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Soft bottom macrobenthos in a Baltic archipelago: Spatial variation and optimal sampling strategy

Michaela Aschan

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Macrozoobenthos was surveyed in August 1982 close to Tvärminne Zoological Station on the SW coast of Finland. In a stratified random design 117 core samples were taken from 41 stations at a depth of 15 m to 47 m.

Abundance was high (mean at 9 200 ind /m^2) and biomass was low (mean at 69.1 g/m^2). While the single remote corer used has a high sampling efficiency, the high abundance may indicate a community change in the Baltic Sea during the last 50 years or it may be related to the maximum abundances in the 6–7 year population fluctuation pattern.

The depth gradient was the most important environmental variable affecting the faunal composition at the stations and within the geographical strata. In an optimal sampling design in the study area, the stations should be randomly distributed within strata defined by depth. Only one sample unit at each station is recommended, whereas the number of stations should be high, especially in shallow (< 20 m) areas.

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1. Introduction

The macrozoobenthos of the Baltic Sea has been studied by several researchers. The first quantitative studies were carried out by Segerstråle (1933a, b) in the Tvärminne area and the Pellinge archipelago in the Gulf of Finland. Segerstråle continued his work at Tvärminne (1937, 1938, 1959, 1960, 1973) and was followed by Lappalainen (1973), Luotamo (1974), Hällfors et al. (1975), Lappalainen & Kangas (1975a), Lappalainen et al. (1977), Karjala & Lassig (1985) and Sarvala (1971, 1985). All these surveys have concentrated on comparing stations within space and time. However, little attention has been given to spatial variation and sampling strategy in macrozoobenthos studies in the Tvärminne area.

In the Baltic Sea a macrozoobenthos study based on stratified random sampling, investigating spatial variation, has been carried out by Ankar & Elmgren (1976) in the Askö area. Similar surveys have been made by Coleman et al. (1978) and Cuff & Coleman (1979) in Western Port (Victoria, Australia) and Saila et al. (1976) in the New York Bight. They also present optimal sampling designs for macrozoobenthic studies where the objective is to characterize spatial faunal composition as was the case in this study. Millard & Lettenmaier (1986) present an optimal sampling design when the objective is detection of ecological change over time.

In this survey the community structure of the macrozoobenthos in the Tvärminne area is mapped in order to show the spatial variation and to calculate an optimal sampling design for the area. The stations were chosen by stratified random sampling and subareas and depth zones were compared. The optimal stratification and the best allocation of sampling units within these strata were estimated in order to discover the optimal survey design for the area studied.

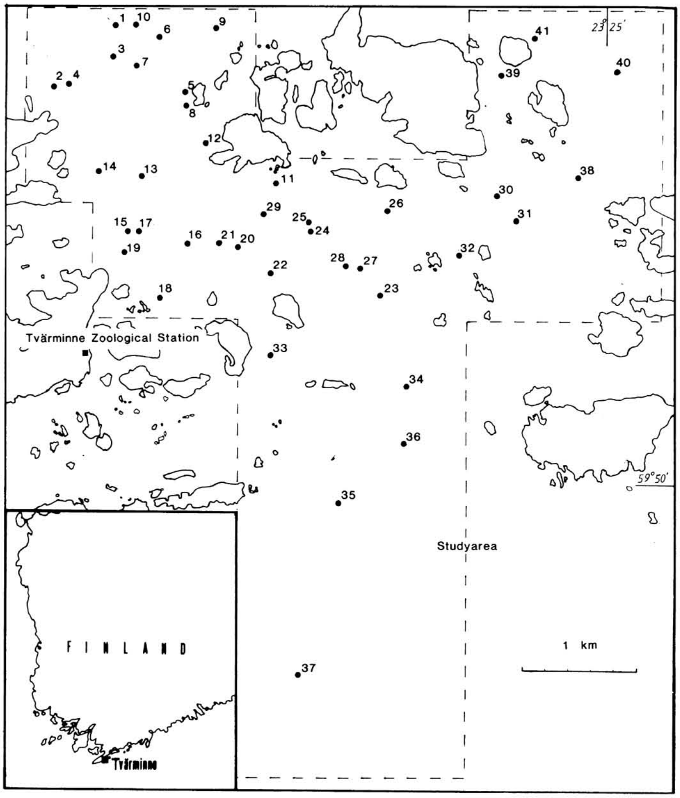

Fig 1. The study area. Stations are shown as dots.

2. Study area

This survey was based on data collected within a 20 km² area fronting the Tvärminne Zoological Station, which is situated on the SW coast of Finland (Fig. 1). The Tvärminne area is among the most thoroughly investigated areas in the Baltic Sea. Häyrén (1931) and Luther (1951) have described the general characteristics of the area, whereas its hydrography and primary production have been studied by Witting (1914), Voipio (1968), Niemi (1973), and Kuparinen et al. (1984). The study area belongs to the outer archipelago (Häyrén 1931). The bottom deepens evenly towards the open sea without sills and the water exchange in the area is good (Luotamo 1974).

Most of the area is between 20 m and 40 m in depth and the maximum depth is 50 m. The shallow bottoms consist of glacial clays, silt, sand and stones, whereas recent clays, mud and ooze dominate in deeper bottoms. The salinity is stable, varying around 6‰, whereas temperature varied, with season and depth, from 0°C to 20°C (Hällfors et al. 1975). Salinity and temperature are presented in Fig. 2.

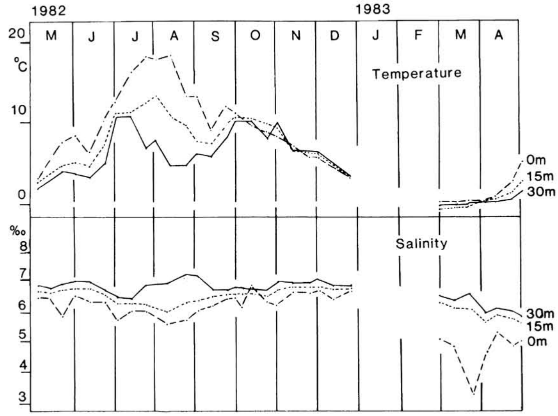

Fig. 2. Temperature and salinity at 0 m, 15 m and 30 m depth at Tvärminne Storfjärden, from May 1982 to May 1983 (Data from the Finnish Institute for Marine Research).

3. Material and methods

3.1. Sampling strategy

The study area was divided into 20 strata e.g. rectangular areas of 1 km² each. Seven stations were chosen in each stratum, using a grid and a random number table. Stations that happened to be on land or were shallow (< 3 m) were not included. The samples were taken in August 1982. If the bottom was too hard,

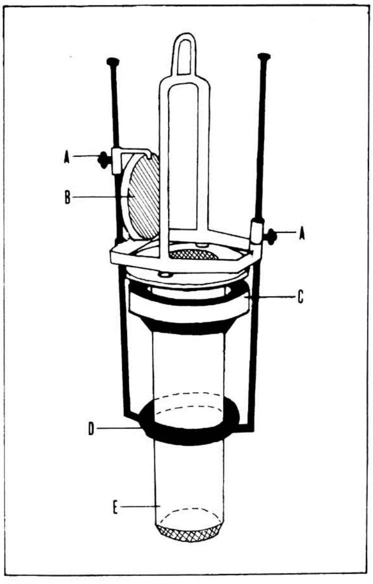

Fig. 3. The single remote corer. A: screws for regulating the position of the copper ring and thereby depth of sample, B: lid, C: lead ring, D: copper ring which is pulled upwards as E: a tube of acrylic plastic, of 8.5 cm diameter, penetrates the sediment.

and sampling not successful after five attempts, another station was chosen. The aim was to have five stations within each stratum.

Five sampling units were taken at each station, but at deep stations only 1–4 samples were taken due to high wave action and a hard or very soft bottom structure. The sampler used was a 56.7 cm² single remote corer (T. Sjölund & J. Sarvala unpublished; see Fig. 3) that resembles the corer of Frithsen et al. (1983).

3.2. Treatment of samples

The sediment quality was roughly characterised as the sample was extruded from the corer. Each sample was washed on a 0.5 mm screen and preserved with buffered 4% formaldehyde. The recommendations of BMB (Dybern 1976) were followed. The animals were identified to species level, with the exception of individuals belonging to the Nematoda, Oligochaeta and Chironomidae. The individuals of *Pontoporeia affinis* were divided into two age groups 0+ (≤ 6 mm) and 1+ (> 6 mm). Biomasses for species are given as formaldehyde wet weight. Bivalve shells were weighed separately and then added to the biomass of the animals in each sample.

3.3. Mathematical and statistical treatment

The mean values and the standard deviation for the biomass and the abundance for the species at each station were calculated. Variance within and between depth classes, and five a posteriori geographical strata representing different degrees of exposure are given (Fig. 4). The stations and the species were ordinated with Principal Components Analysis (PCA), Reciprocal Averaging (RA) and Detrended Correspondence Analysis (DCA) (see Gauch 1982).

The three factors that affect the number of sampling units required for quantitative sampling are the desired precision, the mean catch and aggregation of the fauna being sampled (Holme & McIntyre 1984). The variance to mean ratio is a good measure for the degree of aggregation of a species. The distribution of a population is regular if the ratio is < 1, random if the ratio is = 1 and aggregated if the value is > 1 (Elliott 1977).

For determining the optimal sampling strategy three methods were used:

1. The optimal number of samples (n) for each species in the whole area and for *Pontoporeia affinis* in each depth class was determined as Elliott (1977) and Eberhardt (1978) suggest,

$$n = \frac{s^2}{D^2 x^2} = \frac{s^2 \cdot 25}{x^2} \quad \text{for an error of 20 \%,} \qquad (1)$$

where D is the index of precision, $\bar{x}$ is the mean of number of individuals and s^2 is the variance.

2. The optimal number of grab samples (n_s) taken at each station (n_p) were calculated separately for the five a posteriori chosen depth classes (h), according to Som (1973) as

$$n = \sqrt{\frac{V_{2h} \cdot C_1}{V_{1h} \cdot C_2}} , \qquad (2)$$

where C_1 is the variable cost for visiting a station (n_s) and C_2 is the cost of taking a grab sample (n_p) and treating it in the laboratory. C_1 was calculated to 10 \$ and C_2 to 40 \$. The variance V_{2h} is the variance within the stations, and V_{1h} is the variance between stations in the same depth class (h).

3. The number of stations (n_p) and replicates (n_s) necessary in each depth class was calculated for four common species with an acceptable level of confidence (90%), where the estimated mean is within ± 50% of the mean (Saila et al. 1976). The variance of the mean $\sigma_{\bar{x}}^2$ is expressed as

$$\sigma_{\bar{x}}^2 = \frac{\sigma_p^2}{n_p} + \frac{\sigma_s^2}{n_p \cdot n_s} , \qquad (3)$$

where σ_p^2 is the population variance due to sampling between depth classes and σ_s^2 is the population variance due to sampling within depth classes. The equation for total costs C_t is written as

$$C_t = n_p \cdot C_1 + n_p \cdot n_s \cdot C_2. \qquad (4)$$

In this equation the same C_1 and C_2 values as in equation (2) are used. Saila et al. (1976) use the same value for C_1 and C_2, but C_1 will only express the costs for visiting a station, whereas C_2 includes field and laboratory work (Cuff & Coleman 1979).

Table 1. Mean ± *SE* and percent share for species abundance and biomass. *F*-values show the ratio of between station to within station variances for abundance. Significance shown as * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

	Abundance (ind./m²)	%	Biomass (g/m²)	%	*F*
Halicryptus spinulosus	72 ± 11	0.8	0.47	0.68	2.25***
Oligochaeta	10 ± 10	0.1	0.02	0.02	1.10
Harmothoe sarsi	1834 ± 94	20.5	1.41	2.05	6.98***
Pontoporeia affinis	6252 ± 267	68.2	22.57	32.69	16.99***
Pontoporeia femorata	483 ± 58	5.3	3.36	4.87	25.44***
Mesidotea entomon	18 ± 4	0.2	2.42	3.50	1.56*
Mysis mixta	73 ± 9	0.8	1.17	1.70	1.48*
Chironomidae larvae	59 ± 12	0.6	0.21	0.22	6.19***
Macoma balthica	319 ± 41	3.5	37.48	54.27	9.09***
Total	9156 ± 313	100	69.11	100	14.74***

C_t is minimised (equation 4) subject to equation (3), where d is defined as half the confidence interval about the mean at a 90% level of probability, $d=1.645\sigma_{\bar{x}}$, then $\sigma_{\bar{x}}^2=(d/1.645)^2$, in order to obtain the n_p and n_s values (Saila et al. 1976).

4. Results

4.1. Station characteristics

Because of bad weather conditions only 79 of the originally 100 stations were visited. At 38 stations the sampling was unsuccessful due to a hard or very soft bottom and 117 samples were taken from 41 stations. All the stations represent soft bottoms containing soft clay, mud and ooze, silt and often harder glacial clays at shallower stations.

The samples represent depths varying between 15 and 47 m. In order to test whether the depth distribution of the stations was representative for the study area or not, the percentage share of depth zones was estimated using maps from sonar investigations (Tvärminne archives) and tested against the distribution of stations within depth zones ($\chi^2 = 6.25$; $df = 3$). The χ^2-test shows that the difference is not significant at a 5% confidence level.

4.2. Faunal abundance and biomass

The species found are typical to the soft bottoms of the northern Baltic Sea. Only 11 species or species groups were present. The species found, the mean of their abundance and biomass, are all shown in Table 1.

The mean of individuals was 9 200 ind./m². The maximum abundance, found at a depth of 36 m , was 20 800 ind./m², 72% of which were *Pontoporeia affinis*. The mean biomass was 69.1 g/m². The maximum value found was 550 g/m² in a sample from a depth of 36 m, in which 5 *Macoma baltica* individuals represent 90.6% of the biomass.

The variation of the abundance for the single species within and between stations, and the *F*-values obtained, indicating the ratio of between-station to within-station variances, are shown in Table 1. The variation between stations is for most species significantly greater than the variation within stations, so that there is a statistically significant difference between stations.

4.3. Variation between geographical strata

The strata (five subareas A–E) and the total abundance and species distribution are shown in Fig. 4. The greatest mean abundance was 11 600 ind./m² in stratum C and the smallest mean was 5 700 ind./m² in stratum B. In all strata *Pontoporeia affinis* dominated, comprising between 66% (A) and 73% (D) of the total abundance.

The variance ratio *F*-test for the species showed that the strata differed significantly ($P \leq 0.0002$) for the common species *Pontoporeia affinis*, *P. femorata*, *Harmothoe sarsi* and *Macoma baltica.* The great variation between the strata is explained by the depth distribution of stations within the strata (Table 2) and the species distribution along the depth gradient.

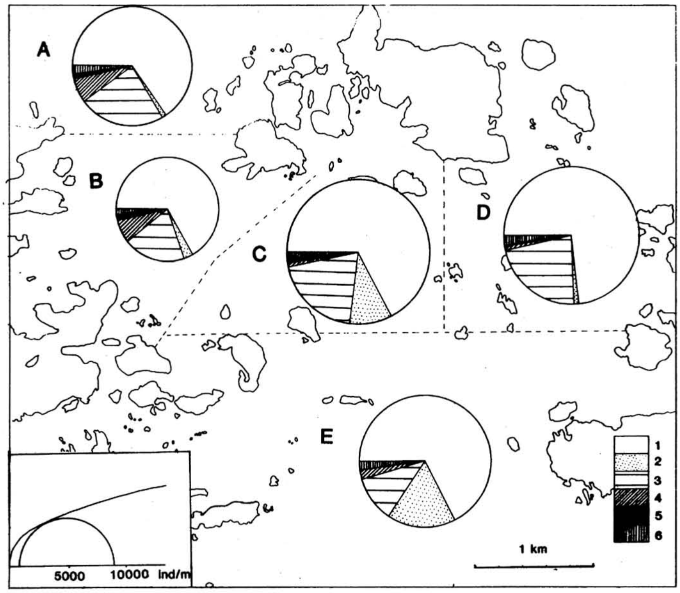

Fig. 4. Mean abundance and the percentage distribution of species in the geographical strata. 1 = *Pontoporeia affinis*, 2 = *P. femorata*, 3 = *Harmothoe sarsi*, 4 = *Macoma baltica*, 5 = Chironomidae and 6 = other species.

Table 2. The distribution of stations from geographical strata in depth classes.

Strata	Stations	*n*	Depth classes (m) 15–20	21–30	31–40	41–47
A	1–10	10	4	3	3	0
B	11–19	9	2	5	2	0
C	20–29	10	1	1	8	0
D	30–32, 38–41	7	1	2	4	0
E	33–37	5	0	0	1	4

4. 4. Ordination of stations

The different ordination analyses gave approximately the same distribution of stations. The PCA analysis and the RA showed a horseshoe effect, which is a common occurrence in these methods. The DCA analysis is discussed further because it gave the clearest picture of the relationships between stations.

DCA creates a multidimensional space where each axis has an eigen value that shows how important the axis representing different variables are. The first axis explained approximately 88% (eigenvalue 4.2) of the variance between stations. Depth and the coordinates along axis 1 (Fig. 5), correlated significantly (r^2 = 0.802). One can conclude that axis 1 represents the depth gradient or another variable correlated with depth.

The shallow stations (< 20 m) show a relatively high variation between the stations, whereas stations at 27 m to 30 m are close together, which indicates that they have a high degree of similarity. Sediment type correlates with depth so that shallow stations (< 22 m) all consist of silt and clay, whereas the deeper stations have ooze, mud and clay. The shallow stations can be further divided into two groups according to the clay type. The five stations at upper left (Fig. 5) consist of silt and hard glacial clay, whereas the three stations on the right have silt and soft clay. Axis 2 explained only about 7% (eigenvalue 0.3) of the variance and no clear environmental variable could be fitted to this axis. The stations in the geographical strata A, B, C, D and E are marked, but no correlation with geographical location or exposure is found.

4.5. Species distribution along the depth gradient

The species, like the stations, are distributed along axis 1 (the depth gradient) (Fig. 6). The Chironomids were mainly present in shallow waters and *Pontoporeia femorata* was only present in samples taken deeper than 26 m. The pelagic species *Mysis mixta* was present in samples from varying depths, and was situated in the central area. The depth distribution of single species thus, explained their location in the two-dimensional plots.

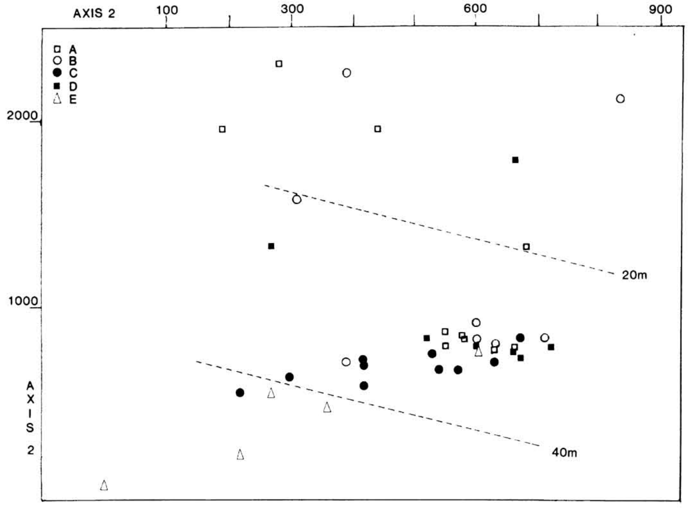

Fig. 5. Detrended Correspondence Analysis for the stations marked regarding geographical strata. The lines divide the stations of the shallowest (≤ 20 m) and the deepest (≥ 41 m) depth class from the other stations.

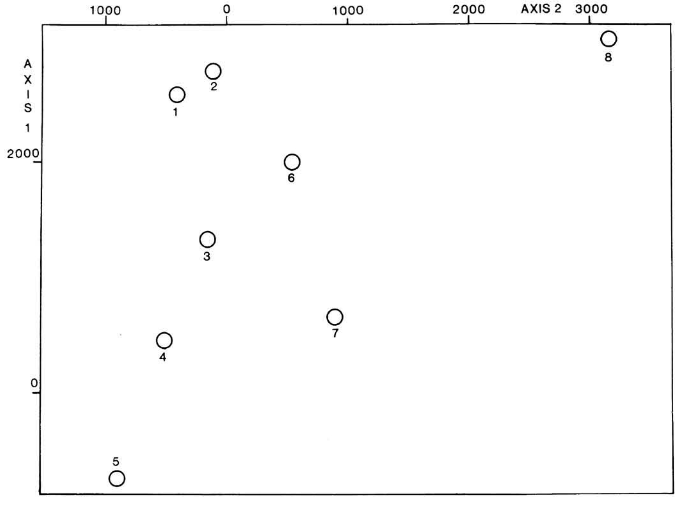

Fig. 6. Detrended Correspondence Analysis for the species. 1 = *Halicryptus spinulosus*, 2 = *Macoma baltica*, 3 = *Harmothoe sarsi*, 4 = *Mesidotea entomon*, 5 = *Pontoporeia femorata*, 6 = *Mysis mixta*, 7 = *P. affinis*, 8 = Chironomidae.

The age groups 0+ and 1+ for *P. affinis* have the same distribution with a maximum around 33 m, but the 0+ group was three times as abundant. *Macoma baltica* dominated on shallow bottoms and 56% of all individuals were 1 mm in length or smaller.

4.6. Variation between depth classes

The stations were divided into five depth classes (15–20, 21–30, 31–35, 36–40 and 41–47 m), and the abundance of each species counted (Table 3). Within the geographical strata only *Mysis mixta* and Oligochaetes do not exhibit a high variance between depth classes. *Pontoporeia femorata* has the highest *F*-values, followed by *P. affinis*, Chironomidae and *Macoma baltica*.

4.7. Number of sampling units required

The greatest similarities in variance to mean ratio values were found when the samples were summed within depth zones, which is a consequence of the

Table 3. Mean abundance (ind./m^2) of species and the F-values of the depth classes. * = $P < 0.05$; ** = $P < 0.001$.

Depth classes Samples	15–20 33	21–30 46	31–35 34	36–40 52	41–47 12	F
Halicryptus	187	57	36	41	44	7.68***
Oligochaeta	48	4	0	0	0	1.03
Harmothoe	470	1758	2778	2406	1307	29.75***
P. affinis	918	6125	9313	7932	5448	75.20***
P. femorata	0	31	109	1020	2276	114.54***
Mesidotea	0	8	41	14	44	3.75**
Mysis	80	50	62	85	117	1.07
Chironomidae	288	11	5	3	0	43.34***
Macoma	1084	245	62	115	103	39.41***
Total	3076	8289	12406	11616	9339	72.86***

Table 4. Mean abundance for all species ($\bar{x}$), standard deviation (σ), aggregation index ($\sigma/\bar{x}$) calculated optimal number of samples (n) for all species for the whole area (equation 1), number of stations (n_p) each depth class and replicates (n_s) at each station (equation 3).

	$\bar{x}$	σ	$\sigma/\bar{x}$	n	n_p	n_s
Halicryptus	0.41	0.81	1.63	400		
Oligochaeta	0.06	0.68	8.26	14745		
Harmothoe	10.63	7.08	4.71	42	95	0.39
P. affinis	35.48	20.16	11.45	32	121	0.06
P. femorata	2.74	4.36	6.93	353	917	0.01
Mesidotea	0.10	0.31	1.03	1069		
Mysis mixta	0.41	0.68	1.12	271		
Chironomidae	0.33	0.33	2.34	703		
Macoma	1.81	3.06	5.19	287	706	0.32

Table 5. Number of samples (n_p) (equation 1) and number of replicates (n_s) (equation 2) required in each depth class for *Pontoporeia affinis*.

Depth class	Replicates n_s without costs	Replicates n_s with costs	Samples n_p within depth class
15–20	0.27	0.13	97
21–30	0.23	0.11	24
31–35	0.89	0.45	6
36–40	0.87	0.43	6
41–47	0.52	0.26	11
		Total:	124

species distribution along the depth gradient. Most species showed high aggregation, with the exception of *Mesidotea entomon* and *Mysis mixta*, which were randomly distributed, probably due to the low number of individuals of these species. The higher the degree of aggregation the higher the number of sampling units needed, (Table 4).

The optimal number of replicates at a station (n_s) and stations needed (n_p) for *P. affinis* in each depth class are shown in Table 5. The high number of stations (n_s) required in the first depth class reflects the high variance in this zone. Replicates are not needed but the number of stations has to be high. All values of n_s are < 1, even when the costs are not taken into account, so that one sample is required at each station.

5. Discussion

5.1. Fauna, abundance and biomass

The nine dominant species in this survey were similar to the survey made by Sarvala (1985). Segerstråle (1933b) used an Ekman grab (234 cm^2) at 1.5 m to 37 m and found a total of 22 species. The inclusion of shallow bottoms in the latter study increased the species richness. In studies carried out in 1964–1967 and 1973–1976, where four stations at Storfjärden were used, 25 species or species groups were found (Karjala & Lassig 1985). Samples were taken over a long time period and thus included a high number of studied individuals and thereby also transient species from the littoral zone, which increased the species total. Another reason for the higher species total in Karjala & Lassig's survey (1985), was the use of the van Veen grab, which

Table 6. The biomass (wet weight g/m²) of seven species in depth classes in the Tvärminne area in 1926–1947 (Segerstråle, = Se), 1967–1970 (Sarvala, = Sa) and 1982 (Aschan, = A).

Depth class	15–20			21–30			31–35			36–40			41–47	
Source	Se	Sa	A	Se	Sa	A	Se	Sa	A	Se	Sa	A	Sa	A
Harmothoe	0.4	0.3	1.2	0.9	0.1	1.3	0.2	0.8	2.0	0.2	0.9	1.7	0.6	1.2
Halicryptus	0.6	0.2	1.8	3.1	0.0	0.4	3.2	0.0	0.0	4.7	0.0	0.0	0.0	0.0
P. affinis	0.4	12.3	0.4	5.6	10.4	22.9	13.7	35.1	36.5	20.2	8.9	26.1	4.9	18.1
P. femorata	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.6	1.7	0.7	1.1	6.9	0.2	14.2
Mesidotea	0.1	0.6	0.0	0.8	1.4	0.1	0.8	3.4	4.9	0.2	4.9	2.1	3.1	12.1
Chironomidae	0.0	0.1	0.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Macoma	109.8	32.9	106.9	93.2	2.1	38.2	77.0	7.3	8.0	60.4	5.1	20.7	1.5	0.1

samples better species typical of harder clay and sand bottoms. The number of species is usually higher on sandy bottoms, since the latter have a more complex structure and offer a higher number of niches (Gray 1974). For example, *Pygospio elegans* is present only on sandy bottoms in the Tvärminne area (Karjala & Lassig 1985), which explains why it was absent in this study.

Differences in methods used make it difficult to qualitatively compare benthic data (Ankar 1979), because the results are, for example, strongly affected by the constructions of the grabs (Andersin & Sandler 1981). This is obvious when the faunal composition is studied, and has to be taken into consideration in particular when abundance and biomass are examined.

The abundance found in this study, 9200 ind./m², is higher than in other studies of the area, with the exception of temporal high *P. affinis* values (Sarvala 1986, see below). Segerstråle (1933b) found a mean of 3300 ind./m², with the mean for the depth class 36–45 m, of 6400 ind/m², whereas the maximum abundance in the study carried out by Karjala & Lassig was 8300 ind/m². The high abundance in this survey is probably due to the high efficiency of the corer used and the fine sieve mesh employed. The Ekman grab has about a 50–75% efficiency and the van Veen less than 50% efficency compared to that of a tube corer (Sarvala unpubl. res.).

The biomass was 69.1 g/m². Segerstråle (1933b) found a mean at 102 g/m² and Sarvala (1985) at 50 g/m². Järvekülg (1970) reports a high biomass 137 g/m², from the Estonian coast, whereas Elmgren et al. (1984) estimated a mean for the whole Bothnian Sea of 62.7 g/m² (162 g/m² at 5–25 m and 17 g/m² deeper than 25 m).

The maximum value for *P. affinis* abundance was 20 800 ind./m². Sarvala (1986) found maximum values of 20 000–25 000 ind./m², where a 0.265 mm screen was used and the samples were taken in early summer, which leads to high density values. Similar high values have been reported by Tulkki (1960) from the Airisto area and Järvekülg (1973) from the Estonian coast. In the studies made by Segerstråle (1933b) the maximum for *Pontoporeia affinis* was only 7000 ind./m².

The high number of *Pontoporeia affinis* in all depth classes is partly due to the corer used. This takes samples only from soft bottoms, where *P. affinis* is most abundant, and it is quantitative because it induces less of a shock wave. Larger shock waves, which are a problem inherent in grabs, tends to blow light individuals at the sediment surface away.

Although the total abundance was high, the biomass was relatively low. The biomass in different depth classes obtained from the investigations carried out by Segerstråle (1933b), Sarvala (1985) and the present survey, were compared to elucidate long-term changes in the community (Table 6). The faunal composition has changed during the last 50 years. Biomass has decreased while abundance has increased, due to the increased number of *Pontoporeia affinis*. Similar conclusions were presented by Karjala & Lassig (1985) and Sarvala (1985). The decline of *Macoma baltica* and *Halicryptus spinulosus* biomass can be explained by the increasing population of *Pontoporeia affinis*, since the latter eats larvae and eggs of these two species (Segerstråle 1962, 1965, 1978, Elmgren et al. 1986).

The *Pontoporeia affinis* population exhibits fluctuations, spanning a period of 6 to 7 years, in the Baltic Sea (Andersin et al. 1978) and the Tvärminne area (Karjala & Lassig 1985). The year 1964–1965, 1970–1971 and 1977 were years with high *P. affinis* population densities and the next maximum should have occurred in 1983, a prediction which was supported by this study.

5.2. Spatial variation

The species distribution along the depth gradient (Fig. 6), the variation between depth classes (Table 3) and the ordination analysis (Fig. 5) show that the depth gradient was the most important factor affecting the spatial variation in the macrozoobenthic community. Within the shallow areas variation was greater, which can be explained by the more complex sediment structure in this area. This agrees with other data from the archipelago of SW Finland (Lappalainen & Kangas 1975, Lappalainen et al. 1977, Blomqvist 1979, Bonsdorff & Koivisto 1982 and Blomqvist & Bonsdorff 1986) where the patchiness on shallow bottoms is a function of sediment character and habitat complexity. Rogal et al. (1978) related the spatial variation differences to grain size composition, which is supported by investigations in the Åland area made by Blomqvist (1979) and Blomqvist & Bonsdorff (1986).

In this survey most of the stations were deeper than 20 m. The soft sediments have more or less the same structure and the sediment characteristics do not correlate significantly with the fauna. Sarvala (1985), who also found the depth axis to be the most important one, could not show any correlation with sediment quality, even though he had some stations with harder sediment.

The Detrended Correspondence Analysis showed that the degree of exposure of the geographical strata did not have any clear effect on the fauna. Sarvala (1985), too, was unable to find any effect of various archipelago zones.

The distribution of the stations in the geographical strata within depth classes (Table 2) and the species distributions along the depth axis explains the variation between the geographical strata. The species distributions in strata A and B are similar but the difference in abundance is 2300 ind./m^2, which cannot be explained by differences in depth range alone.

The Koverhar steel factory, located north of the study area, could conceivably have an effect on these two strata. But in that case the abundance would be expected to be lower close to the factory (stratum A), and higher further away (stratum B), and the proportion of *Macoma baltica* should be greater, whereas the proportion of *P. affinis*, a species susceptible to pollution, should be lower in stratum A. However, this was not the case. A higher eutrophication effect from Pojoviken is a possible explanation for the high abundance in stratum A. Further studies should be made to verify this.

5.3. Optimal sampling strategy

The corer used in this survey takes smaller samples than samplers used previously in the area (van Veen 0.1 m^2, Muus-sampler 200 cm^2 and Ekman 225 cm^2). A grab does not necessarily take the correct sample size for the community or species under study. In general a large number of small samples is preferable to a smaller number of large samples. With the same counting effort a greater spread of habitats can be covered, and the number of degrees of freedom for statistical tests is increased, thereby reducing the error variance (Gray 1981).

Many authors (Finney 1946, Taylor 1961 and Angel & Angel 1967) have studied the way in which the size of the sample affects sampling efficiency. They conclude that small sampling units are more effective when aggregated populations are studied. Aggregated distribution is the most usual in marine communities (Gray 1981), a contention which is supported by the present study. Although the ideal solution is to use the smallest possible sampling unit when costs are not taken into account, many practical factors will set a lower limit to the dimensions of the sampling unit, e.g. stone size will be a limiting factor on a stony substratum. With a small sampling unit, the sampling error at the edge of the unit is proportionally greater. Therefore, the choice of the final size is always a compromise between statistical and practical requirements. Round sampling units are an advantage because the edge effect is diminished (Elliott 1977). When costs are taken into consideration the attainable sample size and precision are constrained by total budgeted costs and the relative and absolute magnitudes of the components (Sheldon 1984).

The results show that the optimal number of sampling units varied for the different species (Table 4). For abundant species like *P. affinis* and *Harmothoe sarsi* 42 stations in the whole study area would be enough, whereas 300 sampling units would be needed for significant results for *Macoma baltica* and *Mysis mixta*. A larger sampling unit for these two species would reduce the required number of sampling units. It is thus desirable to find an allocation that simultaneously maximises the precision of each species variable (Cuff & Coleman 1980).

Stratification may be important to guarantee the spatial representativeness of the data. This is especially important in a situation where the study area is unknown. If the area is known, the stratification should divide the area into homogeneous parts in respect of an environmental gradient like depth in the present survey. Green (1980) argues that stratified random sampling must be more efficient than simple random sampling when the individual strata are homogeneous. Cuff & Coleman (1980) conclude that a simple random sampling would have given as good a result as stratified random sampling, probably because the stratification was not optimal.

The variation within depth classes is smaller than within geographical strata, meaning that an optimal stratification should be made on the basis of depth zones. Ankar & Elmgren (1976) concluded that a stratification based on the depth gradient would have been better than the geographical stratification used in their study, made outside Askö. A disadvantage is that the depths in a study area have not necessarily been mapped beforehand. The number of stations needed for the depth classes differ. If the stratification is based on the depth gradient, more sampling units are required in the shallow strata, where the variation is greatest. The deeper zones (> 30 m) are more homogeneous and the number of stations needed is consequently smaller.

The number of replicates at a station has usually been chosen on the basis of the cumulative curve for the species number as a function of the number of replicates (Holme 1953). Studies based on this method have recommended 3 (Lie 1968) to 5 (Holme & McIntyre 1984) samples at each station, whereas Stephenson et al. (1974) should have taken 25 replicates, but were forced to reduce the number to only 5 owing to limited time and effort. This kind of approach attempts to describe the single station as exactly as possible. It makes it possible to compare stations, but does not necessarily result in a good knowledge of the faunal composition and the distribution of communities in the study area.

Two methods were used to determine the optimal number of second stage units, replicates, for the single species in the whole area (Table 4) and for *Pontoporeia affinis* in the depth classes (Table 5). All the results show that only one sample is needed at each station, but that the reqired number of stations is high. Cuff & Colemann (1979) conclude that only one sample per station is to be recommended in Western Port. Saila et al. (1976) obtained the same result for four of seven species. If they had used different cost estimates for visiting a station (C_1) and sampling and treating a replicate (C_2), all the species would have required one replicate. Jörgensen & Jensen (1976) also recommended only one sample at each station. In spite of this, one cannot conclude that one replicate is always enough, as the sampling strategy always has to be applied to the area and fauna under survey. Pilot studies are required before one chooses a "one sample per station" design. In this kind of survey, stations cannot be compared, but groupings of stations like geographical areas, depth zones, stations with similar bottom quality or related through some other environmental variable, e.g. degree of eutrophication, can be compared.

In the Tvärminne area in the annual sampling three replicates from four stations, already used by Segerstråle in the 1930s, have been taken with a van Veen grab. The stations represent only two depths (20 m and 35 m). The bottom quality is different, but as the present survey shows, depth has a great influence on the composition of the fauna. While the species distribution along the depth gradient changes within and sometimes between years, differences within time can be drastic at one station, even if the total population in the whole area is the same. An advantage is that the stations can be compared with each other and over time. But with the same sampling and counting effort, a more representative picture of the faunal composition could have been achieved if more stations and fewer replicates had been taken. The number of stations should be especially increased in shallow areas.

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