Polish Journal of Environmental Studies Vol. 14, No. 2 (2005), 173-177

Original Research

Some Aspects of Nitrogen, Carbon and Calcium Accumulation in Molluscs from the Zegrzyński Reservoir Ecosystem

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Received: 4 June, 2004
Accepted: 25 August, 2004

Abstract

Comparison of N and C concentrations in bodies and shells of molluscs from the Zegrzyński Reservoir as well as an assessment of nitrogen, carbon and calcium accumulation in molluscs living in the reservoir and spatial variability of these values were performed. Interspecific differences of nitrogen and carbon concentrations were found, whereas calcium percentage in shells was similar. The amounts of the investigated elements accumulated in molluscs per $1m^2$ varied within the reservoir. The total amounts of carbon, nitrogen and calcium stored in molluscs were comparable to those contained in the water column, but much smaller than those contained in surficial sediments.

Keywords: molluscs, nitrogen, carbon, calcium, dam reservoir

Introduction

Nitrogen and carbon are the basic macroelements and nitrogen together with phosphorus determine the trophic status of freshwater ecosystems. Calcium is also an essential element, but most organisms use it up in relatively small amounts. Mollusc shells consist mainly of $CaCO_3$, however, so that calcium demand of these animals is big. Many studies on the role of molluscs in water ecosystems take into account only soft tissues. Especially underestimated is organic fraction of mollusc shells which may contain considerable amounts of macroelements. Cameron and co-workers [1] showed a significant contribution of organic shell matter to the total shell weight of unionid bivalves. Their results indicate that measures of standing stock biomass, production, or energy flow in bivalve populations can be considerably underestimated unless the organic material contained within the shells was included in the estimates.

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Molluscs can play a significant role both in accumulation and circulation of N, C and Ca, especially in habitats where they are numerous and their biomass is high [2-5], but studies concerning these problems are scarce. In the Zegrzyński Reservoir they are abundant and dominate the biomass of bottom macrofauna [6-8].

The present work aimed at a comparison of N and C concentrations in the soft tissues and shells of mollusc species that are the main components of malacocoenoses of the Zegrzyński Reservoir. An assessment of nitrogen, carbon and calcium accumulation in molluscs living in the reservoir and spatial variability of these values were also performed.

Material and Methods

The concentrations of nitrogen and carbon were analyzed in the soft tissues and shells of 2 snail species: *Viviparus viviparus* (L.) and *Lymnaea stagnalis* (L.) as well as 2 bivalves: *Dreissena polymorpha* (Pall.) and *Anodonta anatina* (L.). *V. viviparus* and *D. polymorpha* are

the dominant species in the mollusc communities of the Zegrzyński Reservoir [6-8]. The other species are significant element of malacocoenoses as follows: *L. stagnalis* within the littoral zone and *A. anatina* in habitats where it occurs (due to large size). The molluscs studied were collected in 1997-1999 (May, July, September) at sites located in different parts of the reservoir using Ekman-Birge's grab with catching area 250 cm^2 and rectangular dredge with working side length of 33 cm. The samples were rinsed on a sieve, some of them were frozen and the others were preserved in 4% formaldehyde solution. Big individuals of similar size were taken for analysis: *V. viviparus* and *D. polymorpha* 20-30 mm, *L. stagnalis* 35-50 mm, *A. anatina* 50-75 mm. The molluscs were washed in redistilled water, soft tissues were separated from shells and both were dried to a constant weight and homogenized in an agate mortar. The samples contained 10 to 30 specimens, or in the case of *Anodonta anatina* 1 to 3 individuals. 10-12 samples of the soft tissues and shells for each species were analyzed. The concentrations of N and C were determined in subsamples of the soft tissues and shells (ca 3.5 g dry wt) by means of a CHN-O apparatus (type 1108, Carlo Erba Instruments), using a sulfanilamide standard. Contribution of the soft tissues and shells to the total weight of the investigated mollusc species was also assessed. Calcium content in shells was calculated assuming that its mineral part consists almost exclusively of $CaCO_3$. Shell organic matter was estimated based on loss of weight on ignition at about 500°C for 4 hours. Shell organic carbon was assessed as a difference between total C and $CaCO_3$-C. The total content of $C_{org.}$, N and Ca in water column and 1 cm thick (yearly) layer of bottom sediments were calculated based on data on $C_{org.}$, N, and Ca concentrations in water and bottom sediments of the Zegrzyński Reservoir (Table 1) as well as the area and volume of this water body (33 km^2 and 100 mln m^3, respectively). The results were statistically processed using Statistica software, using a probability level of <0.05.

Table 1. Selected chemical characteriscics of water (ranges of mean annual values in different parts of the reservoir) and bottom sediments (mean values) of the Zegrzyński Reservoir (according to [9] and [10]).

Parameter	Water (mg/dm^3)	Bottom sediments (% dry wt)
C org.	13.8-15.6	5.49
TN	2.3-3.1	0.69
TP	0.16-0.18	0.20±0.09
Ca	76.6-91.2	14.98±3.70

Results

The mean content of nitrogen in the soft tissues of the investigated molluscs ranged from about 7% to over 12% dry wt. The respective values in shells were considerably lower (from 0.19 to 0.56% dry wt), being higher in bivalves than in snails (Table 2). Interspecific differences in nitrogen content were in most cases statistically significant (Tukey test, $p<0.05$) except these in the bodies of *V. viviparus* and *A. anatina*, as well as two comparisons concerning shells: *V. viviparus* - *L. stagnalis* and *D. polymorpha* – *A. anatina*.

Mean values of carbon content in the soft tissues of the investigated molluscs ranged from about 36% to about 46% dry wt (interspecific differences were significant except *L. stagnalis* and *D. polymorpha*), whereas C content in shells was similar in all cases, on average *ca* 13% dry wt. The content of organic carbon in shells reached 1.14 – 2.07% dry wt. Its contribution to the total organic carbon of molluscs ranged from 5.3% in *L. stagnalis* to 29.5% in

Table 2. Concentrations of total C and N (% dry wt) in the soft tissues and shells of the investigated mollusc species (mean values and standard deviations).

Species	C		N	
	tissues	shells	tissues	shells
Viviparus viviparus	40.06±0.81	12.73±0.21	7.86±0.43	0.22±0.03
Lymnaea stagnalis	44.49±2.11	12.85±0.31	11.01±0.65	0.19±0.03
Dreissena polymorpha	45.89±0.83	13.12±0.16	12.41±0.28	0.38±0.05
Anodonta anatina	35.65±3.37	13.33±0.40	6.99±0.96	0.56±0.14

Table 3. Percentage of shells in the total mollusc dry weight, organic matter content in shells and shell organic carbon contribution to the total $C_{org.}$ in the investigated mollusc species.

Species	% of the total mollusc weight	organic matter content (%)	% of the total C_{org} content in mollusc
Viviparus viviparus	85	6.3	17.4
Lymnaea stagnalis	67	3.2	5.3
Dreissena polymorpha	91	6.5	29.5
Anodonta anatina	82	6.1	20.9

D. polymorpha (Table 3) depending on proportion of the shells in total biomass and percentage of $C_{org.}$ Generally, the organic C:N ratio was higher in the snail shells (6:1 and 8.6:1 in *L. stagnalis* and *V. viviparus* respectively) than in bivalve ones (3.6:1 in *A. anatina*. and 3.9:1 in *D. polymorpha*). Positive correlation between $C_{org.}$ and N content both in the soft tissues and shells was found (Pearson's correlation, r=0.90 and r=0.85 respectively).

The calculated Ca content in shells of the investigated mollusc species was similar, mostly amounting to 37% dry wt and only in *L. stagnalis* was it somewhat higher (39% dry wt).

Owing to interspecific differences in C and N content in bodies and shells of the investigated molluscs (Table 2) and different contribution of soft tissues and shells to the total weight of the representatives of particular species (Table 3) percentages of these elements accumulated in bodies and shells varied among the investigated taxa (Fig. 1).

The amounts of N, C and Ca accumulated in molluscs inhabiting 1m^2 of bottom in different habitats of the Zegrzyński Reservoir varied considerably, resulting mainly from unequal distribution of their biomass (Fig. 2). Dominance relations of malacocenoses may also exert an influence on N and C pools stored in bodies and shells because of interspecific differentiation in concentrations of these elements. The highest amounts of N, C and Ca accumulated in molluscs were found near the dam (sampling site VIII).

Estimated values of N, C and Ca accumulated in molluscs living in the Zegrzyński Reservoir amounted to 1570 t ($C_{org.}$ 550 t), 140 t and 3130 t respectively. These values made about 37% of the total $C_{org.}$ and Ca and 52% of N contained in the water column. $C_{org.}$, N and Ca accumulated in molluscs made only a few percent of the pools of these elements in bottom sediments (1 cm thick layer) – 2.5, 5.2 and 5.3% respectively (0.3, 1.1 and 5.3% accumulated in shells).

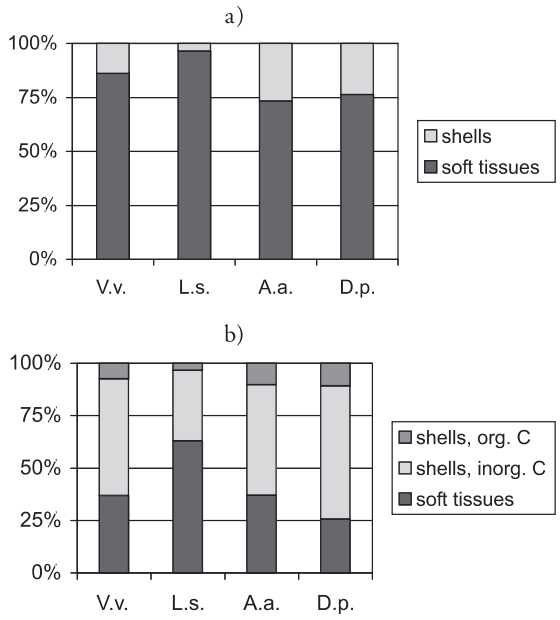

Fig. 1. Contribution of the soft tissues and shells to the total accumulation of nitrogen (a) and carbon (b) in representatives of the investigated mollusc species; V. v. – *V. viviparu*s, L. s. – *L. stagnalis*, A. a. – *A. anatina*, D. p. – *D. polymorpha*.

Discussion

Data on nitrogen and carbon content in molluscs are relatively sparse and concern mainly bivalves [e.g. 2-3, 11-14]. The level of carbon and nitrogen in the tissues and shells of *D. polymorpha* from the Zegrzyński Reservoir was comparable to the data obtained for this species from several Masurian lakes [3, 11]. Nitrogen concentrations in the shells of the analyzed molluscs were of the same level as these in Sphaeriidae found by Burky et al. [12] and in *Margaritifera margaritifera* from considerably acidified Scandinavian environments [14].

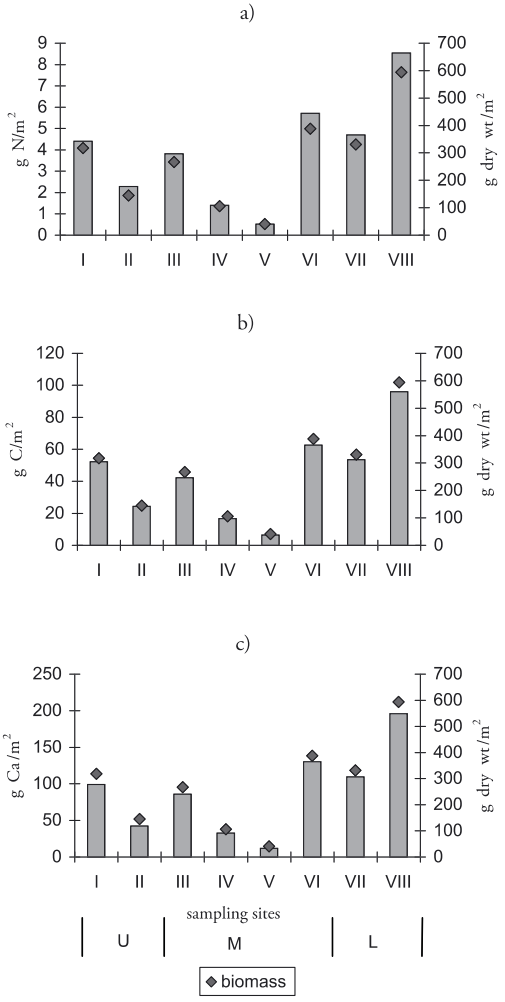

Fig. 2. The amounts of nitrogen (a), carbon (b) and calcium (c) stored in molluscs inhabiting 1 m^2 of bottom in various habitats of the Zegrzyński Reservoir characterized by different mollusc biomass; U, M, L – upper, middle and lower parts of the reservoir.

Concentrations of organic carbon in mollusc shells calculated in the present study were similar to the values reported for *Musculium partumeium* and higher than in the other Sphaeriidae investigated by Burky et al. [12]. C:N ratio in shells of the investigated bivalves as well as positive correlation between shell $C_{org.}$ and N are consistent with findings of Burky et al. [12] and they show that the organic carbon and nitrogen content represents mostly structural proteins [e.g. 12, 15]. Considerably higher C:N ratio in snail shells and positive correlation between $C_{org.}$ and N found in the present study may result from a high proportion of polysaccharide fraction (C:N ratio is similar to the value calculated from the chitin composition, especially in the case of *V. viviparus*). The surficial layer of mollusc shells (periostracum) is commonly supposed to consist of the conchiolin being a compound similar to the chitin [e.g. 16, 17].The ratio of proteinaceous to polysaccharide component of mollusc shells presumably varies within a wide range.

The proportion of organic matter in the shells of the investigated mollusc species was comparable to the values reported for *Mytilus edulis* [1] and *Modiolus demissus* [18]. However, Kuenzler [19] found higher values for the latter species. Contribution of shell organic matter to total organic matter was relatively high, except for *L. stagnalis*, and it was comparable to the values reported by Cameron et al. [1] for big specimens of unionid bivalves. According to the findings of these authors as well as the results obtained by Nyström and Dunca [20] the importance of shell organic matter increases with length of individuals of a given mollusc species, because of the increasing ratio between shell weight and tissue weight. In the present work only big individuals of the investigated species were analyzed. It must be stressed that organic matter contained in shells will cycle at a much slower rate than body fraction. Investigations concerning Quaternary molluscs (the Eemian Interglacial) show that periostracum can be partly preserved for a long time [e. g. 21].

Calcium content calculated for the shells of the investigated molluscs was lower than that reported by Alimov [22]. It was similar in all of the four species, which may indicate dependence on environmental Ca concentrations or the existence of some environmental factor influencing shell mass. As a matter of fact, a direct relationship between shell calcium and water hardness wasn't found either in sphaeriid clams (except negative correlation for *Musculium striatinum* [12]) or in the case of snails [23-25], but inverse relationship between shell $CaCO_3$ and organic matter content may indicate that higher trophic status which is conducive to more proteinaceous shells [12] may indirectly lower the proportion of $CaCO_3$ in shells. Such a situation may occur in the Zegrzyński Reservoir characterized by high trophic status [e.g. 26].

The amounts of nitrogen accumulated in molluscs in different habitats of the Zegrzyński Reservoir were similar to the higher values of N content in *D. polymorpha* per 1 m^2 in the zone of occurrence in a few Masurian lakes [2-3].

Molluscs remove nutrients from cycling during their lifetime and in the case of shells much longer. The amounts of the investigated elements stored in molluscs were of the same order of magnitude as their content in the water column of the Zegrzyński Reservoir. Accumulation of nutrients and Ca by molluscs may significantly contribute to total retention of these elements, especially in the parts of the reservoir characterized by high mollusc biomass. Higher participation of nitrogen and calcium in the pool of these elements stored in yearly layer of bottom sediments was found as compared to that of carbon. However, the amounts of nutrients flowing through mollusc populations are several times higher than the amounts accumulated in their bodies and shells [e.g. 3-4, 19].

Conclusions

1. Significant interspecific differences were found in nitrogen concentrations in bodies and shells of the investigated molluscs as well as in carbon level in the soft tissues.
2. Calcium percentage content in the shells of the investigated species was similar.
3. Considerable differences in participation of bodies and shells in nitrogen and carbon accumulation by particular mollusc species were observed.
4. The amounts of N, C and Ca accumulated in molluscs inhabiting 1m^2 of the reservoir bottom showed spatial variation resulting mainly from unequal distribution of mollusc biomass.
5. The amounts of carbon, nitrogen and calcium stored in molluscs were comparable to these contained in the water column, but constituted only a few percent of the content of yearly layer of bottom sediments.
6. Contribution of shell organic matter to total organic matter of the investigated molluscs was relatively high (up to 29.5%).

References

1. CAMERON C. J., CAMERON I. F., PETERSON C. G. Contribution of organic shell matter to biomass estimates of unionid bivalves. Can. J. Zool. **57**, 1666, **1979**.
2. STAŃCZYKOWSKA A. Role of bivalves in the phosphorus and nitrogen budget in lakes. Verh. int. Ver. Limnol. **22**, 982, **1984**.
3. STAŃCZYKOWSKA A., PLANTER M. Factors affecting nutrient budget in lakes of the R. Jorka watershed (Masurian Lakeland, Poland). X. Role of the mussel *Dreissena polymorpha* (Pall.) in N and P cycles in a lake ecosystem. Ekol. Pol. **33**, 345, **1985**.
4. STAŃCZYKOWSKA A., LEWANDOWSKI K. Effect of filtering activity of *Dreissena polymorpha* (Pall.) on the nutrient budget in the littoral of the Lake Mikołajskie. Hydrobiologia, **251**, 73, **1993**.

5. JURKIEWICZ-KARNKOWSKA E. The occurrence and role of molluscs in selected rivers and reservoirs of the Mazowiecka Lowland. Ph.D. Th., IE PAN, Dziekanów Leśny, **1986**.
6. DUSOGE K., LEWANDOWSKI K.B., STAŃCZYKOWSKA A. Benthos of various habitats in the Zegrzyński Reservoir (central Poland). Acta Hydrobiol. **41**, 103, **1999**.
7. JURKIEWICZ-KARNKOWSKA E. Long-term changes in mollusc communities in shallow biotopes of a lowland reservoir (Zegrzyński Reservoir, central Poland). Pol. J. Ecol. **46**, 43, **1998**.
8. JURKIEWICZ-KARNKOWSKA E. Long-term changes and spatial variability of mollusc communities in a lowland reservoir (Zegrzyński Reservoir, central Poland). Folia Malacologica, **9**, 137, **2001**.
9. GÓRNIAK A. Humic compounds and their role in the functioning of freshwater ecosystems. University Press, Białystok, **1996**.
10. Report about the state of the environment in Mazovian province in 1999. WIOŚ, Warszawa, **2000**.
11. STAŃCZYKOWSKA A., ŁAWACZ W. Caloric value of the *Dreissena polymorpha* (Pall.) dry body weight in some Mazurian lakes. Pol. Arch. Hydrobiol. **23**, 271, **1976**.
12. BURKY A. J., BENJAMIN M. A., CATALANO D. M., HORNBACH D. J. The ratio of calcareous and organic shell components of freshwater sphaeriid clams in relation to water hardness and trophic conditions. J. Mollusc. Stud. **45**, 312, **1979**.
13. DORGELO J., KRAAK M. H. S. Seasonal variation in tissue dry biomass and its relative ash and organic carbon and nitrogen content in the freshwater mussel *Dreissena polymorpha* (Pallas). Arch. Hydrobiol. **127**, 409, **1993**.
14. WESTERMARK T., CARELL B., FROBERG S., MUTVEI H., KULAKOWSKI E. Freshwater unionid (Mollusca: Bivalvia) shells as environmental archives: methodology and observations. Bull. Inst. Oceanogr., Monaco, n° spécial **14**, 73, **1996**.
15. RUSSELL-HUNTER W. D., BURKY A. J., HUNTER R. D. Interpopulation variation in calcareous and proteinaceous shell components in the stream limpet, *Ferrissia rivularis*. Malacologia, **20**, 255, **1981**.
16. PIECHOCKI A. Molluscs. Snails. Freshwater fauna of Poland, 7. PWN, Warszawa - Poznań, **1989**.
17. PIECHOCKI A., DYDUCH-FALNIOWSKA A. Molluscs. Bivalves. Freshwater fauna of Poland, 7A. PWN, Warszawa, **1993**.
18. PRICE T. G., THAYER G. W., LA CROIX M. W., MONTGOMERY C. P. The organic content of shells and soft tissues of selected estuarine gastropods and pelecypods. Proc. Natl. Shellfish. Assoc. **65**, 26, **1976**.
19. KUENZLER E. J. Phosphorus budget of a mussel population. Limnol. Oceanogr. **6**, 400, **1961**.
20. NYSTRÖM J., DUNCA E. Nuclear microscopy of freshwater bivalves. Bull. Inst. Oceanogr., Monaco, n° spécial, **14**, 121, **1996**.
21. SKOMPSKI S. Eemian Interglacial molluscsans from Żmigród upon the Barycz River. Kwart. Geol. **27**, 151, **1983**.
22. ALIMOV A. F. Functional ecology of freshwater bivalve molluscs. Tr. Zool. Inst. AN SSSR, **96**, 1, **1981**.
23. RUSSEL-HUNTER W., APLEY M. L., BURKY A. J., MEADOWS R. T. Interpopulation variations in calcium metabolism in the stream limpet Ferrissia rivularis (Say). Science, **155**, 338, **1967**.
24. HUNTER R. D. Variation in populations of Lymnaea palustris in upstate New York. Am. Midl. Nat. **94**, 401, **1975**.
25. HUNTER R. D., LULL W. W. Physiologic and environmental factors influencing the calcium-to-tissue ratio in populations of three species of freshwater pulmonate snails. Oecologia (Berl.), **29**, 205, **1977**.
26. KAJAK Z., DUSOGE K. Temporal and spatial diversity of trophy-indicators in a lowland dam reservoir Ekol. Pol. **37**, 211, **1989**.