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BIG CLAMS OF THE ESTONIAN FRESHWATERS: COMPARISON OF THE AGE, SHELL LENGTH, AND SHELL WEIGHT IN DIFFERENT SPECIES AND POPULATIONS

Henn TIMM

Eesti Teaduste Akadeemia Zooloogia ja Botaanika Instituudi Võrtsjärve Limnoloogiajaam (Võrtsjärv Limnological Station, Institute of Zoology and Botany, Estonian Academy of Sciences), Rannu, EE-2454 Tartumaa, Eesti (Estonia)

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Abstract. Age of 584 unionid and margaritiferid specimens from different Estonian freshwaters was measured, counting annual lines on thin cross-sections, or in some cases, annual rings on shell surfaces. The first method enabled to estimate age with ±1—2 years' confidence. The results were related to shell length and weight; all these features were compared in standing and flowing waters, and in upper and lower reaches, respectively. *Margaritifera margaritifera* and *Unio crassus* had the highest mean and maximal age, and the *Anodonta* species the lowest, respectively. *M. margaritifera* had also the lowest length/age, and the highest weight/length ratio among the 7 clam species studied. *Anodonta cygnea* revealed the highest length/age ratio.

Key words: Estonia, freshwaters, age, Unionidae, Margaritiferidae.

INTRODUCTION

Big clams have relatively long life-span compared to other bottom animals. Therefore their occurrence indicates stable conditions without drastic impairments in waterbody. Unionids sometimes constitute a remarkable part of the macrozoobenthos biomass in freshwaters: 90% of the total macrozoobenthos in the Thames River (Negus, 1966); over 10 kilograms per square metre (Haukioja & Hakala, 1974). Some species have become rare in Europe (*Margaritifera margaritifera*, *Unio crassus*) (Bauer, 1988; Bednarczuk, 1986). Clams like the other macroinvertebrates are often used as bioindicators (Rosenberg, Resh, 1993).

Knowledge on precise longevities of animals is often necessary when ecological studies are carried out, especially in production studies. Nevertheless, the correct measuring of age in big clams, especially in the old and dark individuals from running waters has still remained a problem for many researchers.

STUDY AREA

The material comprises 17 sections of 14 rivers and streams, 9 lakes, and one reservoir (Fig. 1, Tables 1, 2). The length of streams and rivers varies from 2 km (Raigastvere Stream) to 112 km (Kasari River). Except for Lake Võrtsjärv (270 km^2) and the Paunküla Reservoir (350 ha), the area of standing water localities does not exceed 200 ha. The only locality studied in the very large Lake Peipsi is situated at the end of narrow Värska Bay. The hydrochemical characteristics available from the sampling localities are presented in Table 1. According to Mäemets (1977), the standing waters studied belong to the following limnological types:

1) oligotrophic, slightly humic, softwater (Palujüri)
2) eutrophic, softwater (Mäha, Pabra)
3) eutrophic, hardwater (Ratasjärv, Võrtsjärv, Õisu)
4) eutrophic, humic, softwater (Valguta Mustjärv)
5) eutrophic, humic, hardwater (Kooraste Suurjärv, Paunküla Reservoir, Värska Bay of Lake Peipsi.

Water quality in the running waters studied did not usually exceed the common criteria (pH=6.5—8.5, BOD_7⇐3 mgO/l; total P⇐0.1, NH_4⇐0.4, NO_2⇐0.02, and NO_3⇐1.2 mg/l, respectively) (Newman, 1988; Starast, 1983; Вельнер et al., 1982). Some localities were situated immediately below lakes (Nava, Raigastvere, and Rõuge Streams), or reservoir (Verilaske Stream).

Most species collected inhabited shallow littoral (<1 m) with hard bottom (muddy sand with macrophytes, sand, gravel or cobbles). *Anodonta cygnea* in Lake Võrtsjärv, Valguta Mustjärv and Väike Pehmejärv, and also *Unio pictorum* in Väike Pehmejärv settled muddy bottom (depth up to 2.5 m).

MATERIAL AND METHODS

Most of material was collected as random samples by hand in connection with routine hydrobiological investigations. *Anodonta cygnea* of Lake Võrtsjärv was caught by fish trawl. In Lake Valguta Mustjärv, shells partly destroyed by muskrats were collected from the quagmire shoreline. Surprisingly, a large number of whole shells (some still alive) of *A. cygnea* and *Unio pictorum* have been observed on a beaver-dam of the outflow of Lake Väike Pehmejärv. The sample size varied, sometimes as a result of insufficient density.

The Estonian lakes and rivers are nowadays inhabited by 12 species of big clams: *Margaritifera margaritifera* (Linnaeus, 1758), *Unio crassus* (Philipsson, 1788), *U. pictorum* (Linnaeus, 1758), *U. tumidus* Philipsson, 1788, *Anodonta cygnea* (Linnaeus, 1758), *A. minima* Millet, 1833 sensu Starobogatov (1977), *A. piscinalis* Nilsson, 1823, *A. ponderosa* Pfeiffer, 1855, *A. stagnalis* (Gmelin in Linnaeus, 1791), *A. zellensis* (Gmelin, 1791), *Pseudanodonta minima* (Millet, 1833) sensu Kennard et al. (1925), and *Dreissena polymorpha* (Pallas, 1771), (Timm & Timm, 1994). In this study, the simple determining system of Ellis (1978) was used, which does not distinguish *A. cygnea*, *A. stagnalis*, and *A. zellensis*, probably placing all of them into the species *A. cygnea* (Linnaeus) sensu lato. *A. minima* and *A. piscinalis* probably belong to Ellis's *A. anatina* (Linnaeus) sensu lato. *Anodonta complanata* Rossmässler, 1835, is a synonym of *Pseudanodonta minima*.

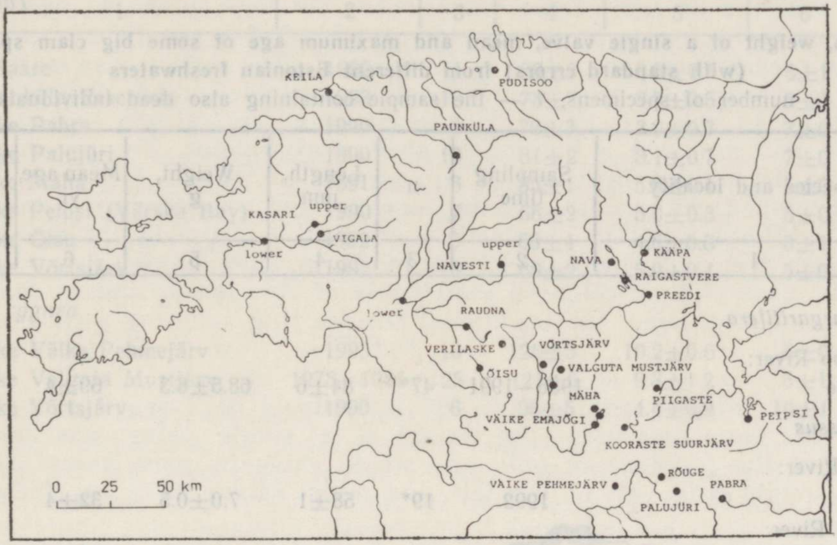

Fig. 1. Map of the localities.

Table 1

Some hydrochemical characteristics of the waterbodies studied

(NH_4, NO_2, NO_3, and total P contents — mg/l; BOD_7 — mgO/l; total alkalinity (Alk.) — mg-eq./l. If not otherwise indicated, the results reveal annual mean values. * — BOD_5, ** — immediately above the Rõuge Stream)

Waterbody	Year & month	pH	BOD_7	NH_4	NO_2	NO_3	Total P	Alk.
Running waters								
Väike Emajõgi (upper)	1992	7.4	2.0	0.20	0.009	2.1	0.04	
Pudisoo	VI 1993	7.7	1.0	0	0	0.2	0.03	1.77
Navesti (upper)	1992	7.6	1.9	0.13	0.010	2.6	0.04	
(lower)	1993	7.7	1.6	0.23	0	0.7	0.06	4.61
Preedi	1992	7.6	2.0	0.07	0.019	2.2	0.05	
Kasari (upper)	1992	7.7	1.7	0.05	0	0.6	0.03	
Vigala	1992	7.7	1.6	0.08	0.010	1.5	0.09	
Raudna	1993	7.7	1.8	0	0.012	1.4	0.13	5.83
Verilaske	1993	7.7	2.5	0.13	0.022	2.3	0.14	5.95
Nava	1992	7.5	4.1	0.10	0.06	0.4	0.05	
Raigastvere	1992	7.6	2.7	0.10	0.011	0.3	0.04	
Kääpa	1992	7.4	2.6	0.23	0.04	0.3	0.04	
Standing waters								
Võrtsjärv	1989	8.3	3.5*	0.06	0	0.47	0.09	4.52
Rõuge Ratasjärv**	VII 1991	8.1					0.02	
Õisu	VII 1992	8.0					0.05	
Kooraste Suurjärv	VII 1991	7.7					0.02	
Paunküla	VII 1990	7.7					0.08	
Pabra	VIII 1990	7.7					0.02	
Palujüri	VIII 1990	6.8					0.03	
Mäha	VII 1991	6.9					0.04	
Valguta Mustjärv	1985	6.5					0.09	

Table 2

Length, weight of a single valve, mean and maximum age of some big clam species (with standard errors) from different Estonian freshwaters

(n — number of specimens, * — the sample containing also dead individuals)

Species and locality	Sampling time	n	Length, mm	Weight, g	Mean age, yr	Max. age, yr
1	2	3	4	5	6	7
M. margaritifera						
Pudisoo River:						
Tõlde	1936—1991	47*	84±6	68.5±6.3	69±4	132
U. crassus						
Keila River:						
Joa	1992	19*	58±1	7.0±0.5	32±4	68
Kasari River:						
Teenuse (upper)	1992	23	44±1	3.6±0.2	31±2	53
delta (lower)	1992—1993	10	51±2	2.8±0.2	29±2	38
Vigala River:						
Vana-Vigala	1992	22	46±1	4.0±0.3	36±4	61
Navesti River:						
Loopre (upper)	1992	20	54±2	6.9±0.7	32±3	58
Jõesuu (lower)	1993	24*	52±1	5.5±0.3	35±3	74
Raudna River:						
Solu	1993	10*	60±4	8.1±1.3	39±8	75
Verilaske Stream	1993	13*	75±6	18.6±3.0	14±2	21
Preedi Stream	1992	11*	42±2	4.0±0.5	16±2	29
Väike Emajõgi River:						
Sihva (upper)	1992	26	52±1	5.3±0.4	15±1	25
Restu (lower)	1992	26	59±2	9.4±0.8	26±2	54
U. tumidus						
Lake Kooraste Suurjärv	1991	10	59±2	4.9±0.4	13±2	21
Lake Õisu	1992	25	70±2	8.6±0.6	27±3	57
Lake Võrtsjärv	1992	21	58±2	5.0±0.5	9±1	17
Rõuge Stream	1991—1992	29	80±1	14.6±0.9	30±7	54
Piigaste Stream	1991	18	78±2	20.2±1.8	19±2	30
Raigastvere Stream	1992	18	68±2	9.1±0.6	12±1	16
Nava Stream	1992	10*	61±6	7.3±1.5	9±1	13
U. pictorum						
Lake Õisu	1992	12	73±3	5.4±0.5	19±3	36
Lake Võrtsjärv	1992	21	76±1	6.9±0.4	11±1	20
Lake Väike Pehmejärv	1993	8	91±5	9.4±1.6	8±0	10
Kasari River (lower)	1992—1993	6	51±2	2.8±0.2	29±2	28
Navesti River (lower)	1993	6	56±2	3.7±0.1	18±2	25
P. minima						
Keila River	1992	6*	73±3	4.5±0.2	18±1	21
Navesti River (lower)	1993	8*	53±2	2.3±0.3	22±2	32
A. anatina						
Rõuge Stream	1992	7	94±3	14.2±0.8	14±1	17
Kääpa River:						

1	2	3	4	5	6	7
Saare	1992	11	88±3	8.5±0.7	6±1	9
Paunküla Reservoir	1993	18	73±5	3.7±0.5	6±1	10
Lake Pabra	1990	8	79±3	3.9±0.7	7±0	9
Lake Palujüri	1990	10	81±2	8.1±0.7	7±0	9
Lake Mäha	1991	6	85±1	5.9±0.1	5±0	6
Lake Peipsi (Värska Bay)	1990	7	68±2	5.0±0.3	5±0	6
Lake Õisu	1992	9	68±4	4.8±0.8	8±1	11
Lake Võrtsjärv	1992	18	69±2	5.9±0.4	5±0	7
A. cygnea						
Lake Väike Pehmejärv	1993	10	126±3	10.2±0.6	6±0	9
Lake Valguta Mustjärv	1978—1981	25	121±5	9.3±1.2	5±1	14
Lake Võrtsjärv	1990	6	98±5	4.4±0.9	10±1	12

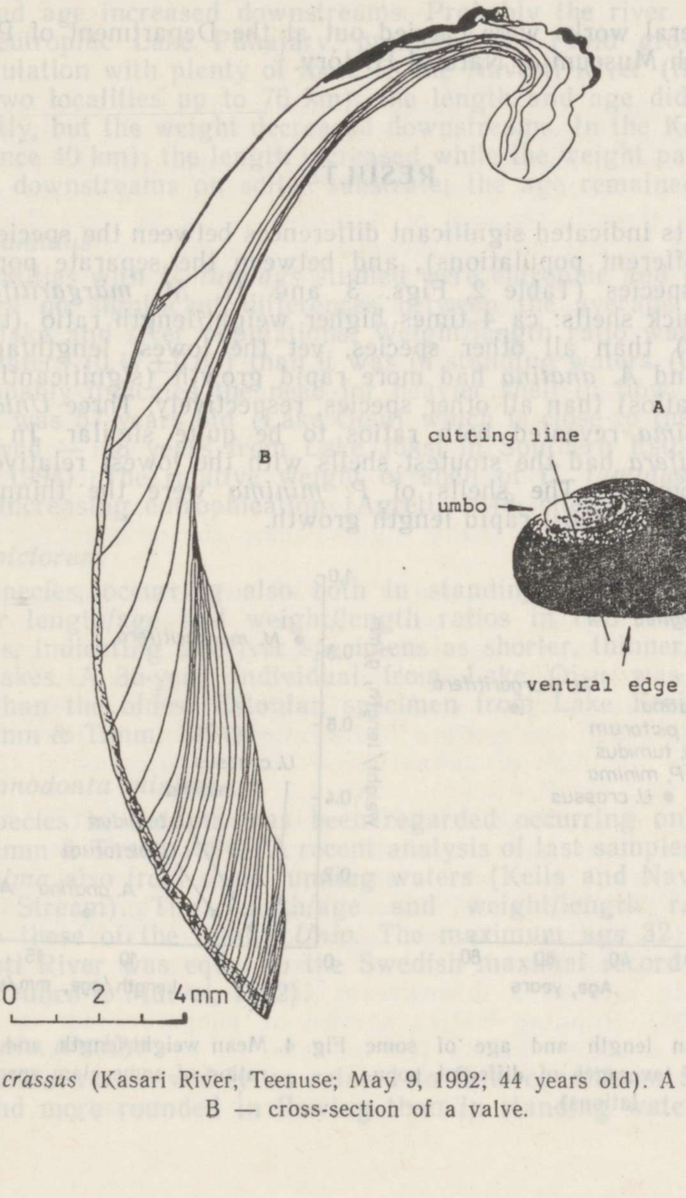

Fig. 2. *U. crassus* (Kasari River, Teenuse; May 9, 1992; 44 years old). A — whole shell, B — cross-section of a valve.

For analyses of age, single valves were cut from umbo to ventral margin, at right angles to growth increments. A 0.6 mm thick section was then prepared on the cutting plane (Fig. 2). 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. The age of a shell was determined by counting annual growth bands. Light microscope, equipped with video-camera, monitor and computer, was used (Timm & Mutvei, 1993). The method enabled to estimate the age of shells with the confidence of ±1—2 years' in most cases.

In the case of light-coloured individuals of *A. cygnea*, and in some instances of *A. anatina*, the traditional surface ring counting gave even better results than the method described above (except for the thick and dark shells collected from the fast-flowing streams). Totally, the length, shell weight, and age of 584 individuals of 7 species (sensu Ellis, 1978) were measured. The weight of a single valve was used because of the presence of only one whole valve in some cases. The length, weight and age of the left and right valves were considered equal.

The cameral works were carried out at the Department of Paleozoology, Swedish Museum of Natural History.

RESULTS

The results indicated significant differences between the species (mean values of different populations), and between the separate populations within the species (Table 2, Figs. 3 and 4). *M. margaritifera* had especially thick shells: ca 4 times higher weight/length ratio (the index of thickness) than all other species, yet the lowest length/age ratio. *A. cygnea* and *A. anatina* had more rapid growth (significantly higher length/age ratios) than all other species, respectively. Three *Unio* species and *P. minima* revealed both ratios to be quite similar. In general, *M. margaritifera* had the stoutest shells with the lowest relative annual length increments. The shells of *P. minima* were the thinnest, and *A. cygnea* had the most rapid length growth.

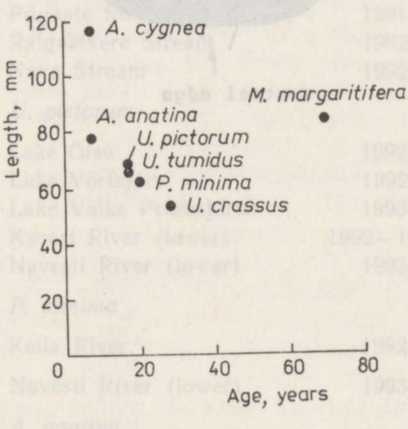

Fig. 3. Mean length and age of some clam species (averages of different populations).

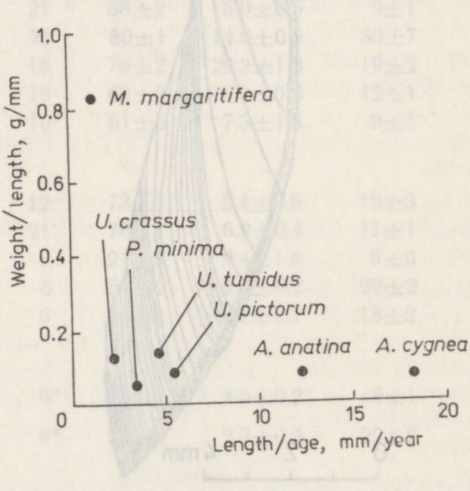

Fig. 4. Mean weight/length, and length/age ratios of some clam species.

Unio crassus

Age, length, and single valve weight of full-grown *U. crassus* individuals were also measured by Timm & Mutvei (1993). Because of the use of only larger and older specimens in the former work, this mean age is not well comparable with present studies. *U. crassus* did not occur in any standing waters. The lowest weight/length ratio was observed in the Kasari River (0.08), and Vigala River (0.09, also in the former study). Extremely thick (and up to 97 mm long) short-living shells with rapid growth were observed in the strongly eutrophic Verilaske Stream below a small reservoir. The length/age ratio was also the highest at the last locality: as high as 5.4. On the contrary, the Kasari River revealed the lowest value: 1.49, which exceeded only the ratio of *Margaritifera* 1.21. The oldest specimen in this study (75 years) was observed in the Raudna River; the absolute record being as much as 90 years in the Vigala River (Timm & Mutvei, 1993).

The comparison of populations of upper and lower reaches in 3 rivers did not give clear trends of any parameter (Table 2). In the Väike Emajõgi River (the distance between localities ca 10 km), length, weight, and age increased downstreams. Probably the river source, the strongly eutrophic Lake Pühajärv, promoted the rapid growth of the upper population with plenty of food. In the Navesti River (the distance between two localities up to 76 km), the length and age did not differ significantly, but the weight decreased downstreams. In the Kasari River (the distance 40 km), the length increased while the weight paradoxically decreased downstreams on softer substrate; the age remained constant.

Unio tumidus

All localities with *U. tumidus* studied were eutrophic and hard-water. There were no significant differences between the average length/age ratios of lake and river populations. Weight/length ratio was higher in running waters (0.17 ± 0.03) than it was in standing waters (0.10 ± 0.01), which probably indicates the need for heavier shell in flow. The oldest individual was 57 years old (Lake Õisu) which is close to the maximum age observed — 58 years from Lake Jõksi in Southern Estonia (Timm & Timm, 1994). The relative weight of shell of *U. tumidus* decreased with the increasing eutrophication (Agrell, 1948, cited in Björk, 1962).

Unio pictorum

This species, occurring also both in standing and flowing waters, had lower length/age and weight/length ratios in two rivers than in three lakes, indicating the river specimens as shorter, thinner, and older than in lakes. A 36-year individual from Lake Õisu was somewhat younger than the oldest Estonian specimen from Lake Korijärv — 41 years (Timm & Timm, 1994).

Pseudanodonta minima

The species in Estonia was been regarded occurring only in Lake Peipsi (Timm & Timm, 1994). A recent analysis of last samples ascertained *P. minima* also from some running waters (Keila and Navesti rivers, Verilaske Stream). The length/age and weight/length ratios were similar to these of the family *Unio*. The maximum age 32 years from the Navesti River was equal to the Swedish maximal record from Lake Rörsjön (Dunca & Mutvei, 1992).

Anodonta anatina

A. anatina varied widely as related to flow conditions. Shells were thicker and more rounded in flowing than in standing waters. Hendelberg (1960) noted a similar effect to *M. margaritifera* with regard to the flowing rate. The individuals from Rõuge Stream and Lake Õisu had much lower length/age ratios than others. The maximum age was observed also in the Rõuge Stream —17 years.

Anodonta cygnea

Prefers muddy habitats, especially lakes. The mean length/age ratio (18.3) was the maximal from among all species. Shells were thin (weight/length ratio only 0.07). Probably, the relatively thin shell occurring even in the largest specimens can serve as an adaptation to resist gravitation in liquid muds. The oldest individual from Valguta Mustjärv was 14 years old; the maximal age for the same species (as *A. stagnalis*) from the same lake was 16 years (Timm & Timm, 1994); and 18 years in a small Swedish stream in Stockholm (Dunca & Mutvei, 1992).

DISCUSSION

The age determining of large clams has usually been realized by counting annual rings on the shell surface (in the case of light-coloured individuals), or counting the annuli on ligament (in the case of dark ones). Neither methods have been satisfactory. Nevertheless, in the case of fast growth, the age of *Anodonta* could be correctly measured by counting annual rings (Haukioja & Hakala, 1978). The age of *U. crassus* was measurable on the basis of shell surface up to the first 5 years (Fleischauer-Rössing, 1990), the age of *U. pictorum* — up to 7 years (Филиппов, Герасимова, 1992). Bauer (1992) and Semenova et al. (Семенова et al., 1992) also found the last annuli on the ligaments of the older specimens of *M. margaritifera* to lie too close together for the correct counting. A brief reference to the maximal age of the species studied here is given in Table 3. The maximal age determined from cross-sections (Dunca & Mutvei, 1992; Timm & Mutvei, 1993; Timm & Timm, 1994; this study) or ligaments (Hendelberg, 1960; Семенова et al., 1992) are significantly higher than those measured on shell surfaces.

Because of the concentration of annual bands near the fragile ventral margin (especially in long-living species) (Fig. 2), the collection, transport, and preservation of shells should be made with care. If possible, living animals without deformities are preferred for the age analyses by cross-section method. To know the exact death date of empty-found shells, one can use shells collected alive so that correlations between the distances of annual bands and environmental factors can be found.

Most of the intraspecific differences in shell weight and longevity among populations have remained unexplained. In some cases eutrophication, reservoir or a lake situated upstreams as complementary food source have probably caused the short-aged, large and thick shells with rapid growth (Verilaske Stream, upper locality of the River Väike Emajõgi). Creation of a new reservoir has significantly increased annual shell growth rate in a downstream *U. crassus* population (Timm & Mutvei, 1993). Running waters seemed to support older and heavier shells than standing waters (*U. tumidus*, *A. anatina*); in the case of *U. pictorum* — older, but smaller. The oldest species inhabited running waters without exception (*M. margaritifera*, *U. crassus*).

Table 3

Maximal age of some freshwater bivalve molluscs

(Determination areas: * — ligaments, ** — cross-sections; other — shell surface)

Species and locality	Age	Source
M. margaritifera		
Swedish streams	116	Hendelberg, 1960*
Swedish rivers	135	Mutvei, 1989**
Carelian streams	163	Semenova et al., 1992*
Pudisoo River (Estonia)	132	This study**
U. crassus		
British rivers	15	Comfort ref. Heller, 1990
North Europe	15	Brander, 1956
German streams	14	Engel & Wächtler, 1989
Vigala River (Estonia)	90	Timm & Mutvei, 1993**
U. tumidus		
Thames River	11	Negus, 1966
North Europe	15	Brander, 1956
Szeszupa River (Poland)	11	Lewandowski, 1990
Lake Jõksi (Estonia)	58	Timm & Timm, 1994**
U. pictorum		
Thames River	15	Negus, 1966
North Europe	15	Brander, 1956
Szeszupa River (Poland)	10	Lewandowski, 1990
Lake Korijärv (Estonia)	41	Timm & Timm, 1994**
P. minima		
Thames River (= *P. complanata*)	10	Negus, 1966
North Europe (= *P. complanata*)	>15	Brander, 1956
Lake Rörsjön (Sweden) (= *Anodonta complanata*)	32	Dunca & Mutvei, 1992**
Navesti River (Estonia)	32	This study**
Anodonta anatina		
Thames River (= *A. piscinalis*)	10	Negus, 1966
British rivers (= *A. piscinalis*)	15	Comfort ref. Heller, 1990
North Europe	15	Brander, 1956
A Swedish stream	12	Dunca & Mutvei, 1992**
Rõuge Stream (Estonia)	17	This study**
A. cygnea		
A Swedish stream	18	Dunca & Mutvei, 1992**
Lake Valguta Mustjärv (= *A. stagnalis*) (Estonia)	16	Timm & Timm, 1994

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EESTI MAGEVETE SUURTE KARPIDE VANUS, KOJA PIKKUS JA KAAL ERI POPULATSIOONIDES

Henn TIMM

Mõõdeti 584 jõe- ja ebapärlikarplase vanus. Selleks valmistati kojapoolmetest õhukesed ristlõigud ning loendati nendel aastajooned; mõnel juhul loendati aastajooned koja välispinnal. Esimene meetod võimaldas vanust hinnata 1—2 aasta täpsusega. Tulemusi võrreldi koja pikkuse ja kaaluga. Ühtlasi võrreldi sama liigi populatsioone nii seisu- kui ka vooluvees ning kõrvutati jõgede ülem- ja alamjooksu populatsioone. Ebapärlikarp (*Margaritifera margaritifera*) ning paks jõekarp (*Unio crassus*) olid kõrgeima keskmise ja maksimaalse vanusega, ebapärlikarp ühtlasi ka aeglaseima pikkuskasvu ja kõige paksema kojaga uuritud seitsme liigi hulgas. Suur järvekarp (*Anodonta cygnea*) aga kasvas suhteliselt kiiremini kui muud liigid.

ВОЗРАСТ, ДЛИНА И ВЕС РАКОВИНЫ КРУПНЫХ ДВУСТВОРЧАТЫХ МОЛЛЮСКОВ ИЗ РАЗНЫХ ПОПУЛЯЦИЙ ПРЕСНЫХ ВОД ЭСТОНИИ

Хенн ТИММ

Определили возраст 584 особей перловиц, беззубок и жемчужниц из 7 видов, а также их длину и вес на основе данных одной створки. Возраст измеряли путем подсчитывания годовых линий на тонком поперечном срезе и на поверхности раковины. Между собой сравнивали особи как из текучих, так и стоячих водоемов, а также из верховьев и низовьев рек. *Margaritifera margaritifera* и *Unio crassus* обладали наиболее высоким как средним, так и максимальным возрастом. У *M. margaritifera* соотношение длина—возраст было минимальным по сравнению с другими видами. Максимальное соотношение длина—возраст наблюдалось у *Anodonta cygnea*.