	max.	avg ± 95% <i>c.i.</i>	max.			
Gulf of Finland								
Tvärminne ¹	May, Sep. 90	1±3	6	0.01±0.01	0.02	20, 35	1/4	4.8–7.2
	May, Sep. 91	6±7	12	0.07±0.11	0.24	20, 35	2/4	5.9–6.7
	May, Sep. 92	10±5	15	0.03±0.03	0.06	20, 35	4/4	5.5–6.8
	May, Sep. 93	64±61	148	0.55±0.45	0.98	20, 35	4/4	5.4–7.0
Tvärminne ²	Aug. 90	11±12	157	–	–	6–10	3/44	5.3–5.6
	Aug–Sep. 92	92±28	786	–	–	3–60	44/123	5.5–6.5
Tvärminne ³	July 93	161±214	475	–	–	9–35	4/4	5.4–6.2
	Aug. 93	367±237	4056	–	–	2.5–56	23/36	5.3–6.8
	Aug. 93	161±157	315	–	–	20	3/3	5.5–6.0
Helsinki	Aug.–Nov. 91	5±4	44	0.1±0.08	0.95	7–61	16/27	4.1–6.0
	May–Dec. 92	5±3	9	0.1±0.05	0.18	8–34	7/10	4.9–6.3
	Apr.–Nov. 93	53±33	333	0.3±0.21	2.14	5–34	19/30	4.1–6.9
Loviisa	May, Aug. 92	8±8	67	0.10±0.14	1.30	7–24	6/20	4.2–4.9
	May, Aug. 93	43±43	290	0.48±0.46	2.66	6–12	5/20	4.1–4.8
Kotka	Sep. 93	1±2	25	–	–	14	1/25	4.4
Gulf of Bothnia								
Olkiluoto	May, Aug. 92	0.5±1	7	0.01±0.02	0.10	13	1/14	6.0
	May, Sept. 93	7±9	60	0.19±0.09	1.95	6–15	5/14	5.6–5.7

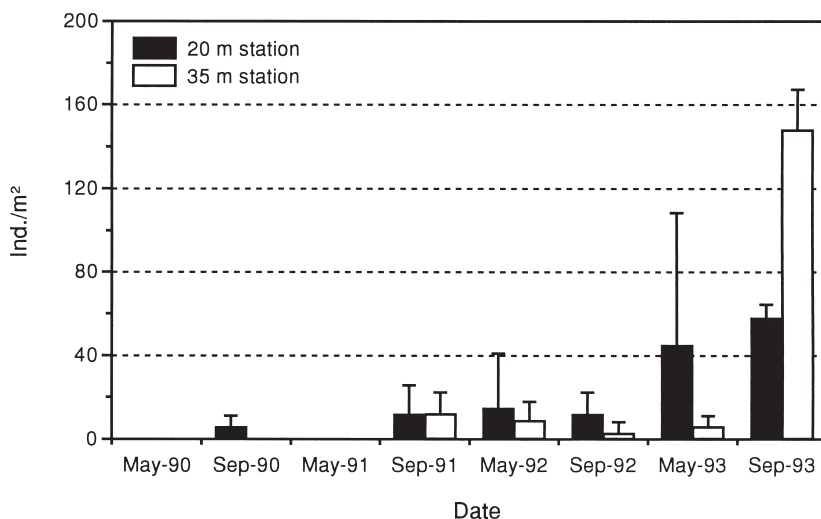


Fig. 3. Changes in the abundance (ind./m² ± S.D.) of *Marenzelleria viridis* at the Tvärminne macrozoobenthos monitoring stations in 1990–93.

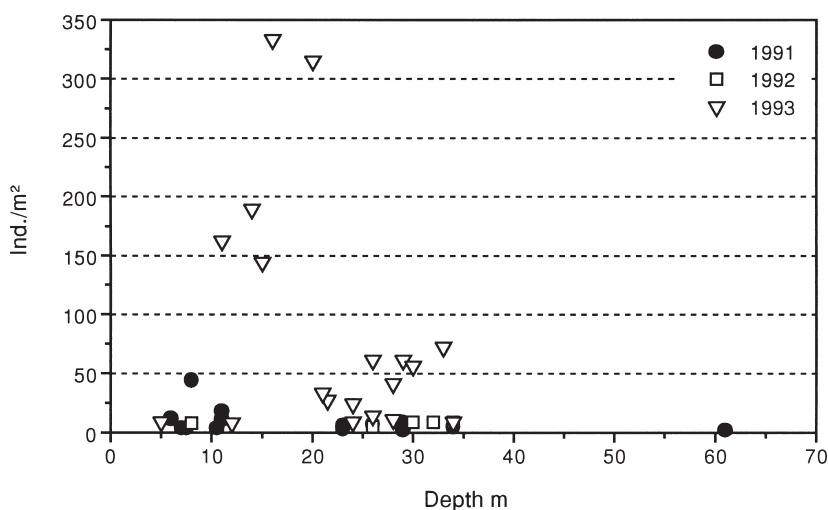


Fig. 4. Abundance (ind./m²) and depth distribution of *Marenzelleria viridis* in the macrozoobenthos monitoring samples from the Helsinki area in 1991–93.

it had invaded the area already in 1990 since the number of *Polydora* observations increased considerably that year. In 1991–92 both the abundance and biomass remained at a low level until higher values, up to 333 ind./m² and 2.14 g/m² ww, were observed in 1993 (Fig. 4). However, the proportion of *M. viridis* did not exceed 11% of the total abundance and 2.5% of the total biomass.

During 1991–93, *M. viridis* has been most frequently found in the outer archipelago and only once in the inner bay areas. In the extensive benthos study of 1991 the species was even found in the highly disturbed harbour areas. In 1993 the highest values were recorded near one of the main municipal waste-water outlets, at a former sand extraction area, and at a dumping area for dredged

sediments. The species was found most frequently in the depth range of 5–35 m, although it has been observed down to a depth of 61 m (in 1991).

3.3. Loviisa area and the eastern Gulf of Finland

The first observation of *Marenzelleria viridis* in the eastern part of the Gulf of Finland was made in the spring of 1992 in the archipelago of Loviisa. At two stations with a depth of 7 m near the cooling water outlet of the nuclear power plant the abundance of *M. viridis* increased from 7–67 ind./m² in 1992, to over 200 ind./m² in the autumn of 1993 (Fig. 5). Thereby, *M. viridis* became the dominant species at one of the two stations, forming

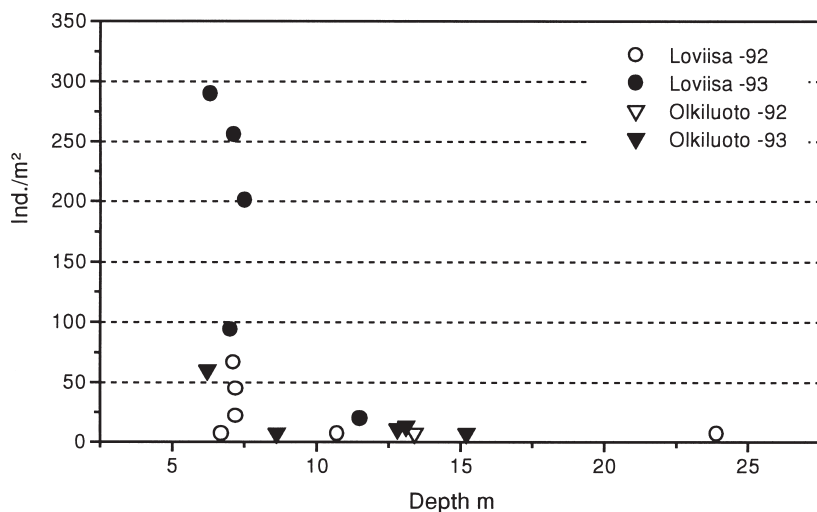


Fig. 5. Abundance (ind./m²) and depth distribution of *Marenzelleria viridis* in the macrozoobenthos monitoring samples from the Loviisa and Olkiluoto area in 1992–93.

52% of the total abundance and 23% of the total biomass of macrofauna. The species was also found in low numbers at three other stations during the period 1992–93.

In September 1993 *M. viridis* was found at only one of the 25 sampled sites in the area east of Loviisa. One specimen was caught in the vicinity of the City of Kotka (Fig. 1), at the depth of 14 m.

3.4. Olkiluoto area (Gulf of Bothnia)

In the autumn of 1992 one specimen of *Marenzelleria viridis* was found in the area outside the Olkiluoto nuclear power plant (Fig. 5). One year later, in the autumn of 1993, *M. viridis* was present at 5 stations (7 to 60 ind./m²). In all cases the percentage of *M. viridis* of the total abundance and biomass was below 5%.

4. Discussion

The introduction of *Marenzelleria viridis* into Europe has apparently taken place through transportation in the ballast water of ships over the Atlantic Ocean (Essink & Kleef 1988). All the first findings of *M. viridis* in this study are connected to harbour areas or main fairways although the widening of the distribution area is most probably due to a combination of ship transport, local reproduction and migration. The species has pelagic larvae, and in addition, juveniles, as well as adults in the re-

productive phase, are reported to move actively in the pelagial during night (Dauer *et al.* 1980).

M. viridis continues to expand its distribution in the Finnish coastal waters and was recorded for the first time in the Åland archipelago in 1993 (Alf Norkko, pers. comm.). In 1996, the polychaete was found in the southern part of the Bothnian Bay (i.e. the northern part of the Gulf of Bothnia) at a 78-m deep monitoring station (Finnish Institute of Marine Research, unpublished data). Norkko *et al.* (1993), also reported the species from the Tvärminne area in 1993, where 400 ind./m² were found at a shallow (4-m) sandy bottom, an abundance comparable with our results.

In the Baltic Sea, *Marenzelleria viridis* has been reported to occur mostly in shallow areas, i.e. only a few metres deep, although the deepest observation is from 90 m (Lagzdins & Pallo 1994, Kube *et al.* 1996). In our material, the species occurred at all sampled depths down to ca. 60 m but the maximum abundance, depending on the area, was found between 6 and 40 m.

Both the bottom type and salinity coincide with the typical habitats described for *M. viridis* in North America, where it occurs in estuaries on bottom types ranging from fine sand to mud (Maciolek 1984), in oligo- to mesohaline areas (George 1966). In the innermost part of the Gulf of Finland, as well as in the Bothnian Bay, the salinity (2–4.5‰) will probably limit its distribution. Although adults and larvae can tolerate and survive very low salinities, the species requires a salinity higher than 5‰ for successful reproduc-

tion (George 1966, Bochert *et al.* 1996).

Our results show that the species tolerates eutrophication and moderate disturbance of the sediment, as it was found in the vicinity of sewage sludge and cooling water outlets, in dumping and sand extraction areas as well as in harbours (cf. Lagzdins & Palo 1994). Bochert and Bick (1995) suggested eutrophication as a factor causing the rapid larval growth observed in the southern Baltic Sea. The results by Fritzsche and Oertzen (1995) showed that *M. viridis* tolerates oxygen deficiency. Furthermore, the remarkable increase of *M. viridis* directly in front of the cooling water outlet of the Loviisa nuclear power plant may indicate its tolerance, or even preference for, thermal discharges in this area. Consequently, it may survive in areas avoided by many other species.

The soft-bottom macrozoobenthos communities in the northern Baltic Sea consist of a few species, the number rarely exceeding 10. Thereby introduced species, such as *M. viridis*, may have a strong influence on the established communities. As a generally selective deposit feeder (cf. Essink & Kleef 1988), *M. viridis* could be a severe competitor to the dominant species on muddy to sandy bottoms in the Baltic Sea. The species' ability to live in deep burrows, penetrating the sediment to a depth of 35 cm (Zettler *et al.* 1995), may reduce predation by invertebrates and fish. An influence of this species on the indigenous benthic communities was reported in the Ems estuary, where the polychaete *Hediste (Nereis) diversicolor* decreased as *Marenzelleria viridis* increased (Essink & Kleef 1988), and in the southern Baltic Sea where a negative correlation between the amphipod *Corophium volutator* and *M. viridis* was observed (Zettler 1995).

M. viridis has shown a remarkable increase in numbers within a relatively short time after its introduction to a new area. In the southern Baltic, *M. viridis* became the dominant species only a few years after its initial appearance (Bochert & Bick 1995, Günter *et al.* 1995, Zettler *et al.* 1995). Similar changes were reported for the Riga Bay where the species corresponded to approx. 40% of the total abundance, five years after its introduction (Lagzdins & Palo 1994).

Despite the deterioration of the macrobenthic communities, observed at several locations during the 1980s (Häkkinä *et al.* 1993, Mattila 1993, Varmo 1994; Tvärminne and Loviisa, unpublished

data), and despite the observed increase in abundance of *M. viridis*, it can be concluded that by 1993 the species had not become such a dominant species as in the more southern parts of the Baltic Sea. However, *M. viridis* is well established in the Finnish coastal waters and seems to have become a permanent member of the macrobenthic communities.

Acknowledgements. This study was supported by the Walter and André de Nottbeck Foundation. We are grateful to Erkki Leppäkoski and Jouko Sarvala for valuable comments on the manuscript.

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