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THE STATE OF MACROZOOBENTHOS OF PÄRNU BAY IN 1991 AS COMPARED TO 1959—60

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Abstract. Macrozoobenthos in Pärnu Bay, Baltic Sea, has undergone serious alterations during the last thirty years. These are an evident increase in the total biomass and abundance, disappearance of most oligosaprobic and some mesosaprobic species, thriving of mesosaprobic molluscs (*Macoma baltica* (L.) and *Cerastoderma lamarcki* (Reeve)). The study showed a clear gradient of community unification towards the northern part of Pärnu Bay, the area where the most intense influx of pollutants into the bay occurs.

Key words: Pärnu Bay, macrozoobenthos in 1991 and 1959—60.

INTRODUCTION

Pärnu Bay, especially its northern part, has been continuously contaminated with toxic substances and nutrients due to insufficient purification of sewage and industrial wastewaters. As a result, during the last two decades on an average a two-fold increase in the content of P, N, and Si has occurred in seawater as well as in the primary productivity of phytoplankton (Tenson et al., 1993). The proportion of copepods, which are sensitive to pollution, has diminished (Ojaveer et al., 1988). Sandy, stony, and clay bottoms, which prevailed in 1959—60 (Järvekülg, 1961), have been replaced by partly or predominantly muddy sediments. The bottom vegetation, especially of the northern part of the bay, was depressed in 1991 (Kukk & Martin, 1992).

In this paper we give a survey of the spatial distribution of macrozoobenthic species as well as their biomasses and abundances in Pärnu Bay in summer 1991. We discuss the role of human impact in the changes of macrozoobenthic communities comparing the data of 1959—60 (Järvekülg, 1961; Ярвекюльг, 1979) and those of 1991.

Similar studies have been previously carried out in Estonian coastal waters (Järvekülg, 1981; Järvekülg, 1982; Järvekülg & Seire, 1985; Ojaveer et al., 1988). As a difference, the autumn of 1991 was revolutionary as a water purification plant was put into operation. The plant meets the needs of the town of Pärnu (Tenson et al., 1993). So, we made a special attempt at fixing the state of macrozoobenthos immediately before it to be able to estimate the efficiency of the plant in the near future.

MATERIAL AND METHODS

Pärnu Bay is a relatively closed part of the Gulf of Riga. It opens towards SW. The prevalent depths are between 5 and 10 m. The volume of the bay is about 2 km³. The annual influx of rivers is the same with the Pärnu River accounting for 80% of the total. The salinity of the bay is 4—5‰, which is considerably lower than that of the Gulf of Riga (Tenson et al., 1993).

The material was collected in Pärnu Bay and in the surroundings of Kihnu Island in 1991 (Fig. 1). All 25 samples (one sample per station) were taken using a Petersen bottom grab (1/58 m²). The samples were sieved through a net with a mesh size of 0.4 mm. For fixation we used 4% formaldehyde solution. Animals were picked up under a stereo-microscope. Wet weights (±0.5 mg), abundance values, and distribution areas of macrozoobenthic species (groups) were assessed.

The first concise study of macrozoobenthic communities in Pärnu Bay dates from 1958—59 (Järvekülg, 1961). Our study covers a smaller area (as our particular interests concern the northern part of the bay) and the number of stations is smaller, too. Nevertheless, we may compare the results of these studies as in both cases the stations (for the overlapping region) were randomly positioned and are higher in number in Pärnu Bay and its close vicinity. Therefore, undetected species may indicate very low densities of these species (or extremely high aggregation, which is less probable because of a relatively uniform environment). The quantitative aspects of the methodology of these studies are similar as to grab type and mesh size and type.

We zoned Pärnu Bay and its surroundings on the basis of the values of biomasses and abundances of every species. Euclidean distances gave us the difference between the elements of different variables and for the grouping of stations the unweighted pair group method was used:

$$\mathrm{Ed}_{ij} = [\textstyle\sum_k (x_{ik} - x_{jk})^2]^{1/2},$$

where x is the value of the kth element of the ith or jth variable. The distance between two groups is defined as the average of all distances between an object in one group and an object in the other. The measure is considered unweighted because each object in the cluster is given an equal weight when the average is calculated. Two stations are considered to belong to the same zone if the similarity between them is 80% or more.

RESULTS

In summer 1991 the mean biomass of the macrozoobenthos of Pärnu Bay was 149.24 g·m⁻² (SE ±27.47, $n=25$). Biomasses were distributed unevenly, beginning from 1.29 g·m⁻² and reaching the maximum at 617.30 g·m⁻² per station. We found the gradient of the biomass to increase towards northeastern and central parts of Pärnu Bay.

The mean abundance was 3037 ind·m⁻² (SE ±948, $n=25$, min=58, max=20 474). The regions of the highest values for abundances were positioned at the northern coastal line of the bay (Table 1).

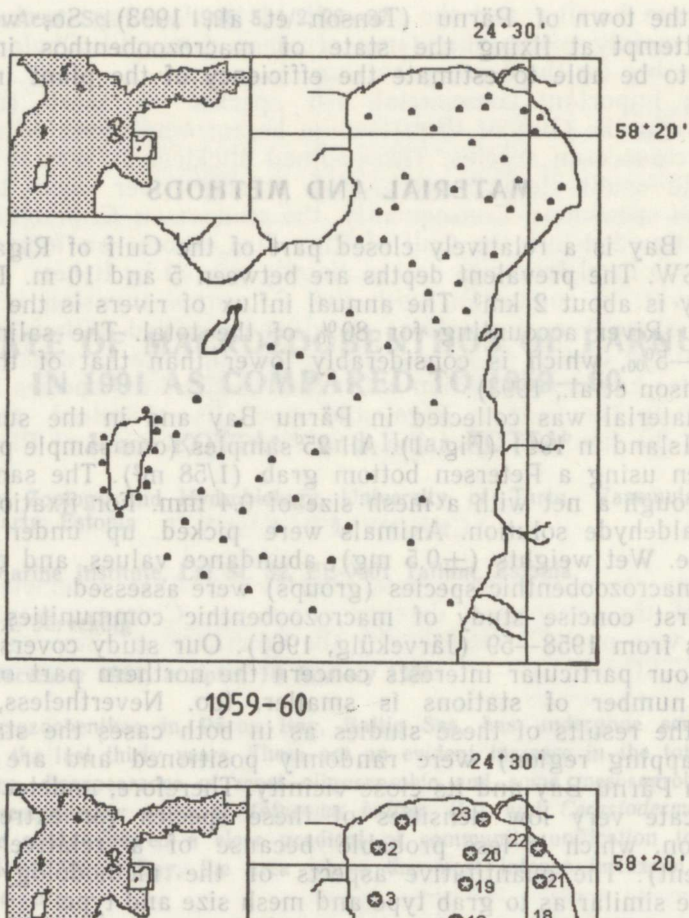

Fig. 1. Quantitative sampling stations of macrozoobenthos in Pärnu Bay and its surroundings in 1959 and 1960 (Ярвекюльг, 1979) and 1991.

Table 1

Macrozoobenthos biomasses and abundances in Pärnu Bay in 1991

Station	Longitude	Latitude	No. of species	Biomass, g·m⁻²	Abundance, ind·m⁻²
1	58°22.2′	24°24.0′	5	83.612	20474
2	58°20.4′	24°22.0′	3	172.562	4118
3	58°18.2′	24°21.1′	3	133.464	638
4	58°16.3′	24°17.9′	4	250.299	2204
5	58°14.6′	24°20.0′	3	211.700	3770
6	58°04.0′	23°57.2′	2	48.200	406
7	58°14.3′	24°14.5′	3	31.036	522
8	58°11.7′	24°14.6′	5	47.444	1392
9	58°09.3′	24°07.4′	5	4.541	1044
10	58°11.7′	24°15.8′	2	41.458	580
11	58°11.2′	24°18.0′	5	34.500	190
12	58°10.3′	24°23.9′	3	122.913	1218
13	58°10.0′	24°25.4′	1	120.269	348
14	58°12.8′	24°25.4′	1	119.608	580
15	58°13.6′	24°19.5′	4	617.300	3422
16	58°15.8′	24°21.5′	3	64.751	638
17	58°15.0′	24°27.0′	2	137.634	2030
18	58°16.8′	24°29.0′	4	26.268	348
19	58°17.7′	24°24.5′	3	183.802	1914
20	58°19.6′	24°25.8′	3	310.230	4524
21	58°19.0′	24°30.0′	2	195.083	4582
22	58°20.6′	24°31.6′	4	324.058	15544
23	58°21.4′	24°27.3′	2	317.637	7714
24	58°06.5′	24°14.1′	1	1.293	58
25	58°07.0′	24°03.0′	3	131.445	754
MEAN			3.0	149.24	3037
SE			0.3	27.47	948

The number of species was quite low in Pärnu Bay. We distinguished fourteen taxa: three of Vermes, four of Crustacea, one of Insecta larvae, and six of Mollusca (Table 2).

The frequency at a station was the highest for Mollusca and the lowest for Vermes. No account was taken of Insecta (occurring only at station 17) because their abundance depends on the season of the year rather than reflects the average degree of pollution.

It was not species richness that determined high biomass and abundance values but a dominant species in each taxonomic class (Table 2). Two of the most common species were *Macoma baltica* and *Corophium volutator* in Pärnu Bay. *M. baltica* had the widest distribution area (being detected at every station), the highest biomass, and the second highest abundance values. *C. volutator* had the second widest distribution area, the third biomass, and the highest abundance values.

Many taxa occurred only at one station: *Halicryptus spinulosus* at the southernmost station; *Gammarus* spp., *Theodoxus fluviatilis, Hydrobia* spp., and *Dreissena polymorpha* in the central part of the bay. Others were more frequently detected. *C. volutator* inhabited practically the whole Pärnu Bay and the vicinity of Manilaid Islet (station 8); *Pontoporeia affinis* was located at two stations in the surroundings of Pärnu Bay (stations 9, 11); *Saduria entomon* was quite evenly but sparsely

Table 2

Check-list of the macrozoobenthos taxa of Pärnu Bay in 1991: their frequencies (% ± SE), mean biomasses (g·m⁻² ± SE), and abundances (ind·m⁻² ± SE) at a station

Taxa	Frequency, %	Biomass, $g \cdot m^{-2}$	Abundance, $ind \cdot m^{-2}$
VERMES	0.42±0.10	0.17±0.06	85.1±52.9
Halicryptus spinulosus (Siebold)	0.04±0.04	0.01±0.01	1.2±1.2
Nereis diversicolor (O. F. Müller)	0.40±0.10	0.13±0.04	30.6±12.1
Oligochaeta	0.16±0.08	0.03±0.03	53.4±41.8
CRUSTACEA	0.69±0.09	9.74±4.72	1583.8±819.5
Saduria entomon (L.)	0.20±0.08	7.15±3.76	30.9±23.6
Pontoporeia affinis Lindström	0.08±0.06	0.10±0.09	31.0±30.1
Gammarus spp.	0.04±0.04	0.01±0.01	2.3±2.3
Corophium volutator (Pallas)	0.68±0.10	2.47±1.21	1519.6±821.5
DIPTERA larvae	0.04±0.04	0.001±0.001	2.3±2.3
MOLLUSCA	1.00±0.00	135.50±26.64	1406.1±348.4
Theodoxus fluviatilis (L.)	0.04±0.04	0.14±0.14	2.3±2.3
Hydrobia spp.	0.04±0.04	0.01±0.01	2.3±2.3
Dreissena polymorpha (Pallas)	0.04±0.04	0.29±0.29	2.3±2.3
Cerastoderma lamarcki (Reeve)	0.16±0.08	0.44±0.24	20.9±11.5
Macoma baltica (L.)	1.00±0.00	133.85±26.63	1369.0±347.7
Mya arenaria L.	0.16±0.08	0.77±0.41	9.3±4.3

distributed; Oligochaeta, *Nereis diversicolor,* and *Mya arenaria* inhabited the western part of the study area; *Cerastoderma lamarcki* was detected in the central part of the bay and in the vicinity of Kihnu Island (Figs. 2—5).

To conclude, most species were unevenly distributed in space and no clear co-occurrence between species, i. e. different communities, was observed within the study area. Therefore, Pärnu Bay and its surroundings may be described on the basis of biomass domination as a *Macoma baltica* community overlapped by the distribution areas of various other species.

Based on the values of abundance and biomass of *M. baltica,* we distinguished five zones in the study area (Fig. 6). These differ from each other mainly in the number of species present and the biomass and abundance of *M. baltica* and *C. volutator*:

Zone I. Three (four) stations; muddy clay bottoms; situated in the vicinity of the estuary of the Pärnu River (plus a detached station outside Pärnu Bay, in which the poverty of species was caused by the stony bottom rather than human impact). *M. baltica* was recorded in the whole zone. *C. volutator* and Oligochaeta occurred in the vicinity of the Pärnu River. The biomasses of *M. baltica* had quite high values (around 300 $g \cdot m^{-2}$).

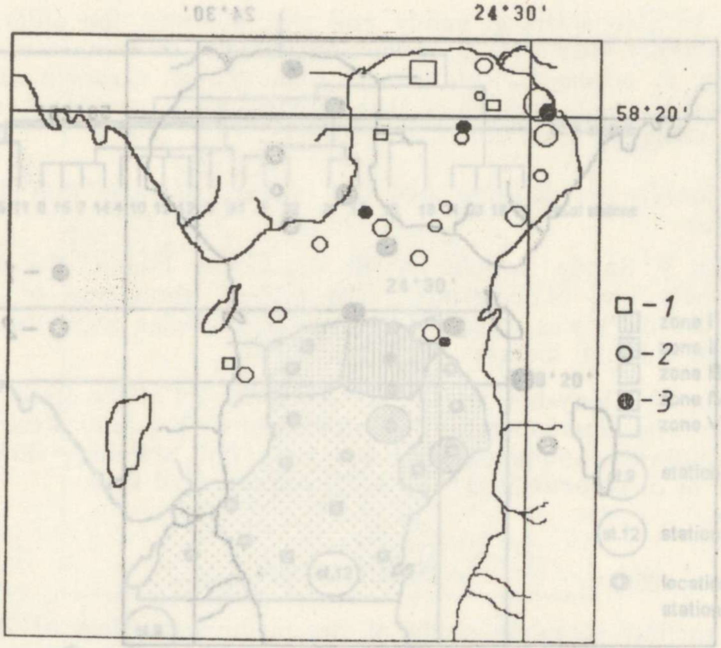

Fig. 2. The distribution areas of Oligochäeta (*1*), *Saduria entomon* (*2*), and *Corophium volutator* (*3*) in Pärnu Bay in 1991. The size of the sign shows the relative biomass of the species in 1991.

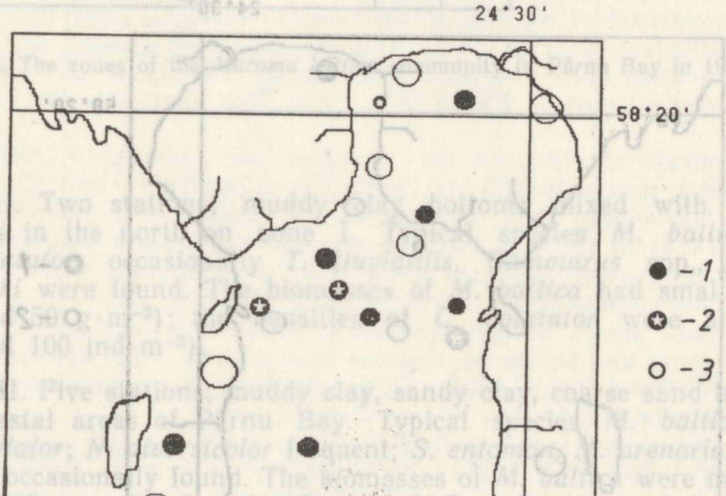

Fig. 3. The distribution of *Nereis diversicolor* in Pärnu Bay in 1959 and 1991 (*1*, detected in 1959; *2*, detected in both years; *3*, detected in 1991). The size of the sign shows the relative biomass of the species in 1991.

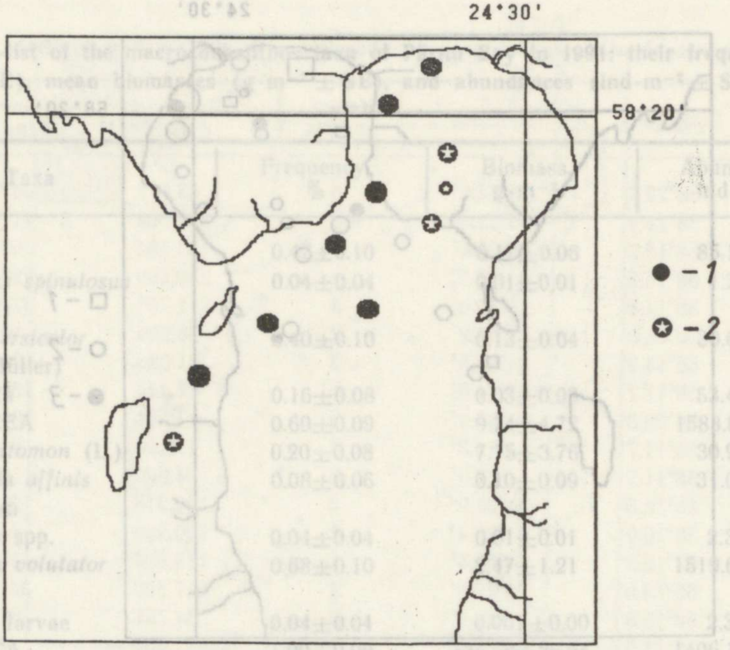

Fig. 4. The distribution of *Cerastoderma lamarcki* in Pärnu Bay in 1959 and 1991 (*1*, detected in 1959; *2*, detected in both years). The size of the sign shows the relative biomass of the species in 1991.

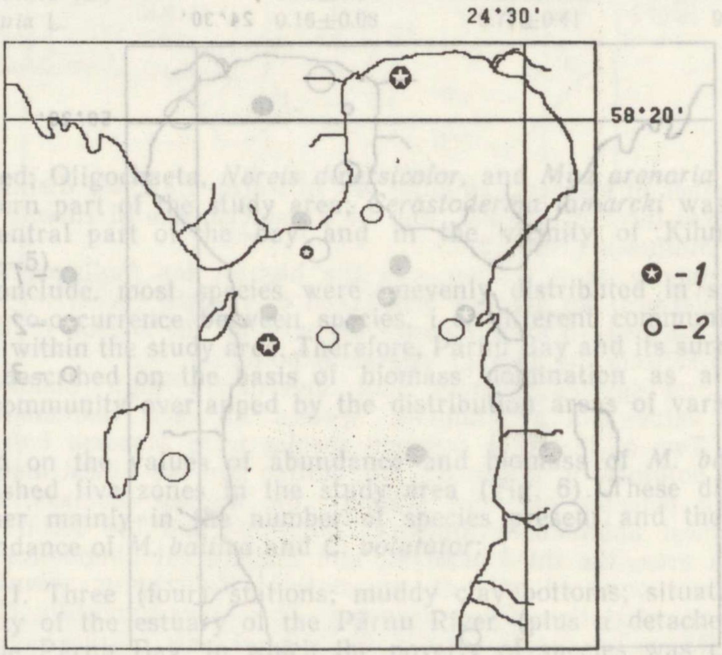

Fig. 5. The distribution of *Mya arenaria* in Pärnu Bay in 1959 and 1991 (*1*, detected in both years; *2*, detected in 1991). The size of the sign shows the relative biomass of the species in 1991.

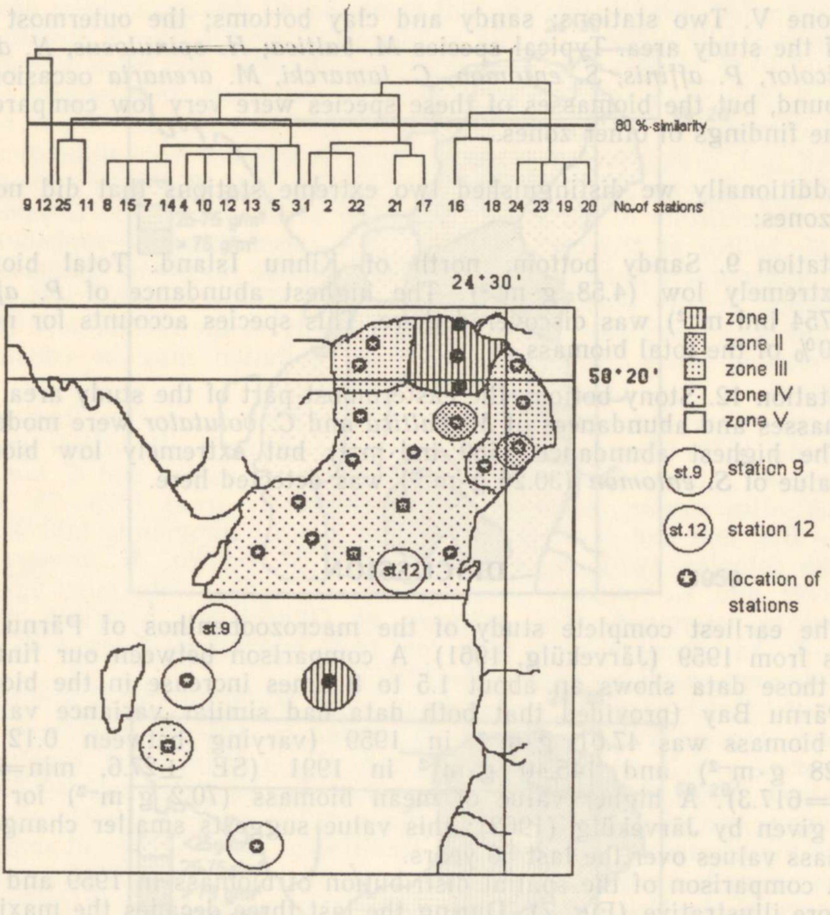

Fig. 6. The zones of the *Macoma baltica* community in Pärnu Bay in 1991.

Zone II. Two stations; muddy clay bottoms mixed with gravel; borders in the north on zone I. Typical species *M. baltica* and *C. volutator*; occasionally *T. fluviatilis, Gammarus* spp., and *C. lamarcki* were found. The biomasses of *M. baltica* had small values (around 50 $g \cdot m^{-2}$); the densities of *C. volutator* were also low (around 100 $ind \cdot m^{-2}$).

Zone III. Five stations; muddy clay, sandy clay, coarse sand bottoms; the coastal areas of Pärnu Bay. Typical species *M. baltica* and *C. volutator*; *N. diversicolor* frequent; *S. entomon, M. arenaria,* Oligochaeta occasionally found. The biomasses of *M. baltica* were moderate (100—200 $g \cdot m^{-2}$); the abundances of *C. volutator* were very high (more than 1000 $ind \cdot m^{-2}$, sometimes more than 10 000 $ind \cdot m^{-2}$).

Zone IV. Ten stations; mostly muddy sand and sandy bottoms, but also stony, gravelly clay, clay bottoms; middle and western part of the study area. Typical species *M. baltica; N. diversicolor* and *C. volutator* frequent; *D. polymorpha, S. entomon, C. lamarcki, M. arenaria,* Oligochaeta, *Hydrobia* spp. occasional. The biomasses of *M. baltica* varied highly, abundances of *C. volutator* were around 100 $ind \cdot m^{-2}$ (maximum 400 $ind \cdot m^{-2}$) at a station.

Zone V. Two stations; sandy and clay bottoms; the outermost part of the study area. Typical species *M. baltica*; *H. spinulosus, N. diversicolor, P. affinis, S. entomon, C. lamarcki, M. arenaria* occasionally found, but the biomasses of these species were very low compared to the findings of other zones.

Additionally we distinguished two extreme stations that did not fit any zones:

Station 9. Sandy bottom, north of Kihnu Island. Total biomass extremely low (4.58 g·m^{-2}). The highest abundance of *P. affinis* (754 ind·m^{-2}) was discovered there. This species accounts for nearly 50% of the total biomass.

Station 12. Stony bottom, the easternmost part of the study area. Biomasses and abundances of *M. baltica* and *C. volutator* were moderate. The highest abundance (589 ind·m^{-2}) but extremely low biomass value of *S. entomon* (30.26 g·m^{-2}) was detected here.

DISCUSSION

The earliest complete study of the macrozoobenthos of Pärnu Bay dates from 1959 (Järvekülg, 1961). A comparison between our findings and those data shows an about 1.5 to 8 times increase in the biomass in Pärnu Bay (provided that both data had similar variance values). The biomass was 47.01 g·m^{-2} in 1959 (varying between 0.12 and 439.28 g·m^{-2}) and 145.40 g·m^{-2} in 1991 (SE ±27.6, min=1.29, max=617.3). A higher value of mean biomass (70.2 g·m^{-2}) for 1960 was given by Järvekülg (1962); this value suggests smaller changes in biomass values over the last 30 years.

A comparison of the spatial distribution of biomass in 1959 and 1991 is more illustrative (Fig. 7). During the last three decades the maximum biomasses have been displaced towards the vicinity of the Pärnu River and the central part of Pärnu Bay, where low biomasses were measured in 1959.

For mean abundances the changes are smaller: 1185 ind·m^{-2} (min=88.9, max=4049.2) in 1959 (Järvekülg, 1961) and 2339 ind·m^{-2} in 1960 (Järvekülg, 1962) against 3077.3 ind·m^{-2} (SE ±978.6, min=58, max=20 474) in 1991. In 1959 the areas of the highest abundance values were situated away from the coast (Järvekülg, 1961), now the maxima occur in the vicinity of the northern coast of Pärnu Bay.

Our data shows a high frequency of mesosaprobic species at these stations (here and below the degrees of saprobity from Ярвекюльг, 1979, and Järvekülg & Kukk, 1985). Oligosaprobic and γ-mesosaprobic species are missing or inhabit one or two stations only.

In addition, we failed to find *Piscicola geometra* (L.), *Idothea viridis* (Slabber), *Jaera albifrons* Leach, *Leptocheirus pilosus* Zaddach, *Bathyporeia pilosa* Lindström, *Lymnaea stagnalis* (L.), *Lymnaea peregra* (O. F. Müller), and *Mytilus edulis* L., which all were recorded in Pärnu Bay in the late 1950s (Järvekülg, 1961). The first four species are oligosaprobic. For the next three species we lack information on the degree of saprobity. *Mytilus edulis*, an α-mesosaprobic species, is somewhat more sensitive than *Macoma baltica* to oxygen deficiency (Järvekülg & Seire, 1985), which may occur during severe winters. Further, *M. edulis* prefers stony bottoms for habitation (Ярвекюльг, 1979), which we established only in 20% of the stations. These may be the reasons why we failed to detect this species.

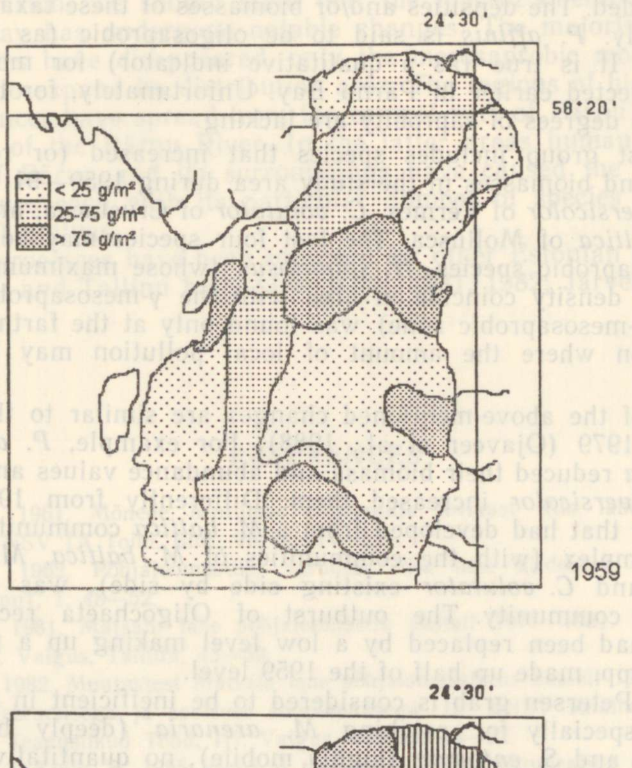

Fig. 7. The biomass distribution of the *Macoma baltica* community in Pärnu Bay in 1959 and 1991.

Mean frequency, biomass, and abundance data of all species occurring at the stations are available for 1959 (Järvekülg, 1961). Though we have no error values, we may still describe approximate tendencies.

In 1959 *P. affinis* and *Gammarus* spp. of Crustacea; *Theodoxus fluviatilis* and *Dreissena polymorpha* of Mollusca; Oligochaeta of Vermes were recorded. The densities and/or biomasses of these taxa have dropped considerably. *P. affinis* is said to be oligosaprobic (as a quantitative indicator). It is true (as a qualitative indicator) for most *Gammarus* species detected earlier in Pärnu Bay. Unfortunately, for the rest of the species the degrees of saprobity are lacking.

The last group includes species that increased (or retained) their densities and biomasses in the study area during 1959—91: *H. spinulosus* and *N. diversicolor* of Vermes, *C. volutator* of Crustacea, and *C. lamarcki* and *M. baltica* of Mollusca. The last four species may be ranked as α- or β-mesosaprobic species. *H. spinulosus* (whose maximum biomass and population density coincide in area with the γ-mesosaprobic and partly with the β-mesosaprobic zone) was found only at the farthermost (deepest) station where the amount of local pollution may be considered negligent.

Some of the above-mentioned changes are similar to the findings of 1976 and 1979 (Ojaveer et al., 1988). For example, *P. affinis* and *D. polymorpha* reduced their biomass and abundance values and *C. lamarcki* and *N. diversicolor* increased them. Differently from 1976—79, when Pärnu Bay that had developed from a *M. baltica* community into a more diverse complex (with the communities of *M. baltica, M. arenaria, C. lamarcki*, and *C. volutator* existing side by side), was now again a *M. baltica* community. The outburst of Oligochaeta recorded during 1976—79 had been replaced by a low level making up a tenth of 1959; *Hydrobia* spp. made up half of the 1959 level.

As the Petersen grab is considered to be inefficient in case of sandy bottoms, especially for catching *M. arenaria* (deeply burrowed into sediments) and *S. entomon* (highly mobile), no quantitative conclusions have been drawn for these species so far. Anyway, the increase in the biomasses and abundances of *M. arenaria* (an α-mesosaprobic species) and in the biomasses of *S. entomon* (indifferent to the degree of saprobity at a very wide scope) can hardly be explained only by the higher efficiency of the Petersen grab after an intense muddying of sediments. Definitely, the increase reflects the actual growth of the populations caused by pollution.

The distribution areas of most species have diminished during 30 years. In addition, populations have moved away from the close vicinity of the Pärnu River and the aggregation of distribution areas occurs in the central part of the bay (Figs. 3—5). This indicates a very high pollution level in the northern part of Pärnu Bay and favourable conditions for most mesosaprobic species in the central part of the bay. The areas near the southern coast of Pärnu Bay are considered to be the least polluted as the conditions there are tolerated by some oligosaprobic species.

The cluster analysis depicts the human impact on the macrozoobenthic species of Pärnu Bay. Its highest level was observed in the estuary of the Pärnu River (zone I) where only one to two species were observed at a station. This region borders on areas of similar type but with a bigger number of individuals and smaller total biomass (zones II and III). Southwards, there are transitional areas from shallow to deeper regions (zone IV). The number of species is the highest there as pollution is not so marked but still strong enough to provide quite high values of biomasses for the majority of species, i. e. probability of detection. Moreover, the distribution areas of species of different habitats meet here. And finally, we have stations typical of the eastern Baltic of low salinity (zone V). Here the development of the community is probably in general determined by the trends of the Gulf of Riga or the eastern Baltic Sea.

In conclusion, we should state that the macrozoobenthic community of Pärnu Bay has undergone notable changes. The majority of oligosaprobic species have disappeared, only the mesosaprobic mollusc *M. baltica* is able to expand its distribution area. The regions of high biomasses and abundances have spread from the central part of Pärnu Bay towards the vicinity of the Pärnu River. In the latter areas human activities in the town of Pärnu and its surroundings have caused the formation of different zones each with its particular number of species and biomass (abundance) values.

Similar processes have been recorded for other Estonian coastal areas like Matsalu and Tallinn bays (Järvekülg, 1981, 1982; Järvekülg & Seire, 1985).

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