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CONTENT OF HEAVY METALS IN *MACOMA BALTICA* AT THE SOUTHERN COAST OF THE GULF OF FINLAND

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Abstract. The concentrations of copper, lead, and cadmium in the mussels sampled at three different sites at the southern coast of the Gulf of Finland vary in a wide range. However, their content in a 'standard animal' with a total weight of 0.175 g is nearly the same for all these areas during different months. Thus the standardization of the concentration of the investigated heavy metals in the soft body of *Macoma baltica* and calculation of their content per one standard animal allows of a comparison of the spatial differences in the bioavailability of the metals.

Key words: heavy metals, *Macoma baltica*, Gulf of Finland.

INTRODUCTION

For the assessment of the state of marine environment the bioindication method is widely used. Mussels, in particular *Mytilus edulis,* have often been used as indicator organisms. In our research area, at the southern coast of the Gulf of Finland, no *M. edulis* population exists in the eastern part where the water salinity is very low. Therefore, we carried out our work with *Macoma baltica* (L.). Several works on site and laboratory research (Phillips, 1977; McLeese, 1981; McLeese & Ray, 1984; Thompson et al., 1984; Kaitala, 1988; Cain & Luoma, 1990; and others) have proved that the given species is suitable for bioindication objectives. High metal concentrations are usually found in relatively contaminated estuaries, harbours, or close to the known point sources. Since the metal concentration in mussels varies widely also in relatively unpolluted areas, the difference of one order is considered essential as a rule (Goldberg et al., 1978) and therefore only relatively contaminated marine regions can be identified.

Several authors have shown that the variation of metal concentration in the soft body of mussels along with the metal concentration in the environment, their specification and bioavailability are highly dependent on the biological and physiological features of the analysed specimens. Among the latter the peculiarities of growth and development related to the nutrition conditions expressed by changes in the weight of the soft body are the most essential. Thus it may be assumed that the metal concentration in mussels is highly dependent on the seasonal changes and local differences in the weight of the soft body. One option for a better use of mussels as indicator organisms is to reduce the weight variation of the analysed specimens' soft body. This can be done by sampling the mussels of the same size in different years at exactly the same time of the year, which is rather complicated in practice. Another possibility is to standardize the results of analysis as it has been done in the present work. Below the variation of copper, lead, and cadmium content due to changes in the weight of mussels is analysed.

MATERIALS AND METHODS

Samples of *Macoma baltica* were collected from 11 areas at the southern coast of the Gulf of Finland (Fig. 1) at a depth of more than 20 m. In the investigated areas a rather essential west–east-oriented water salinity gradient may be assumed: from the salinity level 7–8 PSU in the Osmussaare region to 2–3 PSU in Narva Bay. The sampling took place in 1988–93 during different months, mostly in spring (April–May) and autumn (October–November). Mussels were sampled mainly with a VanVeen-type bottom sampler, in some cases a drag was used. The animals separated from sediments were exposed to clean seawater for 24 h to allow them to filter water in order to ensure an empty gut prior to metal

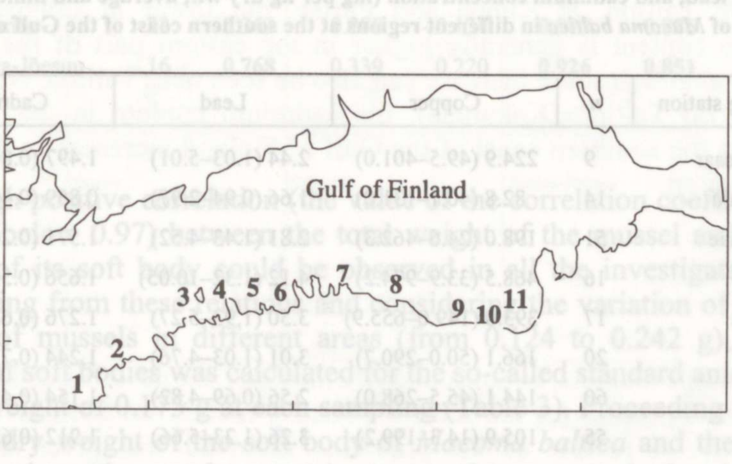

Fig. 1. Sampling stations of *Macoma baltica* on the southern coast of the Gulf of Finland. *1*, Osmussaar; *2*, Lohusalu; *3*, Kakumäe; *4*, Tallinn; *5*, Ihasalu; *6*, Kolga; *7*, Käsmu; *8*, Kunda; *9*, Purtse; *10*, Sillamäe; *11*, Narva–Jõesuu.

analysis. Then the mussels that were alive were sorted out and stored refrigerated until the analyses could be performed.

In the laboratory the mussels were sorted into groups according to their length and the soft bodies were scraped out from the shells. The dry weight of both the soft bodies and shells was determined in pooled samples (by drying for 8 h at 90ºC) and the average values were calculated per one specimen. The dried soft body samples were homogenized and 2–3 subsamples analysed. The subsamples were digested with concentrated nitric acid (suprapur). Approximately 0.2–0.3 g of the material was heated to 110ºC in the acid for 8 h, and then the acid was evaporated to near dryness. Finally the solutions were diluted to a volume of 25 ml with distilled water. The analyses were done using atomic absorption spectrophotometry, AAS, Perkin–Elmer 5000 (flameless technique; HGA-500).

RESULTS

In the analysed samples the dry weight of the soft body of the mussels ranged between 3.6 and 41.4 mg and that of the shell varied from 17.8 to 362.8 mg. According to the average data both indices were the lowest at Osmussaar Island and the highest at Purtse. The total dry weight of a mussel was calculated by adding the shell dry weight to that of the soft body. The average total weight of *Macoma baltica* was 181.8 ± 90.9 mg, ranging from 124.0 ± 53.4 (Osmussaar) to 241.7 ± 105.7 mg (Purtse).

The average concentration of copper, lead, and cadmium in different investigation areas varied from 82.8 to 468.5, 1.66 to 4.12, and 0.859 to 2.305 mg per kg dry weight, respectively (Table 1). The average concentrations

Table 1

Copper, lead, and cadmium concentration (mg per kg dry wt.; average and limits) in the soft body of *Macoma baltica* in different regions at the southern coast of the Gulf of Finland

Sampling station	*n*	Copper	Lead	Cadmium
1. Osmussaar	9	224.9 (49.5–401.0)	2.44 (1.03–5.01)	1.497 (0.860–2.070)
2. Lohusalu	14	82.8 (40.1–131.0)	1.66 (0.94–2.97)	0.859 (0.400–1.270)
3. Kakumäe	51	198.0 (24.6–462.3)	2.81 (1.43–4.52)	1.571 (0.204–2.830)
4. Tallinn	16	468.5 (33.9–974.2)	4.12 (1.32–10.05)	1.656 (0.580–3.450)
5. Ihasalu	17	393.0 (149.0–655.9)	3.50 (1.93–5.27)	1.276 (0.630–2.300)
6. Kolga	20	166.1 (50.0–290.7)	3.01 (1.03–4.76)	1.244 (0.730–1.930)
7. Käsmu	60	144.1 (45.5–268.0)	2.56 (0.69–4.82)	1.154 (0.411–2.220)
8. Kunda	55	105.9 (14.3–199.2)	3.26 (1.23–5.66)	1.912 (0.680–2.969)
9. Purtse	12	171.9 (70.4–267.3)	3.74 (2.10–5.66)	2.164 (1.240–3.690)
10. Sillamäe	22	96.0 (32.0–196.6)	2.75 (1.20–4.80)	2.305 (0.780–3.890)
11. Narva-Jõesuu	16	115.8 (35.4–179.8)	2.06 (0.20–3.65)	2.028 (1.130–3.560)

of all the three studied metals were lower in the mussels collected at Lohusalu, higher for copper and lead in Tallinn and for cadmium at Sillamäe. The variation of metal concentrations was rather high – the coefficient of variation (CV) for copper was 80.5, for lead 42.3, and for cadmium 44.0%. The correlation analysis showed that there was no relation between the total weight of *Macoma baltica* and the concentrations of lead and cadmium in most of the investigated areas (Table 2). However, a statistically reliable relationship between the copper concentration and the total weight of the mussel was observed practically in all the investigated areas.

Table 2

Correlation coefficients between the total weight of *Macoma baltica* and the concentration and content of the investigated metals in different areas at the southern coast of the Gulf of Finland (statistically reliable values of the coefficient, $p < 0.01$, are given in bold)

Sampling station	*n*	Concentration, mg per kg			Content, ng per ind.		
		Cu	Pb	Cd	Cu	Pb	Cd
1. Osmussaar	9	**0.907**	0.675	–0.673	**0.968**	**0.822**	0.771
2. Lohusalu	14	**0.771**	0.650	0.315	**0.939**	**0.900**	**0.925**
3. Kakumäe	51	**0.713**	0.113	**0.415**	**0.888**	**0.862**	**0.805**
4. Tallinn	16	**0.808**	0.409	**0.776**	**0.893**	**0.657**	**0.869**
5. Ihasalu	17	**0.591**	–0.275	–0.031	**0.874**	**0.902**	**0.782**
6. Kolga	20	**0.804**	0.044	–0.510	**0.903**	**0.771**	**0.767**
7. Käsmu	60	**0.688**	–0.078	–0.209	**0.930**	**0.832**	**0.873**
8. Kunda	55	**0.857**	**0.533**	**0.784**	**0.947**	**0.916**	**0.957**
9. Purtse	12	0.511	0.304	0.213	**0.895**	**0.825**	**0.819**
10. Sillamäe	22	**0.363**	0.280	–0.134	**0.917**	**0.876**	**0.845**
11. Narva-Jõesuu	16	**0.768**	0.339	0.220	**0.926**	**0.851**	**0.797**

A high positive correlation (the value of the correlation coefficient did not fall below 0.97) between the total weight of the mussel and the dry weight of its soft body could be observed in all the investigated areas. Proceeding from these relations and considering the variation of the total weight of mussels in different areas (from 0.124 to 0.242 g), the dry weight of soft bodies was calculated for the so-called standard animal with a total weight of 0.175 g at each sampling (Table 3). Proceeding from the data on dry weight of the soft body of *Macoma baltica* and the defined concentrations, the metal content in one specimen was calculated. Table 2 shows a statistically reliable relationship of the metal content in a specimen and its total weight in all the investigated areas (excl. cadmium

Table 3

Average dry weight (mg) of the soft body of *Macoma baltica* and metal content (ng) in one specimen in different areas at the southern coast of the Gulf of Finland (calculated per one 0.175 g 'standard animal')

Sampling station	Soft body	Copper	Lead	Cadmium
1. Osmussaar	15.6	5434	53.8	19.8
2. Lohusalu	16.6	1565	30.2	14.8
3. Kakumäe	19.8	4465	56.3	33.3
4. Tallinn	16.6	8567	72.2	29.9
5. Ihasalu	17.0	7478	57.4	21.4
6. Kolga	18.2	3394	54.4	21.5
7. Käsmu	19.4	3119	48.6	21.7
8. Kunda	19.1	2228	64.6	39.2
9. Purtse	18.9	3142	68.3	41.2
10. Sillamäe	17.5	1744	49.7	40.1
11. Narva-Jõesuu	21.6	2740	45.6	45.1

content in mussels collected at Osmussaar). These research results provided data for the regression curves in Figs. 2–4 showing relations between the metal content in specimens of *Macoma baltica* and their total weight. Basing on these data, the metal content for one 0.175 g standard animal was calculated (Table 3).

Figure 5 shows that the copper content is relatively higher in Tallinn and at Ihasalu as well as in the Osmussaar region. The lead content is relatively homogeneous for the whole investigated area being somewhat higher in Tallinn, at Kunda and Purtse, but lower at Lohusalu. The cadmium content is generally higher in the eastern part of the Gulf of Finland, although some increase can also be seen near Tallinn. Neglecting the data on Tallinn (Kakumäe), the cadmium content in the *Macoma baltica* at the southern coast of the Gulf of Finland increases in the west–east direction.

DISCUSSION

The use of mussels, in particular *Mytilus* spp., for describing the state of marine environment for the content of heavy metals has been investigated thoroughly. A review of the problems involved was given by Cossa (1989). Fischer (1988, 1989) demonstrated the successful use of *Mytilus edulis* for indication purposes in the Baltic Sea. The data on *Macoma baltica* are relatively scarce. Yet in several investigations, including those in the Baltic Sea, metal concentrations in this mussel were determined (Phillips, 1977; Kaitala, 1981; Tervo et al., 1980; Szefer, 1986; Frelek et al., 1994; and others). The dependence of metal concentrations on the variation of environmental and biotic conditions has been treated more profoundly on the example of *Macoma baltica* collected in San Francisco Bay (Cain & Luoma, 1990). In the Baltic Sea for *Macoma baltica*, similarly to *Mytilus edulis*, an index that relates the cadmium content to the shell weight of the animal (the so-called Cd/shell weight index) was recommended by Fischer (1983).

Usually a good relation between the metal, mainly cadmium, concentration and changes in the dry weight of soft body has been reached for both *Mytilus* spp. and *Macoma baltica* (Borchardt et al., 1988; Cossa, 1989; Broman et al., 1991; and others). In our material no relation between

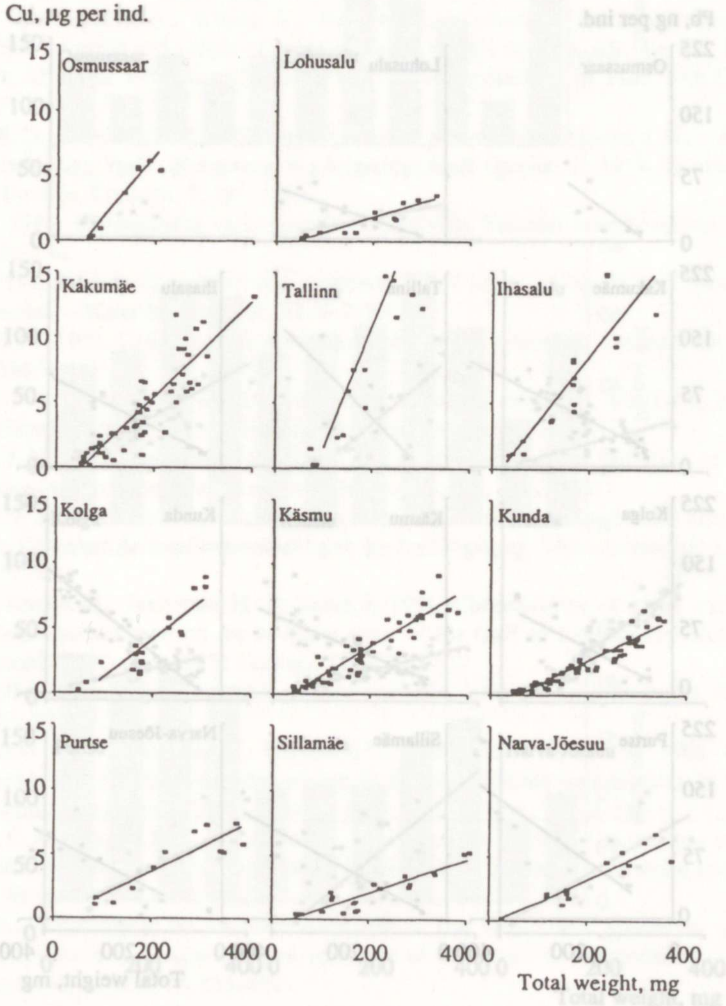

Fig. 2. Relation of copper content to the total weight of *Macoma baltica*.

the metal concentration and the dry weight of the soft body or the total weight of *Macoma baltica*, generally occurs. Only for copper a statistically reliable positive relation between the concentration and the mussel's total weight can be observed.

The standardization of the concentration of the investigated heavy metals in the soft body of *Macoma baltica* and the calculation of their content per one 0.175 g 'standard animal' allows us to compare the spatial differences in the bioavailability of the metals. At the southern coast of the Gulf of Finland the major known contamination sources are certainly Tallinn with its industry and seaports and the industrial region of North-East Estonia with oil shale mines and big power plants. The content of the investigated metals in *Macoma baltica* proved to be generally higher in these two areas (Fig. 5). The copper content in one standard specimen of

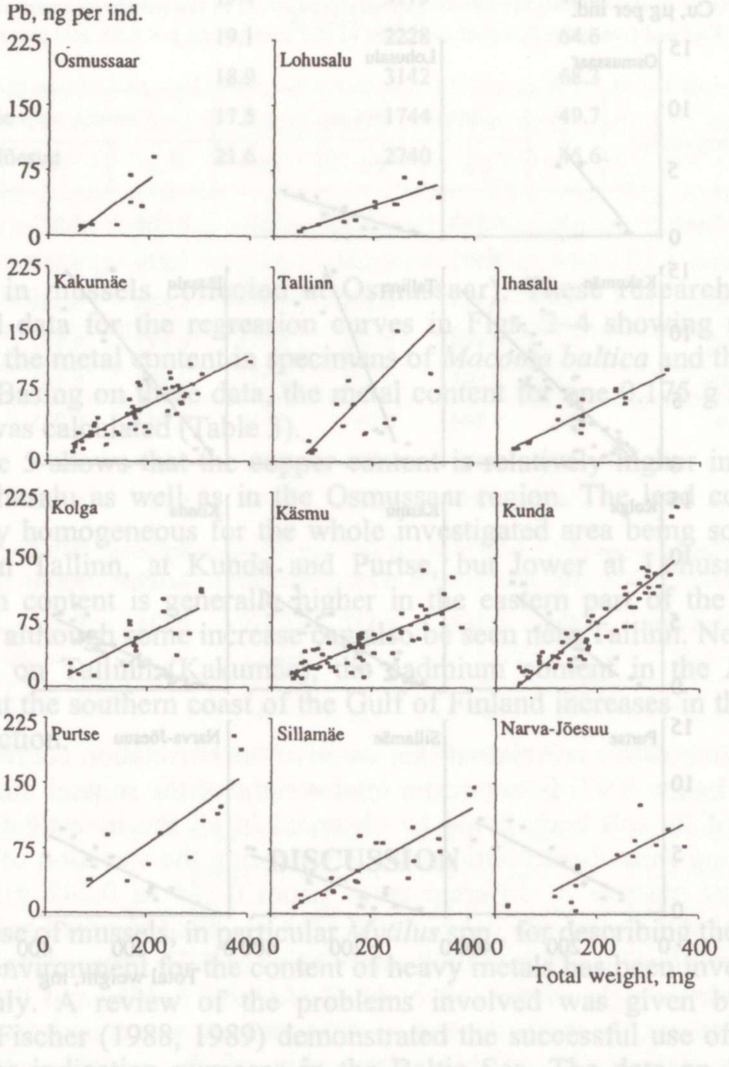

Fig. 3. Relation of lead content to the total weight of *Macoma baltica*.

Macoma baltica exceeds 7000 ng in Tallinn and at Ihasalu; that of lead is over 60 ng in Tallinn, at Kunda and Purtse. The cadmium content exceeds 30 ng at Kakumäe, in Tallinn, and throughout the whole region of Narva Bay. In other areas the copper content is generally below 3000 ng, that of lead varies from 30 to 50 ng, and the cadmium content is about 20 ng. For cadmium a slight west–east growth trend could be seen: at the entrance of the Gulf of Finland (Osmussaar, Lohusalu) the cadmium content in one standard specimen of *Macoma baltica* is below 20 ng, in the central part of the gulf (Käsmu, Kolga) it exceeds 20 ng and in Narva Bay even 40 ng. Evidently, the changes in the cadmium speciation and bioavailability are expressed here according to the variation of water salinity. It is known that cadmium, e.g. in the estuaries of rivers where the salinity is low, is tied up to 85% to particles travelling in the water, but the same index is only 15–20%

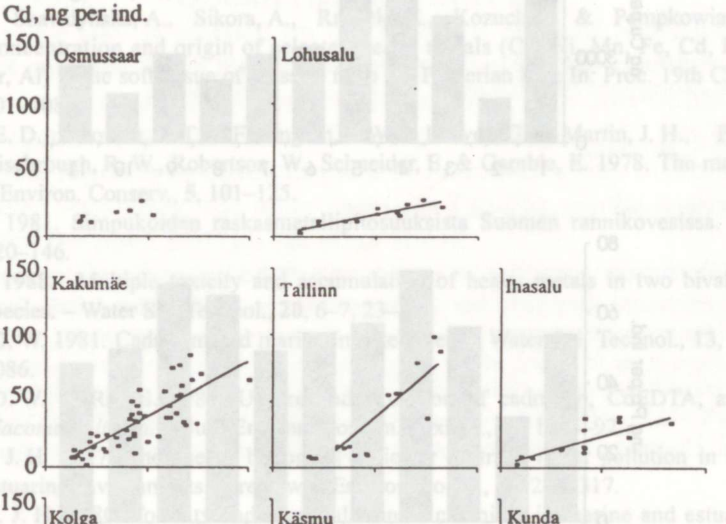

Fig. 4. Relation of cadmium content to the total weight of *Macoma baltica*.

in the coastal waters (Phillips, 1980). The amount of free cadmium ions decreases also with the increase of water salinity due to the formation of chlorocomplexes (Turner et al., 1981). Thus generally speaking the bioavailability of cadmium increases with the reduction of water salinity and our results on cadmium content in the soft body of *Macoma baltica* sampled at the southern coast of the Gulf of Finland seem to reflect it well. Our earlier investigations with *Saduria entomon* as an indicator organism (Simm et al., 1991) also showed a similar west–east directed growth of cadmium content in the Gulf of Finland.

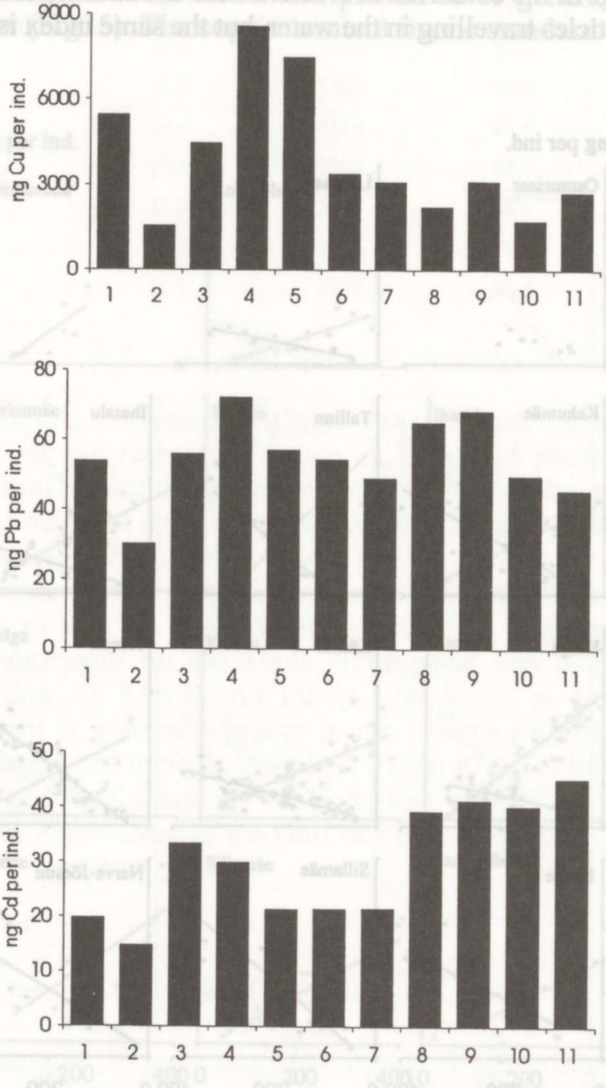

Fig. 5. Copper, lead, and cadmium content in *Macoma baltica* in different areas of the Gulf of Finland calculated per one 0.175 g 'standard animal'. *1*, Osmussaar; *2*, Lohusalu; *3*, Kakumäe; *4*, Tallinn; *5*, Ihasalu; *6*, Kolga; *7*, Käsmu; *8*, Kunda; *9*, Purtse; *10*, Sillamäe; *11*, Narva–Jõesuu.

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