

A comparison between 1928 and 2000 indicates major changes in the macrozoobenthos species composition and abundance on the SW coast of Finland (Baltic Sea)

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Abstract. In 1928, Sven G. Segerstråle made detailed analyses of benthic communities in the Tvärminne region (SW coast of Finland). In addition to traditional presentation, he included illustrative photographs where the collected macroinvertebrates were laid on black background, in natural density, and reproduced in their natural size. This approach was replicated in the present study. The photographs highlight changes that have taken place during the past century in the benthic communities. In the deeper area there has been a change from an amphipod (*Monoporeia affinis*) dominated community to one dominated by the Baltic clam *Macoma baltica*. In the shallower study area the diverse *Corophium volutator*–*M. baltica*–chironomid community has been replaced by a community dominated by *Macoma* and a North American invader, the polychaete *Marenzelleria viridis*. Furthermore, the density of macroinvertebrates has declined considerably. The causes for these changes remain unclear, but are most likely connected to eutrophication related factors in the coastal ecosystem and concurrent interspecific interactions.

Key words: macrozoobenthos, long-term change, Baltic Sea.

INTRODUCTION

Soft bottom macrozoobenthos communities in the northern Baltic Sea have typically a low diversity, resulting often from the high dominance of only a few species adapted to the brackish water conditions (e.g. Andersin et al., 1977;

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Elmgren, 1978). Both long-term trends and sudden changes have been reported in the communities, illustrating high variability in abundance and changes in the species composition (Segerstråle, 1960a; Karjala & Lassig, 1985; Andersin & Sandler, 1991; Laine et al., 1997; Hänninen & Vuorinen, 2001). The main abiotic factors causing both spatial and temporal variability in the communities include salinity and oxygen conditions (Andersin et al., 1977; Bonsdorff et al., 1996; Laine et al., 1997; Bonsdorff & Pearson, 1999) but also changes caused by food availability and eutrophication have been suggested (Cederwall & Elmgren, 1980; Bonsdorff et al., 1997; Lehtonen & Andersin, 1998). In addition, complex intra- and interspecific competition and predation effects have been demonstrated (Uitto & Sarvala, 1990; Bonsdorff & Blomqvist, 1993; Ejdung & Elmgren, 1998) and settlement of nonindigenous species has added new components to the species poor benthic communities (Stigzelius et al., 1997), which may affect the original species (e.g. Kotta et al., 2001).

In the 1920s Segerstråle (1933a, 1933b) started extensive quantitative macrofauna studies on the SW coast of Finland, which now serve as a valuable reference for the long-term change of the communities. The studies in the Tvärminne area were continued sporadically during the following decades (Segerstråle, 1960b) and since 1964 two of the sampling stations established by Segerstråle have been monitored annually (Karjala & Lassig, 1985). Macrofauna communities have notably changed in the Finnish coastal waters during the last decades. A common feature seems to be a deterioration of the communities, especially a decline of the formerly abundant amphipod populations (Mattila, 1993; Varmo, 1994; Valkama & Anttila-Huhtinen, 2000; Kangas et al., 2001). However, many of these studies have been made in areas affected by direct pollution (municipal or industrial) and reference to an unaffected state is meager. The Tvärminne area has been considered as a relatively unaffected area and it can be suggested that the 1920s represent a period with only minor anthropogenic effects.

In the studies conducted in 1928, Segerstråle (1933b) presented detailed descriptions of benthic communities in the Tvärminne region. He included illustrative photographs where the collected macroinvertebrates were reproduced in their natural size and density. In the present study we replicated this approach by taking benthos samples from the same locations and photographing the specimens in the same way as Segerstråle did. The aim of this study is to demonstrate differences in the macrozoobenthos communities over a period of more than 70 years.

MATERIAL AND METHODS

The study area is located in SW Finland, in the archipelago area of the western Gulf of Finland. Two sampling sites (Fig. 1) studied in September–October 1928 (Segerstråle, 1933a) were revisited in July 2000.

Station I is located in shallow and sheltered Krogarviken Bay just outside the Tvärminne Zoological Station. Bottom samples were taken from 3 m depth.

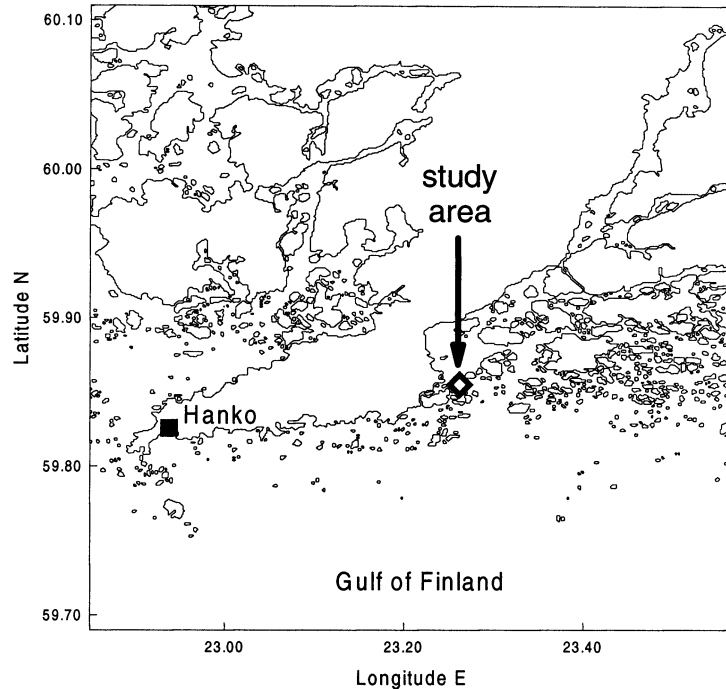


Fig. 1. Location of the study area on the SW coast of Finland, Baltic Sea.

Samples consisted of soft mud rich in organic debris. Segerstråle (1933a) described the bottom as dark gray mud and some sand, with relatively heterogeneous and coarse detritus, thus corresponding to the present samples. Station XLIV is located in the more open Storfjärden basin, with a depth of 35 m. According to Segerstråle (1933a) the bottom consists of soft, blackish mud with relatively fine and homogeneous detritus. This is in line with the sampling in 2000.

In 1928 an Ekman-Birge grab was used, with a sampling area of 0.023 m^2 . At station I 30 samples were taken, thus covering a total area of 0.70 m^2 . At station XLIV 25 samples were taken, corresponding to 0.59 m^2 . The samples were washed with seawater on a 1-mm sieve, preserved, and afterwards identified and counted. Specimens were laid on black cardboard (area 0.018 m^2) at a natural density and photographed (Segerstråle, 1933a, 1933b).

In 2000 samples were taken with a Van Veen grab, which samples an area of 0.1052 m^2 . Only one sample was taken at both stations. The samples were washed with seawater on a 1-mm sieve and counted and identified under a dissecting microscope. As in 1928, specimens were laid on black background (area 0.018 m^2) at a density representing the natural situation on the bottom and photographed with a digital camera. Rare species that occurred at a density less than one specimen on the photographed area are represented in the inserted smaller pictures.

RESULTS

At the 3-m station I a change from a *Corophium volutator*–*Macoma baltica*–Chironomidae community to one dominated by *M. baltica* had occurred. In 1928, 14 species were recorded compared to 8 species in 2000 (Table 1, Figs. 2 and 3). There also was a decline in total abundance from 4676 ind. m⁻² in 1928 to 345 ind. m⁻² in 2000. As many as 11 species, including all crustacean species, had disappeared and only 3 species were found that occurred both in 1928 and 2000. One of the four new species in 2000 was the North American invader *Marenzelleria viridis* (Polychaeta).

Table 1. Macrozoobenthos density (ind. m⁻²) in 1928 (Segerstråle, 1933b) and in 2000 at stations I and XLIV. The numbers in bold represent the most abundant species shown in the main pictures in Figs. 3 and 4

Species	Station I		Station XLIV	
	30.09.1928	03.07.2000	03.10.1928	03.07.2000
Nemertinea				
<i>Prostoma obscurum</i>	1		2	
Priapulida				
<i>Halicryptus spinulosus</i>			75	
Oligochaeta		10		
<i>Tubifex tubifex</i>	67			
Polychaeta				
<i>Nereis diversicolor</i>		10		
<i>Harmothoe sarsi</i>			145	19
<i>Marenzelleria viridis</i>		95		19
Crustacea				
<i>Asellus aquaticus</i>	3			
<i>Saduria entomon</i>	1		14	200
<i>Corophium volutator</i>	2433			
<i>Gammarus locusta</i>	67			
<i>Monoporeia affinis</i>	46		7006	57
<i>Pontoporeia femorata</i>			9	
Gastropoda				
<i>Theodoxus fluviatilis</i>	4	10		
<i>Bithynia tentaculata</i>	3			
<i>Potamopyrgus jenkinsi</i>		10		
<i>Hydrobia</i> sp.		10		
Bivalvia				
<i>Cardium edule</i>	14	10		
<i>Macoma baltica</i>	1078	190	353	990
Insecta				
Chironomidae	942			
Trichoptera	16			
<i>Sialis lutaria</i>	1			
Total ind. m ⁻²	4676	345	7604	1285
No. of taxa	14	8	7	5

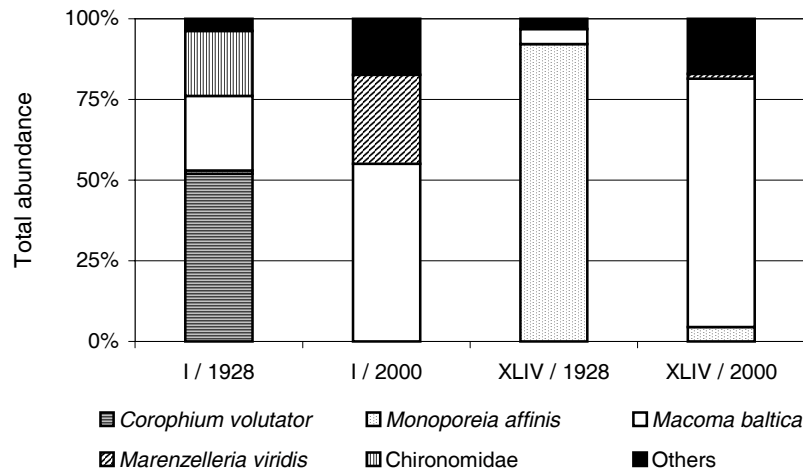


Fig. 2. A comparison of the community structure at stations I and XLIV in 1928 and 2000.

At the 35-m station XLIV the earlier amphipod *Monoporeia* (*Pontoporeia*) *affinis* dominated community had changed to a *Macoma baltica* dominated assemblage (Table 1, Figs. 2 and 4). Concurrently, the total abundance declined from 7600 ind. m⁻² in 1928 to less than 1300 ind. m⁻² in 2000. The most drastic change was the decline of *M. affinis*, contributing to more than 90% of the total abundance in the late 1920s, compared to less than 5% in 2000. *M. baltica* had increased in abundance, and made up more than 75% of the total abundance in 2000. Compared to the shallower site, the difference in the species composition seems to be smaller (7 and 5 species in 1928 and 2000, respectively, with 4 common species).

DISCUSSION AND CONCLUSIONS

Changes in the macrofauna community

The results showed distinct differences between the two sampling occasions, a 6- to 14-fold decline in the total abundance and changes in the species composition. In 1928 the communities were dominated by deposit-feeding amphipods, *Corophium volutator* (station I) and *Monoporeia affinis* (station XLIV), while in 2000 *Macoma baltica* clearly dominated in abundance at both sites. This has resulted in a greater similarity in the community structure between the two sites in 2000. Despite the smaller total abundance today, the biomass of the community at the deeper site is obviously much higher due to the presence of large *Macoma*.

However, caution is needed when drawing conclusions on changes that have taken place between the two samplings. In this case we know that the abundant

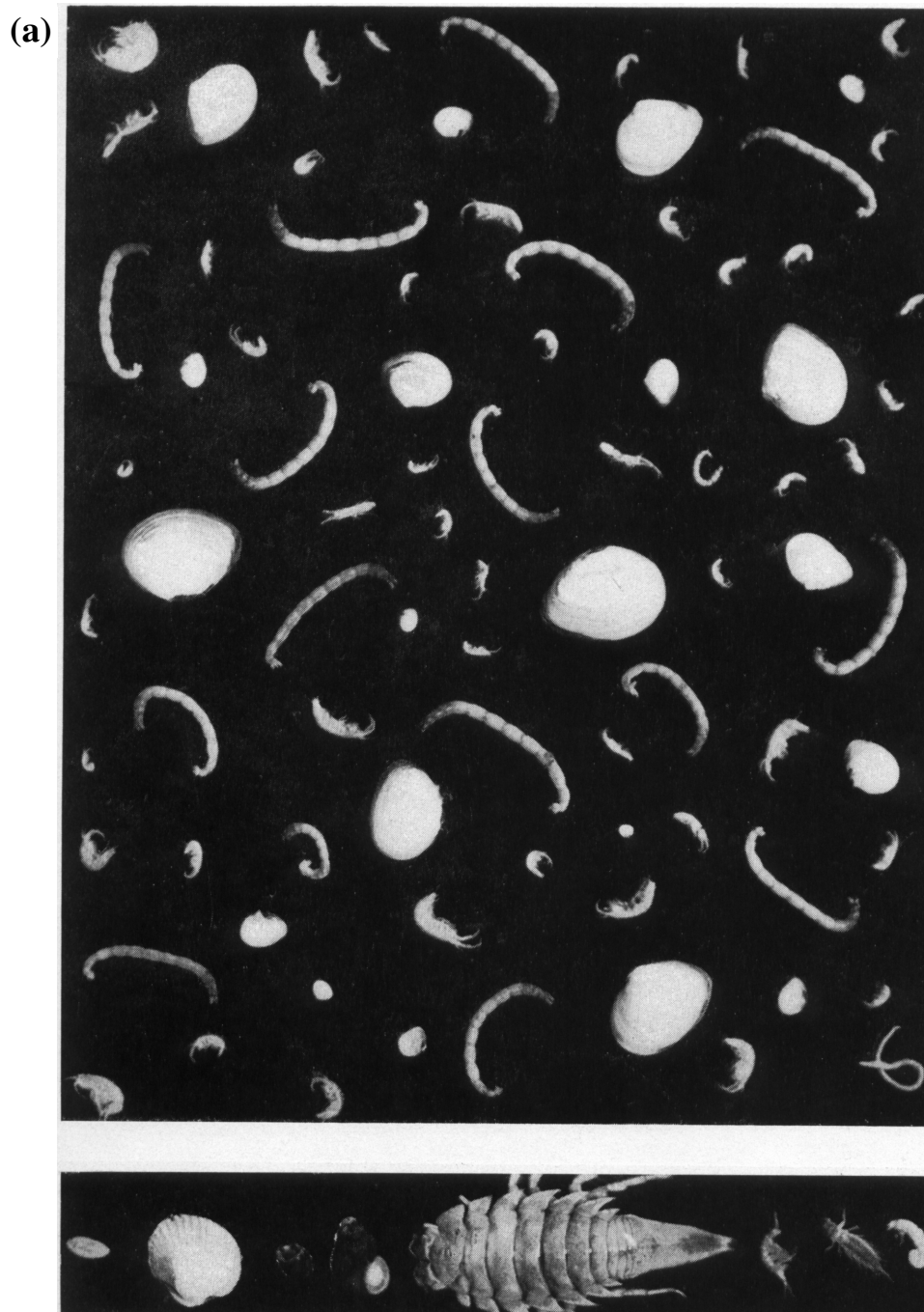


Fig. 3. Macrozoobenthos community at station I (3 m) photographed in its natural density in (a) 1928 (Segerstråle, 1933b) and (b) 2000. The area of the main picture is 0.018 m². The inserted smaller pictures below show rare species, with a density less than the depicted area (<56 ind. m⁻²) See Table 1 for the species list.

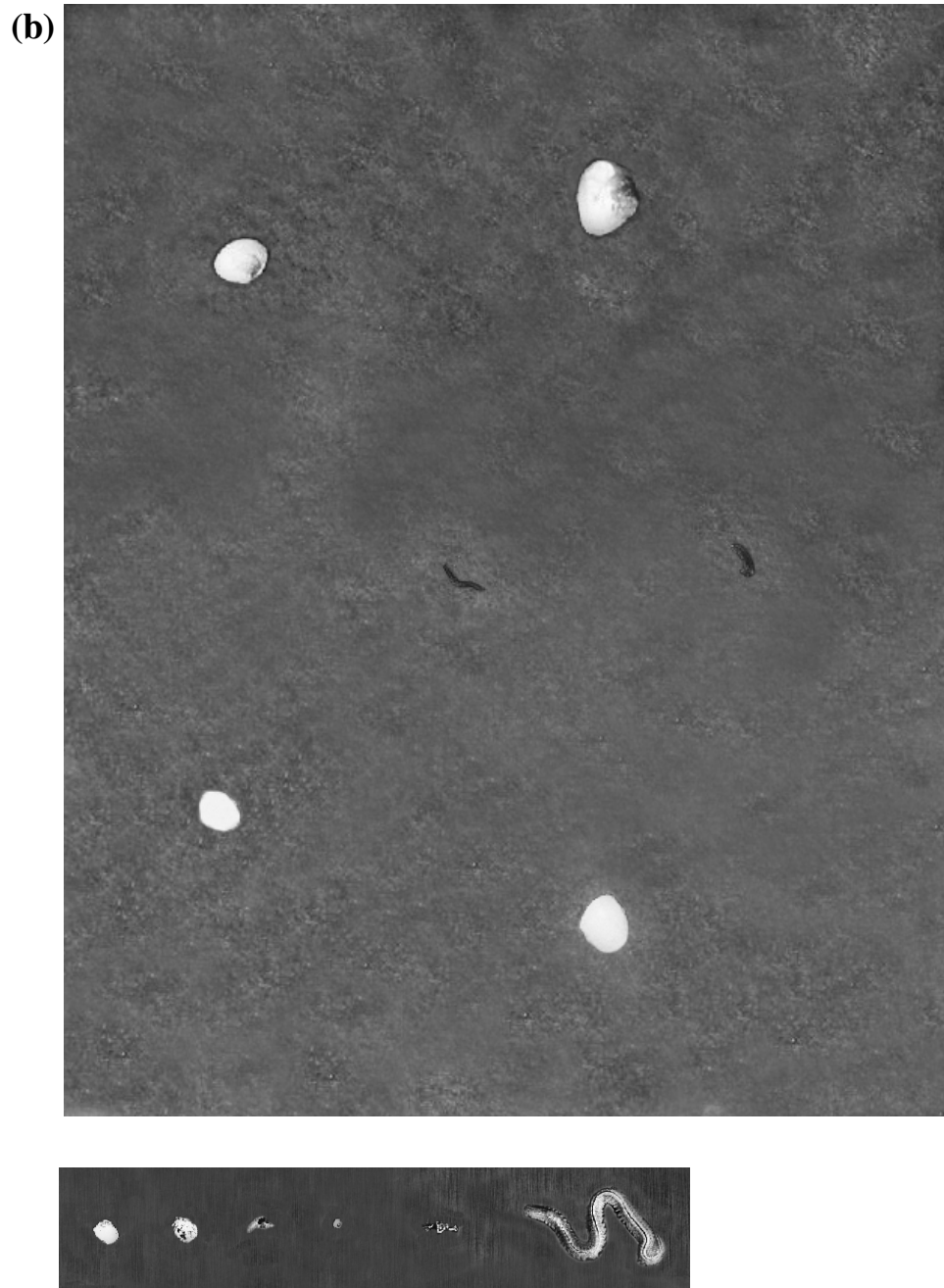


Fig. 3. *Continued.*



Fig. 4. Macrozoobenthos community at station XLIV (35 m) photographed in its natural density in (a) 1928 (Segerstråle, 1933b) and (b) 2000. The area of the main picture is 0.018 m². The inserted smaller pictures below show rare species, with a density less than the depicted area (< 56 ind. m⁻²). See Table 1 for the species list.

(b)



Fig. 4. *Continued.*

Chironomidae, *Corophium volutator*, and *Monoporeia affinis* populations recorded in 1928 decreased dramatically in the following years (Segerstråle, 1960a), thus not necessarily representing a lasting state of the communities. In the case of *M. affinis*, a true long-term decline has been observed in the study area since the high-abundance period in the 1960s and 1970s, accompanied by a distinct increase of *M. baltica*. This species was abundant also in the 1920s–30s but occurred in low abundance for decades until the recent increase in the 1990s (Segerstråle, 1960b; Karjala & Lassig, 1985; Kangas et al., 2001). For *C. volutator* a decline since the 1970s has been reported on shallow sandy bottoms (Boström et al., 2002). The truly new species found at both sites, the North American polychaete *Marenzelleria viridis*, was introduced to the Baltic Sea in 1985 and was found for the first time in the Tvärminne area in 1990 (Stigzelius et al., 1997). Since then the species seems to have established permanent populations and is found commonly in coastal waters (e.g. Norha, 2001; Perus et al., 2001).

We recognize that our study only shows two snapshots in time. In the light of other studies we, however, consider these snapshots representative ones, correctly illustrating the change in benthic communities that has taken place in the study area.

Could methodological differences explain the observed differences?

Methodological differences may affect results (Ankar et al., 1979; Elliott & Drake, 1981) but are unlikely to explain the observed differences in the community structure. The main factors of concern in this study are the difference in the grab type and sample size. The Van Veen grab is much heavier and obviously penetrates deeper in the sediment than the light Ekman corer used by Segerstråle (1933a, 1933b). Therefore, the number of deep burrowing animals could be underestimated in the 1928 material. In 1928 the total area sampled was smaller; however, due to the high number of samples per station, rare species are obviously better represented in the earlier material and can partly explain the higher number of observed species. However, both methods are obviously adequate for studying major differences between the samplings. The sieve size and the difference in the sampling time may affect the number of small amphipods. However, according to Uitto & Sarvala (1991) the 0+ age group of *Monoporeia* reaches a length of 3 mm by July and thus these factors are unlikely to explain the considerable difference in the abundance between the two sampling occasions. In general, the present results for the deeper station XLIV agree well with the monitoring data for the area (Kangas et al., 2001).

Changes in the environment and interspecific interactions

One of the main environmental factors affecting species distribution and community structure in the Baltic Sea is salinity (e.g. Segerstråle, 1965; Bonsdorff & Pearson, 1999). In the 1930s a salinity minimum prevailed in the northern

Baltic and a maximum was experienced in the late 1970s. Since then salinity has been decreasing almost continuously, followed by a small increase again in the late 1990s (Alenius & Haapala, 1992; Alenius et al., 1998). In the study area salinity has declined by 1 psu since the 1970s when near-bottom values exceeding 7 psu were observed (Finnish Institute of Marine Research, unpublished data). Thus both sampling occasions represent low-salinity periods and are comparable in this respect. However, low surface temperatures were recorded in the 1920s (Alenius & Haapala, 1992), which could have contributed to the occurrence of the cold-stenothermal *M. affinis* in the shallow waters (Segerstråle, 1978).

Eutrophication of the Baltic Sea has been documented since the 1950s (Larsson et al., 1985; Nehring & Matthäus, 1991) and for example deposition of organic matter has been estimated to have almost doubled in the northern Baltic proper during the last decade (Jonsson & Carman, 1994). In the Gulf of Finland an intensification of the spring bloom has been observed (Grönlund & Leppänen, 1992) and an increase in the nutrient concentrations was observed again in the late 1990s (Perttilä et al., 1995; Kuparinen & Tuominen, 2001; Pitkänen et al., 2001a). Stratification related oxygen deficiency has been mainly considered a problem of the deeper subhalocline areas and some local isolated basins in the archipelago (Bagge & Voipio, 1967; Andersin & Sandler, 1991). Recently there has been increasing concern about the deterioration of bottoms in the more coastal waters as well, manifested as increasing loading of organic matter, more frequent hypoxia, and consequently increased internal loading (Rosenberg & Diaz, 1993; Bonsdorff et al., 1997; Pitkänen et al., 2001a, 2001b). In the study area, however, no direct evidence exists on changes in the oxygen conditions, this is also supported by the presence of permanent infauna. On the other hand, the decline of *M. affinis* and the increase of *M. baltica* are in agreement with the species response to eutrophication, as studied by Leppäkoski (1975). It has been suggested that *M. baltica* populations thrive in areas where disturbance generated by *M. affinis* is minimal, thus allowing successful recruitment of *M. baltica* larvae (Segerstråle, 1973; Ejdung & Elmgren, 1998). The scarcity of the amphipods could explain the abundance of *Macoma* in the present study.

In conclusion, a considerable decline in the abundance and a change from an amphipod to a bivalve dominated community were observed when comparing the present results to previous findings. The reasons underlying these changes remain unresolved, but as the salinity level during both periods was similar, we suggest that they are most likely connected to eutrophication related factors in the coastal ecosystem and concurrent interspecific interactions.

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Olulised muutused Soome edelaosa rannikumere põhjaloostiku liigilises koosseisus ja arvukuses – 1928. ja 2000. aasta võrdlus

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1928. aastal uuris Sven G. Segerstråle Tvärminne regiooni põhjakooslusi (Soome edelaosa rannikumeri). Lisaks traditsioonilisele esitusele ta ka fotografeeris uuritud kooslusi. Loomad olid asetatud mustale taustale ning nende paigutus vastas looduslikule asustustihedusele. Siinses uuringus kasutati sama meetodikat. Fotode võrdlus näitab, et loomakooslused on viimase sajandi jooksul oluliselt muutunud. Sügavamatel aladel on kirpvähi (*Monoporeia affinis*) kooslus asendunud balti lamekarbi (*Macoma baltica*) kooslusega. Madalamatel aladel on mitmekesine *Corophium volutator*-i-*Macoma baltica*-Chironomidae kooslus asendunud *Macoma baltica* ja Põhja-Ameerika tulnukliigi *Marenzelleria viridis*-e kooslustega. Lisaks on suurselgrootute asustustihedus oluliselt vähenenud. Muutuste põhjused on ebaselged, kuid suure tõenäosusega võib neid seostada eutrofeerumisnähtustega ning sellest tulenevate muutustega liikidevahelistes vastastikmõjudes.