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DISTRIBUTION AND FILTRATION ACTIVITY OF THE ZEBRA MUSSEL, *Dreissena polymorpha*, IN THE GULF OF RIGA AND THE GULF OF FINLAND

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Abstract. This paper gives an overview of the dispersion of the population of *Dreissena polymorpha* in the Gulf of Riga and the Gulf of Finland. The relationships between depth, sediment type, and biomass values of the species are described. Higher biomasses were found on stony bottoms at 5–7 m in the southeastern part of the Gulf of Riga. In order to estimate the impact of the species on the energy and matter flows the filtration rates of *D. polymorpha* were measured in the southern part of the Gulf of Riga. Higher filtration activity of *D. polymorpha* population coincides with the location of higher biomasses. Maximum population grazing rates reached 65 l h^{-1} m^{-2}, the lowest values were around 0.005 l h^{-1} m^{-2}.

Key words: Gulf of Riga, *Dreissena*.

INTRODUCTION

In recent years an increased interest towards human induced changes in the ecosystem can be observed. As an example one could mention successful introductions of so-called alien species, also known as non-indigenous estuarine and marine species, into the Baltic Sea (Baltic Marine Biology Working Group, 1995). As the Baltic is poor in species, these invaders may relatively quickly supplant other species and therefore become detrimental, destabilizing the structure and functioning of the communities (Segerstråle, 1957).

The wide expansion of dispersion area of *Dreissena polymorpha* (Pallas), a brackish water species of Ponto-Caspian origin (Morton, 1969; Rosenberg & Ludyanskiy, 1994), was induced by the augmented freight transportation by rivers in the beginning of the 19th century (Morton, 1969). In Estonian coastal areas (Pärnu Bay and some streams flowing into the Gulf of Finland) the species was first recorded in the middle of the 19th century (Schrenk, 1848). Nowadays, permanent populations occur in the northeastern, eastern, and southern parts of the Gulf of Riga (Shurin, 1953, 1961; Järvekülg, 1979) as well as very shallow areas in the easternmost part of the Gulf of Finland (Karpevich & Shurin, 1970).

In this study the distribution of *D. polymorpha* in Estonian coastal waters is described in relation to some abiotic characteristics of the habitat. Additionally we assess the impact of the species in energy and matter flows in the littoral zone of the Gulf of Riga.

MATERIAL AND METHODS

The material for the study was obtained from different sampling programmes. Eleven transects were investigated in the Gulf of Riga. Additionally 180 stations were sampled around the Estonian coastal sea (Fig. 1).

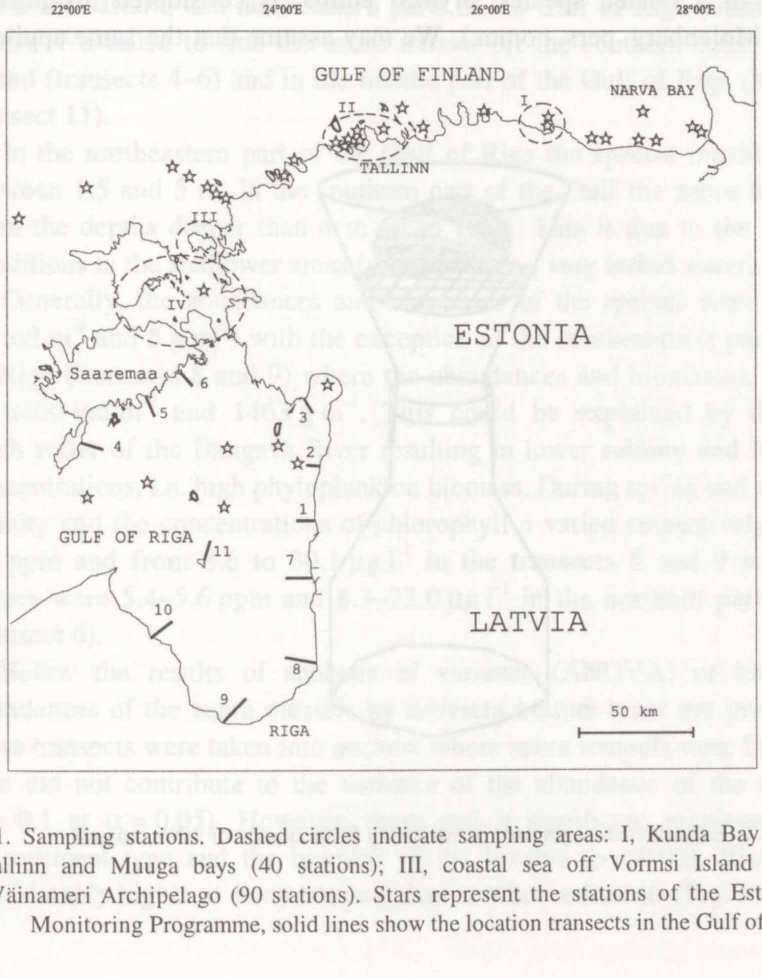

Fig. 1. Sampling stations. Dashed circles indicate sampling areas: I, Kunda Bay (15 stations); II, Tallinn and Muuga bays (40 stations); III, coastal sea off Vormsi Island (15 stations); IV, Väinameri Archipelago (90 stations). Stars represent the stations of the Estonian Coastal Monitoring Programme, solid lines show the location transects in the Gulf of Riga.

A Van-Veen bottom sampler was used in the Gulf of Finland and a Tvärminne sampler (samples collected by scuba diver) in the Gulf of Riga. The material was sieved through a net of 0.5 mm mesh size and preserved in 4% buffered seawater formaline solution. In the laboratory animals were counted under a binocular microscope. Dry weights were obtained (to the nearest 0.1 mg) after drying the material at 70 °C for 48 h.

Filtration experiments were carried out on transect 8 (southern coast of the Gulf of Riga). Animals of an average size (13 mm) of the population of *Dreissena polymorpha* were collected with a scuba diver and placed into experimental cages (Fig. 2). The incubations were performed at 2.5 and 5 m depths for 72 h in May and August 1996. Water samples from the near-bottom layer and faeces from the trays of the incubation cages were collected in each 12 h. The contents of chlorophyll *a* and phaeophytin were measured fluorometrically in the water sample and faeces. The loss of total chlorophyll in the guts of a related species, *Mytilus edulis*, is considered insignificant (Flemming Mølenberg, pers. comm.). We may assume that the same applies to

Fig. 2. Experimental cages used in estimating filtration rate of zebra mussels.

the zebra mussel and therefore the filtration rates could be directly calculated from the amount of chlorophyll in the faeces. Additionally the values of salinity and temperature were monitored during four days in both seasons.

RESULTS

Dispersion

Gulf of Finland. *Dreissena polymorpha* was found only in one locality in the southern side of the Gulf of Finland, in the vicinity of the town of Sillamäe (Narva Bay), on stony bottom at 2 m depth. The population density was around 100 ind m^{-2}.

Gulf of Riga. *D. polymorpha* was caught along the whole coastline in the southern, eastern, and northeastern parts of the Gulf of Riga (transects 1–3 and 7–10). We failed to find the zebra mussel off the southern coast of Saaremaa Island (transects 4–6) and in the middle part of the Gulf of Riga (Ruhnu Island, transect 11).

In the northeastern part of the Gulf of Riga the species inhabits the depths between 1.5 and 5 m. In the southern part of the Gulf the zebra mussel occurs from the depths deeper than 4 m up to 10 m. This is due to the unfavourable conditions in the shallower areas (sandy bottoms, very turbid water).

Generally, the abundances and biomasses of the species were low (around 50 ind m^{-2} and 5 g m^{-2}) with the exception of the southernmost part of the Gulf of Riga (transects 8 and 9) where the abundances and biomasses were as high as 8400 ind m^{-2} and 1463 g m^{-2}. This could be explained by the inflow of fresh water of the Daugava River resulting in lower salinity and high nutrients concentrations, i.e. high phytoplankton biomass. During spring and summer 1996 salinity and the concentrations of chlorophyll *a* varied respectively from 3.6 to 4.5 ppm and from 8.6 to 30.1 µg l^{-1} in the transects 8 and 9 whereas these values were 5.4–5.6 ppm and 8.3–22.0 µg l^{-1} in the northern part of the Gulf (transect 6).

Below the results of analysis of variance (ANOVA) of biomasses and abundances of the zebra mussels by different bottom types are presented. Only those transects were taken into account where zebra mussels were found. Bottom type did not contribute to the variance of the abundance of the zebra mussel ($p = 0.1$ at $\alpha = 0.05$). However, there was a significant relationship between the sediment type and the biomass of the bivalve ($p < 0.05$). Biomasses were considerably higher at stony bottoms than at other sediments (Fig. 3).

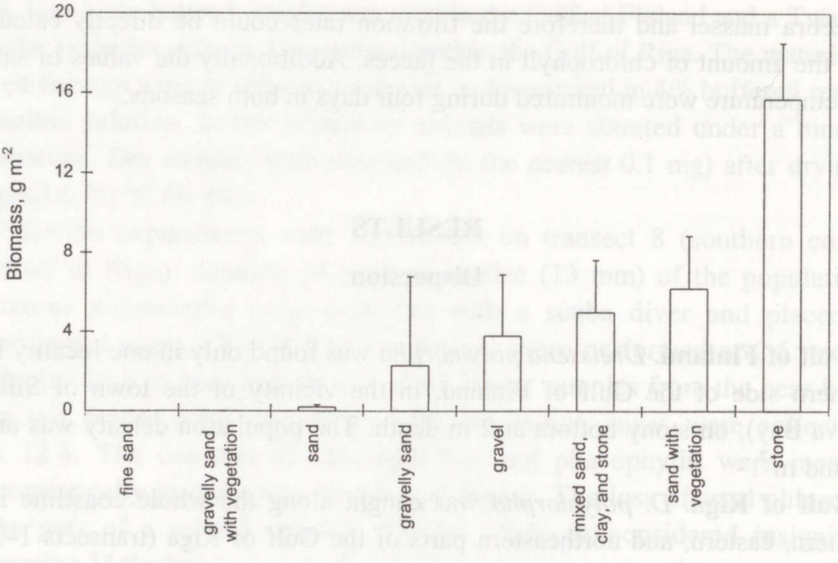

Fig. 3. Biomass values of zebra mussel (with 95% confidence intervals) at different sediment types in the Gulf of Riga.

Length–frequency distributions

The length–frequency distribution (LFD) of the population of the zebra mussels was measured in transect 8 where the highest densities and biomasses were recorded. There was no correlation between the depth and the value of modal class. The proportion of 13 mm individuals was the highest throughout the depth range studied (around 15% of the population). LFD was uniform in shallower areas (4.4 m), polymodal at intermediate depths (5–6 m), and bimodal in deeper areas (7–9 m). According to Stanczykowska (1977), the life expectancy of the species is 4 to 5 years. We may assume that the cohort with the mode at 7 mm represents the 1995 year-class, 10 mm respectively 1994 year-class, and 13 mm 1993–91 year-classes. The proportion of the 1995 year-class was the highest in shallower (4.5 m) and deeper areas (8 m), the share of the 1994 year-class increased towards deeper areas. The percentage of the cohort of 1994 was around 15% at 5 m depth whereas it was more than 30% at 9 m depth.

Filtration experiments

Our experiments showed that filtration efficiency is higher in the deeper areas (5 m) than in the shallower areas (2.5 m). Phytoplankton abundance and salinity did not vary much between these depths. The concentration of chlorophyll *a* was around 25 g l^{-1} in spring and 3 g l^{-1} in summer, salinity varied between 3.6 and 4.5 ppm. Two factors could contribute to the differences in the filtration capacity of zebra mussels: in the shallower areas water temperature was higher and currents were very strong.

Taking into account the different condition of the individuals of the zebra mussel at different depths and the variation in filtration activity due to seasons, grazing pressure of the populations was calculated for the spring and summer (Table). Basic differences derive from differences in the population density. Therefore, the greatest impact of the species on the matter flow between water and sediment can be expected in the southernmost part of the Gulf of Riga.

Abundance, biomass (± standard error), and grazing values of zebra mussel populations in the Gulf of Riga

Transect	Depth range studied, m	Depth, m	*N*	Abundance, ind m^{-2}	Biomass, g m^{-2}	Population grazing in spring, l h^{-1} m^{-2}	Population grazing in summer, l h^{-1} m^{-2}
1	0.3–3.0	2.5	2	32 ± 0	0.41 ± 0.05	0.008	0.003
2	0.2–2.4	1.5	3	42 ± 28	6.35 ± 6.13	0.095	0.013
		2.1	1	63	12.78	0.192	0.026
3	0.1–5.0	5.0	3	21 ± 21	4.97 ± 4.97	0.139	0.094
4	0.1–1.7		0	0	0	0	0
5	0.1–4.0		0	0	0	0	0
6	6.9–9.5		0	0	0	0	0
7	0.5–6.0	2.6	3	10 ± 10	4.59 ± 4.59	0.092	0.037
		6.0	2	32 ± 32	12.62 ± 12.62	0.568	0.038
8	0.5–9.5	4.5	1	125	31.88	0.925	0.574
		5.0	1	163	36.80	1.030	0.699
		6.0	1	8400	1463.18	65.843	48.285
		7.0	1	5400	574.46	31.595	24.702
		8.0	1	705	88.75	5.858	4.793
		9.5	1	1125	99.84	8.986	7.987
9	0.5–6.0	3.0	3	1376 ± 1008	51.15 ± 33.79	1.023	0.409
		6.0	3	533 ± 347	11.04 ± 7.81	0.497	0.364
10	0.5–6.0	6.0	3	85 ± 11	1.88 ± 0.46	0.085	0.062
11	0.5–5.5		0	0	0	0	0

DISCUSSION

Dispersion

Gulf of Finland. Only a single find of *D. polymorpha* was made in the Gulf of Finland. According to Whittier et al. (1995) *D. polymorpha* fails to colonize areas where the pH value drops lower than 7.3. This condition was almost met in the outermost part of Pärnu Bay (transect 2, pH 7.57), for other regions pH never fell below 8.

On the other hand, the paucity of the data from the shallower parts of the littoral zone could be a possible reason why the species was not found elsewhere. Two successful introductions of *D. polymorpha* into Estonian waters have been made: the first into the Gulf of Riga in the middle of the 19th century (Schrenk, 1848) and the second into Lake Peipsi during the 1930s (Mikelsaar & Voore, 1936). It is probable that the specimens found in the Gulf of Finland originate from the population of Lake Peipsi and the Narva River where zebra mussels have been constantly observed (Haberman, 1976).

Gulf of Riga. The dispersion area of *D. polymorpha* coincides with the area previously documented in the literature (Shurin, 1953, 1961; Järvekülg, 1961, 1979) with the exception that Shurin (1961) also found a population of the zebra mussel living on flowering plants in the southern coastal sea off Saaremaa Island. Because of the acceleration of eutrophication processes, the phytobenthos biomass has significantly reduced in recent decades. Therefore, it may be lack of substrate that limits the dispersion of the zebra mussel in these areas.

Our data indicate that in the northeastern part of the Gulf of Riga the zebra mussel occurs in shallow areas whereas in its southern part it is found in deeper areas. Unfortunately, we lack data on the distribution of the zebra mussel at higher depths of the northern part of the Gulf of Riga. However, according to our previous investigation (Kotta & Kotta, 1995) zebra mussels occur at a depth of 7 m in the outermost part of Pärnu Bay (adjacent area to transect 3). Shurin (1961) suggested that the distribution of the zebra mussel is influenced by salinity. In more saline water the species inhabits shallower areas. According to the same author the zebra mussel has been found up to depths of 11–12 m in the northeasternmost part of the Gulf of Riga (Pärnu Bay), up to 5–7 m in the southeastern part of the Gulf (between transects 7 and 8), and only up to 3 m at the estuary of the Daugava River (transect 9) where saline water reaches very shallow areas. The last finding disagrees with our data as we found the species as deep as 6 m in this region.

Length–frequency distribution

According to the present investigation the population mode did not correlate with depth. This may be the case for most populations of zebra mussels in the eastern part of the Baltic Sea as Valovirta & Porkka (1996) described the same phenomenon in the northeastern part of the Gulf of Finland.

On the contrary, the proportion of different year-classes (especially juveniles) varied with the depth value. At intermediate depths the population density was extremely high, that is the whole hard substrate was practically covered with zebra mussels. Therefore, one may assume the toughest competition for space at these depths. This, in turn, may explain the lowest proportion of juveniles in the population. Similar intraspecific competition for space has been previously observed for other bivalves such as *Macoma balthica* and *Mytilus edulis* (e.g., Seed, 1969; Bachelet, 1986; Olafsson, 1986). In the deepest areas (9 m) the scarcity of juveniles could be explained by several factors. First, as this bivalve is, due to its origin, a thermophilous species (Järvekülg, 1979), lower average temperatures are unfavourable for its settlement and growth. Secondly, higher predation pressure could be mentioned. During sampling we observed very high densities (around 1–2 ind m^{-2}) of eelpout (*Zoarces viviparus*) in these sites. According to Shurin (1961) eelpout feeds predominantly on bivalves in the Gulf of Riga.

Why does the proportion of the 1994 year-class diminish with the increasing depth value? It is possible that due to slower growth in the deeper areas this cohort actually represents a mixture of several year-classes and therefore this decrease could be considered as artefact. Besides, the maximum size of the bivalves was the highest in the shallowest areas and the lowest in the deeper areas giving support to the previous hypothesis. According to Stanczykowska (1977) the individuals of the zebra mussel are smaller in saline water (i.e. deeper areas) than the individuals of the same age in fresh water.

Filtration experiments

According to our data the filtration capacity of the zebra mussel increased with depth. We may exclude temperature in explaining the differences in filtration efficiency. One may hardly expect that feeding activity falls when mussels are exposed to more favourable conditions. Firstly, *D. polymorpha* is thought to be thermophilous (Järvekülg, 1979) and secondly, several findings indicate its higher filtration activity at higher temperatures within the range of temperature optimum (e.g. Bayne et al., 1976). Zhadin (1946) showed that small sand particles in suspension are detrimental to the zebra mussel injuring its siphons. It could explain the smaller filtration activity in very turbid water.

Our experiments suggest that the zebra mussel plays an important role in structuring the pelagic ecosystem, especially in areas of its very high abundance. As an example, the filtration capacity of the population may exceed 65 l h m^{-2} (at a depth of 6 m on transect 8). In other words, in case the vertical mixing is strong and the production of phytoplankton is insignificant, the population of the zebra mussels is capable of depleting the water from the phytoplankton in 3.8 days and therefore exerting significant pressure on the phytoplankton community and, indirectly, controlling the abundance of zooplankton. Additional experiments are needed to clarify the relationship between the abundance of zebra mussels and zooplankton.

CONCLUSIONS

The zebra mussel is relatively common everywhere in the Gulf of Riga except in its middle part and at the southern coast of Saaremaa Island. We found the species in only one locality in the Gulf of Finland. The biomass and abundance values are high in the southernmost part of the Gulf of Riga. In these sites the mussel population may be considered an important factor limiting the growth of the phytoplankton population.

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RÄNDKARBI (*Dreissena polymorpha*) LEVIK JA FILTREERIMISAKTIIVSUS LIIVI NING SOOME LAHES

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On antud ülevaade rändkarbi levikust Liivi ja Soome lahes ning kirjeldatud sügavuse ja põhja tüübi mõju rändkarbi biomassile. Rändkarbi biomass oli suurim Liivi lahe lõunaosas kivisel põhjal 5–7 m sügavuses. Lisaks mõõdeti Liivi lahe lõunaosas rändkarbi populatsiooni filtratsioonikiirust, et hinnata liigi mõju ökosüsteemi energia- ja aineringele. Filtreerimine oli kiireim suurema biomassiga piirkondades ulatudes 65 l h^{-1} m^{-2}, väikseim filtratsioonikiirus jäi 0,005 l h^{-1} m^{-2} juurde.