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SHELL GROWTH OF THE FRESHWATER UNIONID *UNIO CRASSUS* FROM ESTONIAN RIVERS

Abstract. Life-span and growth rate of the bivalve mollusc *Unio crassus* from some small Estonian rivers were estimated. Growth rate was compared to the current mean summer air temperature, and to the amount of precipitation of the previous year. The reasons probably causing the different growth patterns are briefly discussed.

Introduction

In the framework of the Swedish-Estonian cooperation, studies are carried out on growth rate and chemistry of shells of the freshwater unionid *Unio crassus* from Estonian rivers. The aim of these works is to elucidate environmental changes in Estonia of the present century. A preliminary report has recently been published (Mutvei, Timm, 1991). The following institutes take part of these studies: Institute of Zoology and Botany of the Estonian Academy of Sciences (H. Timm, V. Timm) and Swedish Museum of Natural History, Stockholm (H. Mutvei, E. Dunca). The chemical studies, dealt with in a separate paper, are carried out by the Institute of Nuclear Chemistry, Royal Technical University, Stockholm (T. Westermark, B. Carell).

Description of the sampling area

The material of *U. crassus* was collected from 15 localities in the following rivers on the Estonian mainland (length of the rivers in brackets) (Fig. 1): Pedja (122 km), Vigala (95 km), Õhne (94 km), Väike Emajõgi (83 km), Soodla (75 km), Reiu (73 km), Velise (72 km), Kunda (64 km), Pärlijõgi (41 km), Mustoja (28 km), Mudajõgi (16 km) and Kokle (12 km). The highest average runoff among these rivers, measured at the mouth, is 10—12 m^3/sec (Pedja River) (Loopmann, 1979; Eesti NSV . . ., 1986).

According to Simm (1975), Estonian small rivers belong to three main hydrochemical regions:

(1) **The northern region.** This region comprises the Rivers Soodla, Mustoja, Kunda, Pedja, Mudajõgi, Vigala, and Velise. The catchment areas are situated on the Ordovician and Silurian carbonate bedrock, covered by spruce and mixed forests. Meadows and wooded meadows dominate in the western part of the region.

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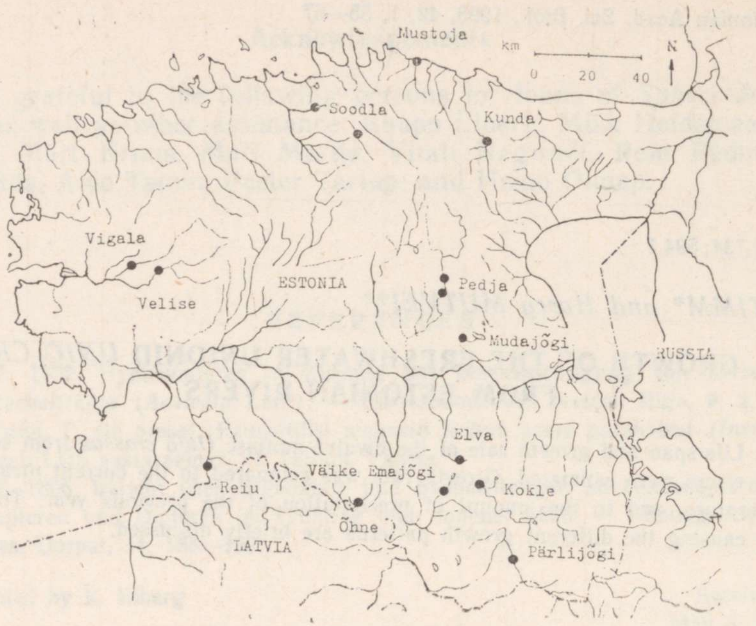


Fig. 1. Studied localities of *U. crassus.*

Water pH varies from 7.3 to 7.9 and the total mineral substance content from 130 to 450 mg/l. In comparison to the southern region, the northern has somewhat higher Ca and N content, and lower HCO_3 and Fe content. Water is weakly coloured.

(2) **The southern region.** The Rivers Elva, Väike Emajõgi, Õhne, Kokle, and Pärlijõgi belong to this region. The catchment areas are situated on the Devonian sandstones and clays, covered by extremely varied types of glacial deposits. The forests are of spruce, and in the south-eastern part also of pine. Water pH varies between pH 7.0 and 7.8 and content of mineral substances from 90 to 440 mg/l. Because of iron rich sandstones in the bedrock, Fe content extends up to 1.0 mg/l. Water therefore is often brown-coloured.

(3) **The intermediate region.** Only the Reiu River belongs here. Catchment areas of this region are covered by bogs and forests. Water pH is between 7.0 and 7.8 and the content of mineral substances varies from 150 to 330 mg/l. Water is comparatively rich in organic substances, originated from bogs, and brownish in colour.

Material and methods

Live and dead shells of *U. crassus* were collected by H. Timm in 1988—1991 from 12 localities of 11 Estonian rivers in connection with routine hydrobiological investigations. Material from three localities of three rivers was added by A. Seire (Institute of Zoology and Botany of the Estonian Academy of Sciences), A. Veegen (Tartu House of Nature) and M. Kivistik (Tartu University). The total material comprises 97 specimens which were weighed and their length was measured (Table). For comparison, 20 individuals from the Mörrumsån river in southern Sweden were also investigated (Table).

Some growth parameters of the shells of *U. crassus* and biological water quality in Estonian rivers

n — number of individuals; *l* — mean length (mm); *w* — mean weight of single valve (g); *t* — mean age (years); ASPT — average score per taxon (after Armitage et al., 1983)

River and region	*n*	*l*	*w*	*w/l*	*t*	*l/t*	ASPT
Northern							
Kunda	4	52	5.1	0.10	58	0.90	5.6
Mudajõgi	6	54	5.8	0.11	23	2.35	4.9
Mustoja	5	66	10.7	0.16	28	2.35	6.2
Pedja (upper)	13	64	10.2	0.16	23	2.79	5.4
Pedja (lower)	6	64	9.2	0.14	29	2.21	5.6
Soodla (upper)	6	56	5.7	0.10	30	1.86	7.3
Soodla (lower)	4	58	7.0	0.12	49	1.18	4.9
Velise	4	59	5.8	0.10	59	0.99	6.3
Vigala	20	50	4.5	0.09	41	1.22	6.9
Average		58±4	7.1±1.6	0.12±0.02	38±10	1.76±0.47	5.9±0.6
Southern							
Elva	5	79	20.5	0.26	51	1.56	5.0
Kokle	3	61	7.6	0.12	37	1.65	6.3
Pärlijõgi	6	64	8.2	0.13	31	2.05	5.7
Väike Emajõgi	2	64	9.8	0.15	44	1.46	7.0
Ohne	2	56	6.1	0.11	43	1.30	7.4
Average		65±8	10.5±5.2	0.15±0.05	41±7	1.60±0.25	6.3±0.9
Intermediate							
Reiu	11	54	6.3	0.12	28	1.93	6.3
Total	97	60±4	8.2±2.0	0.13±0.02	38±6	1.72±0.29	6.1±0.4
Mörrumsån	20	62±2	7.5±0.7	0.12±0.01	21±2	3.16±0.28	

For analyses of annual growth rates, shells were cut from umbo to ventral margin, at right angles to growth increments. A 0.6 mm thick thin-section was then prepared of the cutting plane. The section was treated for one hour with a 1 : 1 mixture of 25% glutaraldehyde and 1% acetic acid, to which alcian blue was added. The treatment etched calcium carbonate in shells and provided a fixation of shell glycoproteins. Width of annual growth increments was measured at the boundary between the prismatic and nacreous layers. Age of shell was determined by counting annual growth bands. Light microscope, equipped with video-camera, monitor and computer was used.

The death year of dead shells was estimated by matching growth curves in live mussels collected in the same or nearby situated river.

Biological estimate of water quality. In order to estimate the degree of organic pollution, the ASPT index was calculated on the basis of the total bottom macrofauna (Armitage et al., 1983) (Table). The index was proposed by the Biological Monitoring Working Party (BMWP, Great Britain) in the late 70s for the classification of the British river localities on the basis of macrozoobenthos composition. The animals (mainly insects, crustaceans, molluscs and worms) with tolerance values from 1 (the lowest) to 10 (the highest water quality), are determined to the family level. The sum of all tolerance values of a sample forms the BMWP score; average score per taxon (ASPT) is the score divided by the number of taxons (families). The ASPT depends less on sample size, sampling method, and season than BMWP score (Armitage et al., 1983).

In this study, qualitative samples of macrofauna were collected during 10—15 min. at each locality of *U. crassus*. Animals were picked from stones, branches and bottom sediments (with pond-net), and placed immediately into 70% ethanole. ASPT had a negative significant correlation with BOD20 and total phosphorus content of Estonian rivers (Timm, 1991). In the Estonian rivers here dealt with, the ASPT mean value was 6.1±0.4, characteristic to unpolluted or slightly polluted water. The tolerance value of unionids, including *U. crassus*, is 6.

Results

Natural habitats

Although special studies on the distribution of *U. crassus* have hitherto not been carried out, this species seems to occur in most Estonian rivers. It prefers gravelly and sandy bottom, often living downstreams of riffles and water-regulation dams. Although it is regarded as an obligatory rheophile, *U. crassus* avoids rapidly flowing areas. In Estonia, it is found in rivers with pH 7.7 to 8.2, BOD5 from 1.8 to 2.0, and oxygen content from 8.2 to 10.5 mg/l (Veegen, 1990). In Russian rivers it preferred Ca content close to 100 mg/l. However, a clear relationship between Ca content and shell weight could not be established. Temperature seemed not to have significant effects on growth parameters (Алимов, 1981).

Shell length and weight

The mean length of 97 full-grown shells from Estonian rivers was 59±2 mm, from 37 to 83 mm (Table). In 20 shells from the Mörrumsån River (Sweden) the mean length was 62±2 mm (Table). The longest shell of all, collected from the Elva River, attained 83 mm in length, and from the Mörrumsån River 70 mm. The shortest mean shell length of full-grown specimens from the Vigala and Kunda Rivers was 50 mm and 52 mm, respectively.

A significant correlation existed between shell length and weight of one valve ($r=0.89$). Mean weight of shells from Estonian rivers was 8.2±2.0 g (for one valve) which is similar to that from the Mörrumsån River (Table). The longest shell valve collected from the Elva River weighed 25.4 g, and the shortest ones from the Vigala River as low as 4.5 g on an average.

The ratio of weight of one valve to shell length was as low as 0.09 g/mm (Vigala River) to 0.26 g/mm (Elva River) (Table). These differences are probably not related to different Ca content in rivers. To understand the problem, further investigations are necessary.

Age

The age of full-grown specimens from Estonian rivers was 15 to 90 years, 38±6 years on an average. The oldest specimens (90 and 84 years) were collected from the Vigala River and Kunda River, respectively. Unfortunately, both these specimens were represented by dead shells.

The mean age of 38 years in *U. crassus* from Estonian rivers is considerably higher than that from the Mörrumsån River where it attains that of only 21±2 years. The maximum age of Estonian *U. crassus*, 90 years, is the highest ever recorded. The maximum age of the Swedish and Central European specimens is less than 50 years (Mutvei, unpubl. observations).

Shell length/age ratio calculations indicated the highest growth rate (2.79 mm/year) at the upper locality of the Pedja River, and the lowest (0.90 mm/year) in the Kunda River. Mean growth rate was 1.72±0.29 mm/year (Table).

Shell growth rates and environment

A comparison of mussels from the three Estonian hydrochemical regions described above, demonstrated significant differences neither in age distribution nor in annual growth rates (Table).

No significant correlations were found between shell length and mean age of the specimens, or between mean age and ASPT.

Shell growth rate usually was high during the first 10—12 years, probably because the animals were sexually immature. Consequently, the environmental influence on the growth rate could be best measured in full-grown shells, more than 40 years old. The first 3—4 annual growth bands in umbonal region were often worn off.

The growth rates of 18 full-grown individuals were compared to each other, mean summer air temperatures, and the amount of precipitation of the previous year. The climatological data were supplied by the Tallinn meteorological station (Метеорологический . . ., 1960—1990). By correlation analysis, three different growth patterns were established (Fig. 2):

(1) Normal, evenly decreasing growth rate in the Rivers Elva, Kokle Reiu, Väike Emajõgi, and Õhne ($n=11$; Figs. 3*a*, *b*, *c*, *d*, *e*).

(2) Irregular growth rate in the River Velise ($n=3$; Fig. 3*f*).

(3) Increasing growth rate during the last 10 years in the Rivers Soodla, and Pärlijõgi ($n=4$; Figs. 3*g*, *h*).

No significant correlations were found between the mean summer temperatures and the growth patterns. The growth patterns of three individuals from the Velise River correlated positively to the amount of precipitation of the previous year. In order to confirm the latter correlation, more material is needed. However, the growth patterns of individuals from the neighbourhood of River Vigala with similar environmental conditions was significantly different (Figs. 3*i*, *m*).

Normal shell growth pattern. — Mussels with long life-span (40 to 60 years) and normal growth pattern, were found in localities usually little influenced by human activities. At the same time, ASPT values were comparatively high (Table). Shells from the Rivers Vigala, Kunda, Pedja, Mudajõgi, and Mörrumsån, close to normal growth pattern, had some additional features discussed below.

Increase of shell growth rate in the Soodla River. In the Soodla River, growth rates of all mussels considerably increased during the last 10—12 years (Fig. 3*g*). The growth acceleration coincides with the construction of the Soodla reservoir in 1981 some hundred meters upstreams. The growth increase seems to have been caused by an increase of the amount of phytoplankton used for feeding the mussels. According to R. Laugaste (Institute of Zoology and Botany of the Estonian Academy of Sciences) and R. Siirak (Tallinn Board of Water Supply and Canalization) (pers. communication), the biomass of phytoplankton in the Soodla River was in 1974—1976 always below 1 g/m^3, but increased in the reservoir to 5.8 g/m^3 in 1982—1984, and fluctuated between 2.6 g/m^3 and 7.0 g/m^3 in 1990. Probably, the reservoir also caused the low ASPT value at the locality (4.9) (Table).

In order to demonstrate the potential influence of the reservoir to the enhanced growth rate, some shells (unfortunately dead) were collected 20 km upstreams of the reservoir and their growth rate was studied (Table; Fig. 3*j*). However, no increase of the growth rate was detected.

Increased growth rates were also observed in shells from the Rivers Pärlijõgi and Mustoja (Figs. 3*h*, *k*) but the causes could not be explained.

Specimens with extremely long life-span. Four empty shells from the Kunda River, impossible to date, demonstrated comparatively low growth rate (Table). One of these shells, 51.5 mm in length, had a life-span as high as 84 years (Fig. 3*l*).

A shell from the Vigala River proved to be 90 years old but only 54.0 mm long (Fig. 3*m*). This specimen has the highest age hitherto found in *U. crassus*.

Influence of urban and agricultural pollution. Shells of the Pedja River were available from two localities; about 10 km upstreams and 10 km downstreams of the Jõgeva town (7000 inhabitants). At the upstreams locality surrounded by farming land, exceptionally high growth rate, normal growth curve, and short life-span were observed (Table; Fig. 3*n*). The mussels at the downstreams had also short life-span; the growth rate showed an extremely abrupt decrease (Fig. 3*o*), probably caused by urban pollution.

The locality of the Elva River is influenced by wastewater from the small town Otepää (2,500 inhabitants) *ca* 5 km upstreams. However, except the relatively low ASPT value (5.0), the effect of pollution on the growth pattern of *U. crassus* could not be observed.

Growth pattern of mussels collected in the small River Mudajõgi is similar to that at the upstreams locality of the Pedja River, characterized by short life-span and high growth rate (Table; Fig. 3*p*). This river is surrounded by farming lands probably decreasing the ASPT value (as low as 4.9; Table).

Mörrumsån River in southern Sweden. Growth pattern expressed by short life-span and high growth rate (Table) was found in mussels from the Mörrumsån River (Fig. 3*r*). This river is little affected by pollution and relatively soft water as indicated by the occurrence of *Margaritifera margaritifera*.

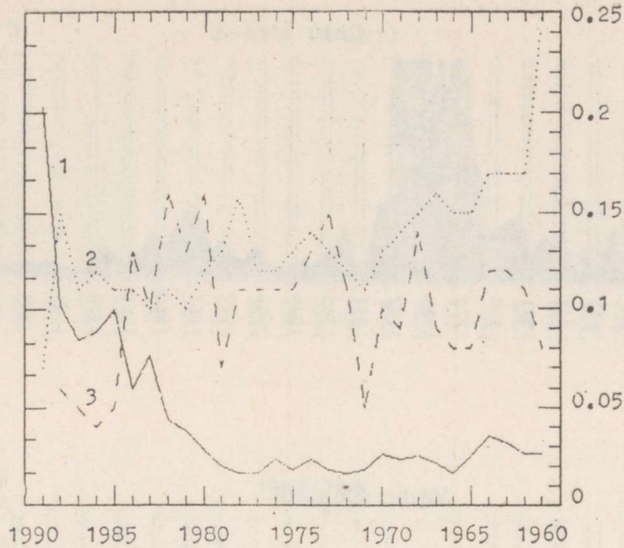
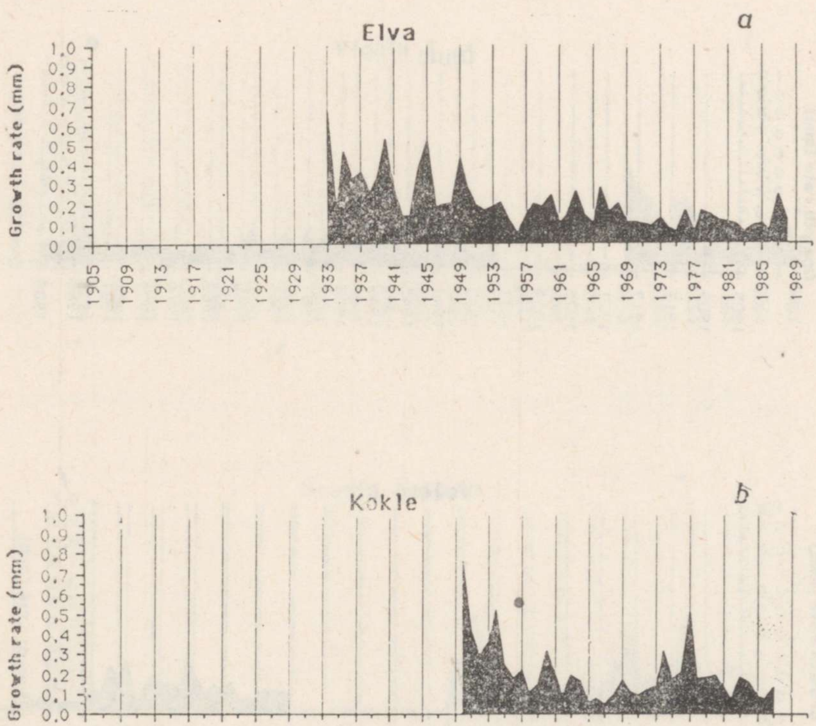
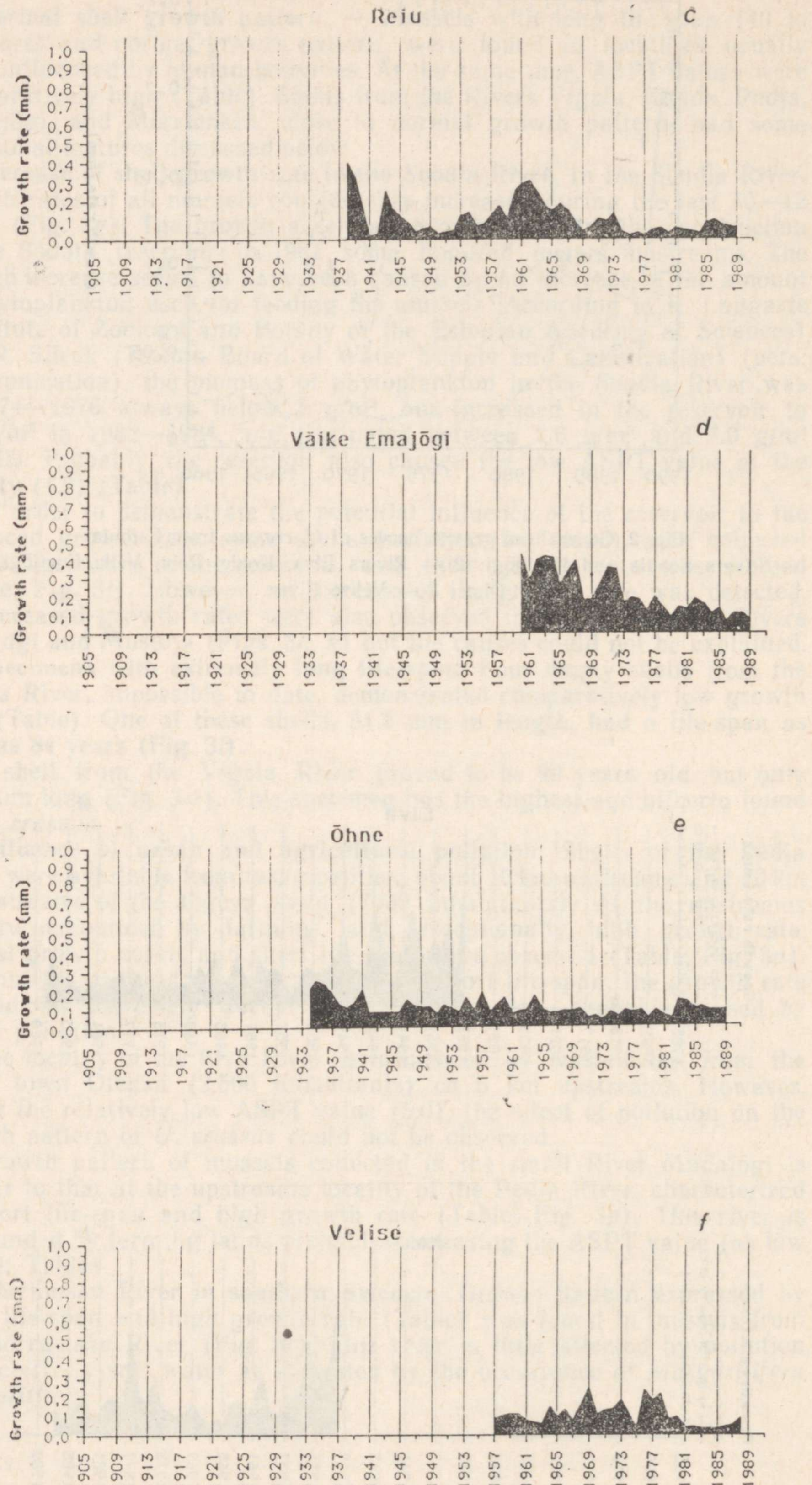
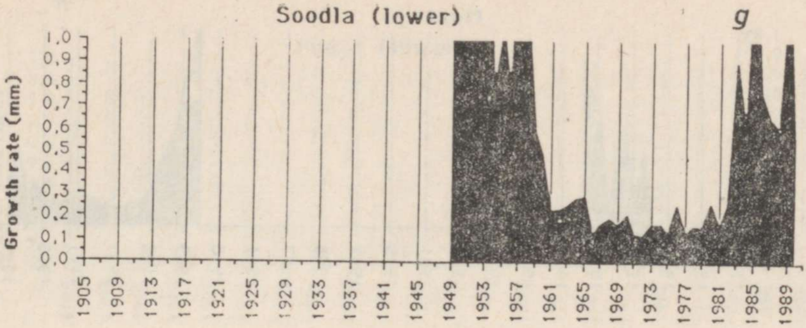


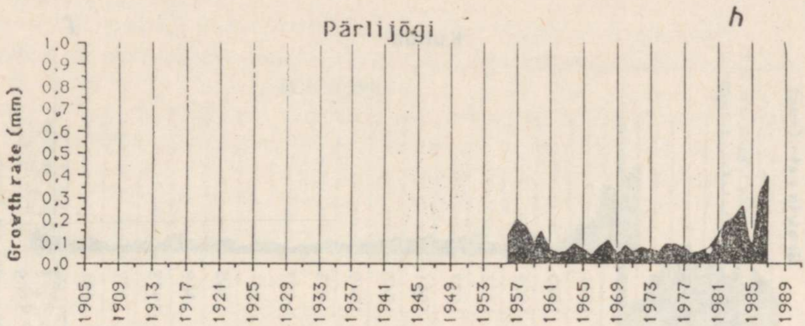
Fig. 2. Generalized growth curves of *U. crassus* from Estonia.
1 — Rivers Soodla and Pärlijõgi; *2* — Rivers Elva, Kokle, Reiu, Väike-Emajõgi, and Õhne; *3* — Velise River.



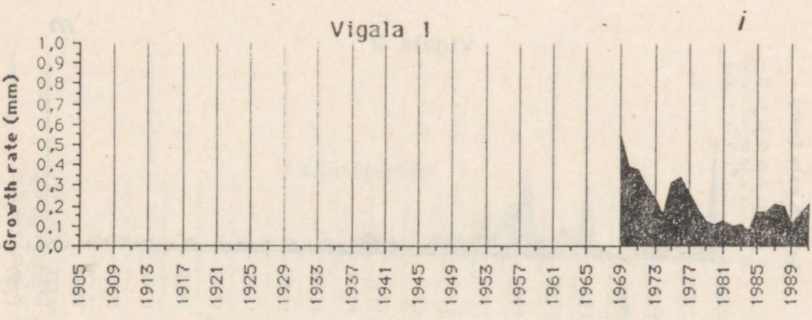

Reiu
c
Väike Emajõgi
d
Õhne
e
Velise
f
Growth rate (mm)
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
1905
1909
1913
1917
1921
1925
1929
1933
1937
1941
1945
1949
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989



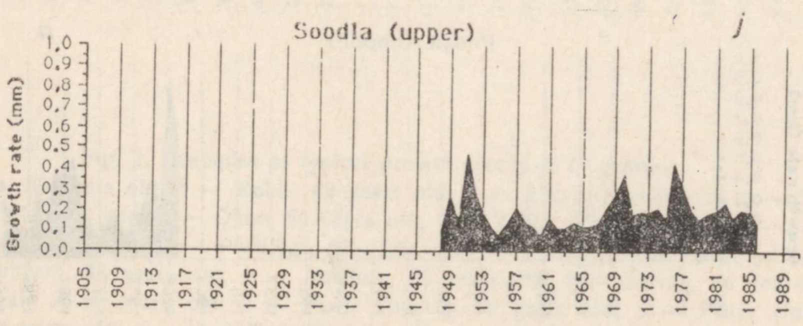
Soodla (lower)
g
Growth rate (mm)
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
1905 1909 1913 1917 1921 1925 1929 1933 1937 1941 1945 1949 1953 1957 1961 1965 1969 1973 1977 1981 1985 1989



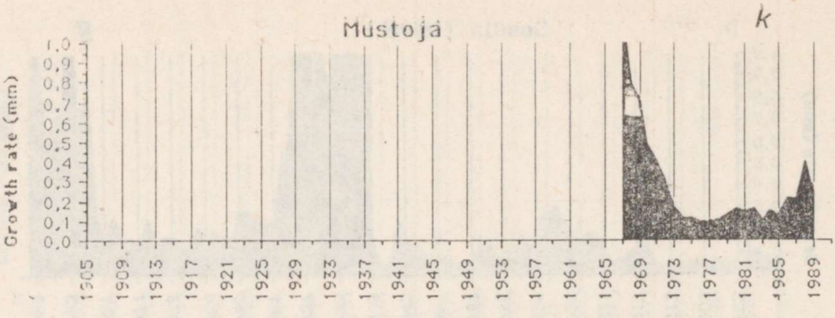
Pārlijõgi
h
Growth rate (mm)
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
1905 1909 1913 1917 1921 1925 1929 1933 1937 1941 1945 1949 1953 1957 1961 1965 1969 1973 1977 1981 1985 1989

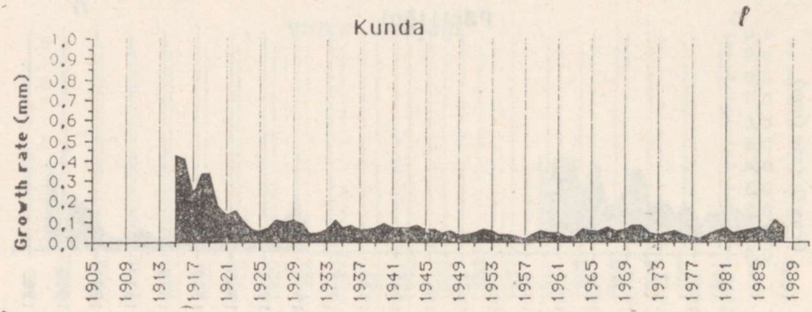


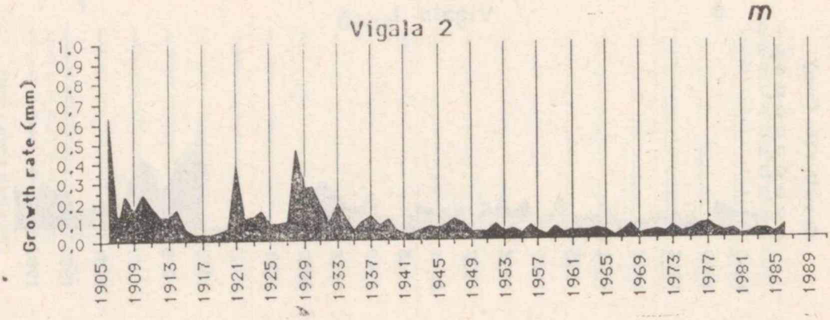
Vigala 1
i
Growth rate (mm)
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
1905 1909 1913 1917 1921 1925 1929 1933 1937 1941 1945 1949 1953 1957 1961 1965 1969 1973 1977 1981 1985 1989

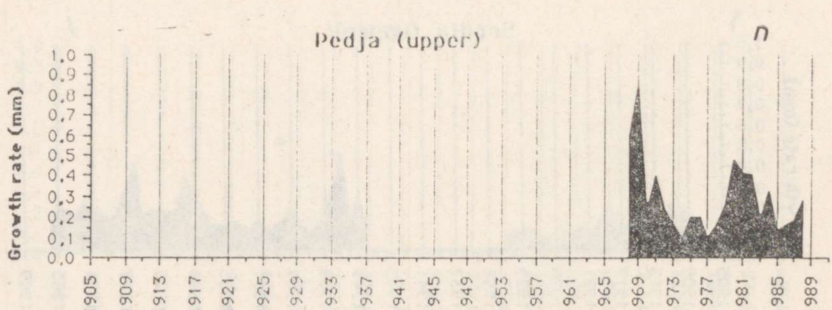


Soodla (upper)
j
Growth rate (mm)
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
1905 1909 1913 1917 1921 1925 1929 1933 1937 1941 1945 1949 1953 1957 1961 1965 1969 1973 1977 1981 1985 1989


Mustoja
k
Growth rate (mm)


Kunda
l
Growth rate (mm)


Vigala 2
m
Growth rate (mm)


Pedja (upper)
n
Growth rate (mm)

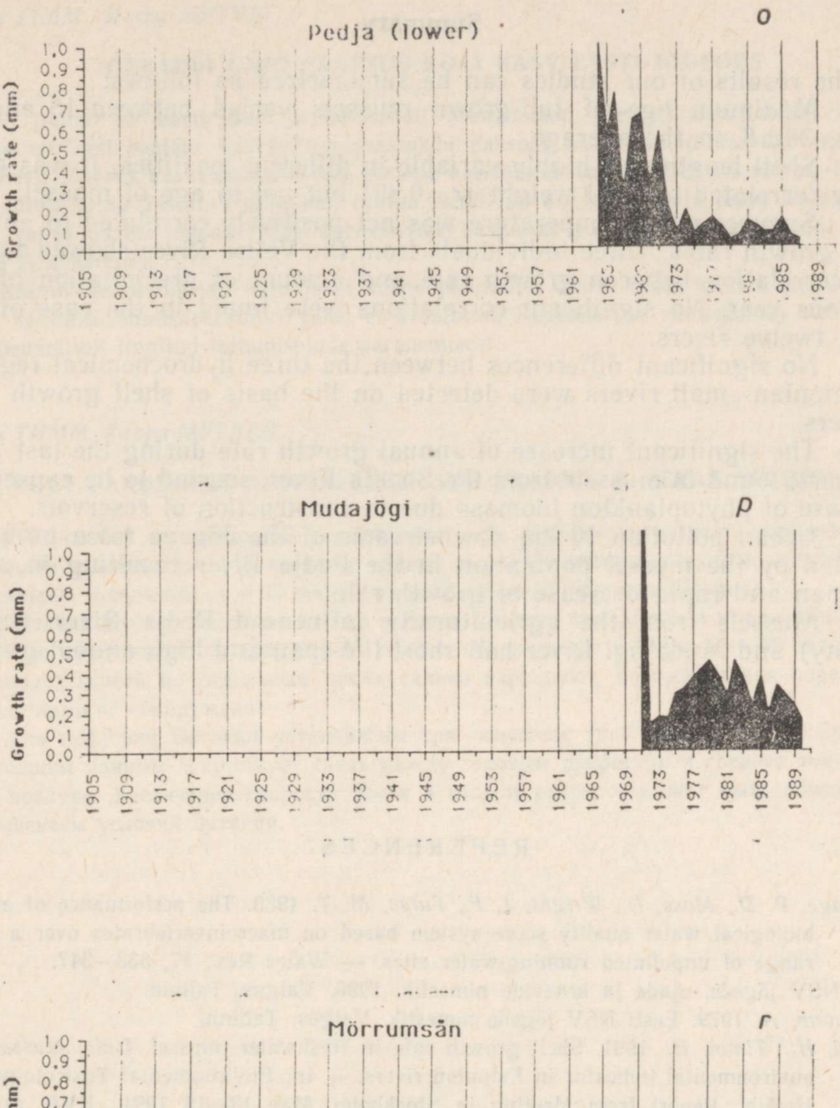


Fig. 3. Examples of typical growth curves of *U. crassus*.
a — Elva, 60 years old; *b* — Kokle, 49 years old; *c* — Reiu, 58 years old; *d* — Väike Emajõgi, 44 years old; *e* — Õhne, 60 years old; *f* — Velise, 53 years old; *g* — Soodla (lower), 67 years old; *h* — Pärlijõgi, 60 years old; *i* — Vigala 1, 41 years old; *j* — Soodla (upper), 43 years old; *k* — Mustoja, 32 years old; *l* — Kunda, 84 years old; *m* — Vigala 2, 90 years old; *n* — Pedja (upper), 32 years old; *o* — Pedja (lower), 35 years old; *p* — Mudajõgi, 22 years old; *r* — Mörrumsån, 28 years old.

Summary

The results of our studies can be summarized as follows:

1. Maximum age of full-grown mussels varied between 15 and 90 years, 38±6 on the average.
2. Shell length was highly variable in different localities. It was positively correlated to shell weight ($r=0.89$) but not to age of mussel.
3. Summer mean temperature was not positively correlated to annual shell growth rates. Three individuals from the Velise River showed a positive correlation between growth rate and amount of precipitation of the previous year. No significant correlations were found in the case of the other twelve rivers.
4. No significant differences between the three hydrochemical regions of Estonian small rivers were detected on the basis of shell growth parameters.
5. The significant increase of annual growth rate during the last 10—12 years, found in mussels from the Soodla River, seemed to be caused by increase of phytoplankton biomass due to construction of reservoir.
6. Urban pollution 10 km downstreams of the Jõgeva town probably affected by the mussel population in the Pedja River resulting in short life-span and rapid decrease of growth rate.
7. Mussels from the agriculturally influenced Pedja River (upper locality) and Mudajõgi River had short life-span and high annual growth rate.

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JÕEKARBI *UNIO CRASSUS* KOJA KASV EESTI JÕGEDES

97 isendil 13 Eesti jõest ja 20 isendil Mörrumsåni jõest (Lõuna-Rootsi) määrati vanus, mõõdeti aastane kasvukiirus (aastakihi paksus) ning hinnati kasvukõvera kuju. Eesti jõgedes saadi täiskasvanud karpide keskmiseks vanuseks 38±6 aastat, Rootsis aga ainult 21±2 aastat. Vanim seni tuntud isend (90 a.) leiti Vigala jõest. Koja pikkus ning vanus on eri jõgedes väga varieeruvad, kusjuures positiivset korrelatsiooni nende vahel ei avastatud.

Kasvukõverad liigitati kuju järgi kolme põhitüüpi. Otsest seost aastase juurdekasvu ning keskmise õhutemperatuuri vahel ei avastatud. Kasvukiiruse suurenemine vanas eas on tõenäoliselt tingitud toitumisolude paranemisest.

Хенн ТИММ, Харри МУТВЕЙ

РОСТ РАКОВИНЫ ПЕРЛОВИЦЫ *UNIO CRASSUS* В РЕКАХ ЭСТОНИИ

У 97 особей перловицы 13 рек Эстонии были определены возраст, скорость роста (толщина годовых слоев) и характер кривой роста. Полученные результаты сравнивали с данными, полученными у 20 особей из р. Мэррумсон (Южная Швеция).

Средний возраст взрослых особей в реках Эстонии был 38±6, а в реке Швеции — 21±2 лет. Рекордный по возрасту *U. crassus* обнаружен в р. Вигала — 90 лет. Длина и возраст особей по отдельным рекам сильно варьируют, положительная корреляция между ними не обнаружена.

Для перловиц Эстонии установлены три основных типа кривых роста. Согласно настоящим данным отсутствует связь между годовым приростом и средней температурой воздуха. Увеличение скорости роста в старом возрасте может быть обусловлено улучшением условий питания.