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GROWTH AND POPULATION STRUCTURE OF THE MUSSEL *ANODONTA WOODIANA* (LEA, 1834) (BIVALVIA, UNIONIDAE) IN THE HEATED KONIN LAKES SYSTEM

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ABSTRACT. The individual growth rate of the Chinese mussel population of the genus *Anodonta* which inhabits the warm channels of the heated Konin lakes system was analysed. Four size and age groups were distinguished. The allometric growth of shells during early developmental stages and the isometric growth of 6-21 cm shells were ascertained. Three to five years old individuals were typical of the *Anodonta woodiana* found in the Konin channels. The theoretical maximal life span of the mussels is 10 years, while the maximal shell length is 21 cm.

Key words: UNIONIDAE (*ANODONTA*), GROWTH, LAKES, CHANNELS, THERMAL POLLUTION

INTRODUCTION

Studies of zoobenthos and zooperiphyton showed that the mussels of the family Unionidae and *Dreissena polymorpha* (Pall.) comprise the basic components of the benthic and periphyton fauna that play a significant role in the processes of biological water purification in the heated lakes and channels of the Konin lakes system (Protasov et al. 1994, 1997, Sinicyna et al. 1997). A special role is being played by the dominant Chinese mussel, *Anodonta woodiana* (Lea) in this system. It was transferred from China to Europe with the fry of herbivorous Chinese fish used for stocking (Petro 1984, Kiss and Pekli 1988, Kiss 1992). The mussel appeared in the Konin lakes in the mid-1980s following the introduction of silver carp, *Hypophthalmichthys molitrix* (Val.).

Several phenotypic forms of this mussel species probably exist in the heated Konin lakes. J. I. Starobogatov has identified two species of the mussel - *Sinanodonta orbicularis* (Heude) and *Sinanodonta gibba* (Benson) (personal communication). However, taxonomic studies (Piechocki and Riedel 1997) and genetic analysis of the isoenzymes (Soroka 1999, Kośmider 2000, Soroka and Zdanowski 2001) did not corroborate this hypothesis.

The polymorphism of the Konin mussel is probably determined by the great variation of environmental conditions in places of its occurrence, and also by the highly adaptive nature of this species. Significant roles are played by variations in thermal conditions, substrate type, access to food, and water inflow (Hillbricht-Ilkowska et al. 1988, Hillbricht-Ilkowska and Zdanowski 1988a, b, Zdanowski 1994).

The purpose of this study was to assess the growth rate of *Anodonta woodiana* which inhabits the channels of the heated Konin lakes system.

MATERIAL AND METHODS

The Konin lakes system is located in central Poland in the area of the Wielkopolskie Lake District. They form a closed system of five lakes connected by channels, which is connected to the cooling systems of the Konin and Pątnów power plants. Descriptions of this system can be found in Zdanowski (1992, 1994) and Protasov et al. (1993).

The mussels originated from a discharge channel of one of the power plants where the water temperature during summer from May to September varied from 20.6 to 35.7°C. The studies were done in a few channel transects during the peak vegetative season from July to August 1993 to 1996. The study sites were chosen using the method described by Protasov et al. (1982) which involved scuba diving and conducting a preliminary reconnaissance of the bottom morphology. The mussels were counted within a surface area of 1-2 m^2. Mussel shells were classified into four size groups: young (up to 5 cm); small (to 10 cm); medium (10-15 cm); large (above 15 cm). In addition to length (L), measurements were made of mussel height (H), and width (S). The animals were cleaned of periphyton and loam deposits, dried, and weighed with the liquid contents of the mantle cavity (live weight - Wl), and after cutting one of the sphincters, but without the cavity liquid (wet weight - Ww). Dry shells (Ws) and the soft tissues (Wt) were weighed separately.

The equation parameters of allometric growth were calculated with statistical methods. The values of standard deviations were considered as the criteria in calculations. The age of mussels and growth rates were determined by counting the annual growth rings after the shells had been washed with a 20% solution of HCl, or by the Sadykhova method (Sadykhova 1972). The von Bertalanffy growth coefficients were determined using the Walford method (Walford 1946).

RESULTS AND DISCUSSION

In the *A. woodiana* population, the height to length ratio and the width to length ratio of shells increased correspondingly with mussel length increase up to 5 cm; after which isometric growth of both these parameters was observed (Figs. 1 and 2). The equation parameters of allometric growth are given in Table 1. The relationship between S and L for the range 0.9 to 6 cm is shown in an exponential equation, while for the 7 to 21 cm length range the relationship is linear. Relationships between growth parameters S and L are described by linear equations, which indicates the general isometrics of the growth of S relative to L. Changes of the H/L ratio show that the increase of shell height in relation to length is more intense also in 4-5 cm long individuals. The H/L ratio decreases for older individuals.

Allometric growth is reflected by the relationship of size and body weight. The exponential coefficient in equations expresses the rate of change of the relative animal body shape during the growth process (Winberg 1971). When geometric similarity is retained, which happens during isometric growth, this coefficient should equal three throughout the life span. This was first shown in fishes by Beverton and Holt (1969). Under the condition that growth and sizes are not allometric (Zotina and Zotin 1967), no significant variations of this coefficient have been shown for mussels (Alimov 1981).

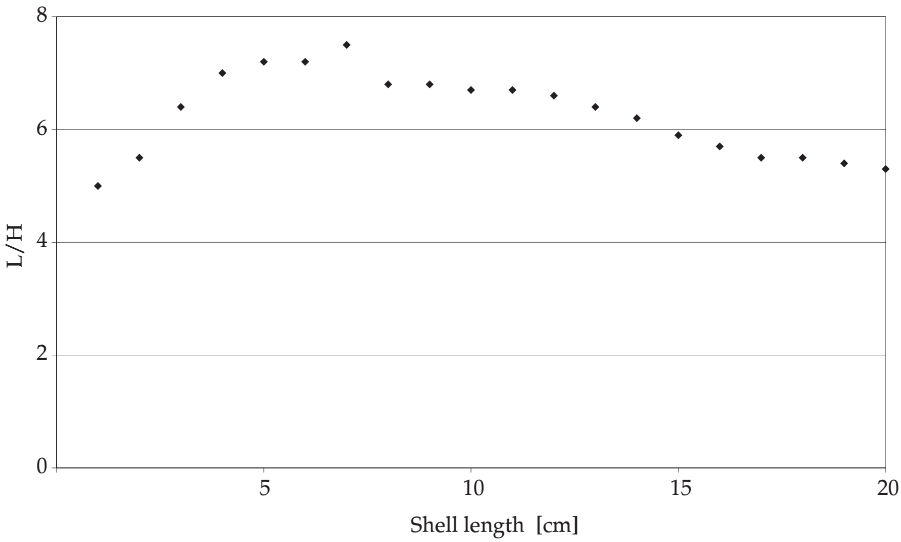

Fig. 1. Relationship between the length (L) and height (H) of shells of the mussel *A. woodiana* from the Konin channels.

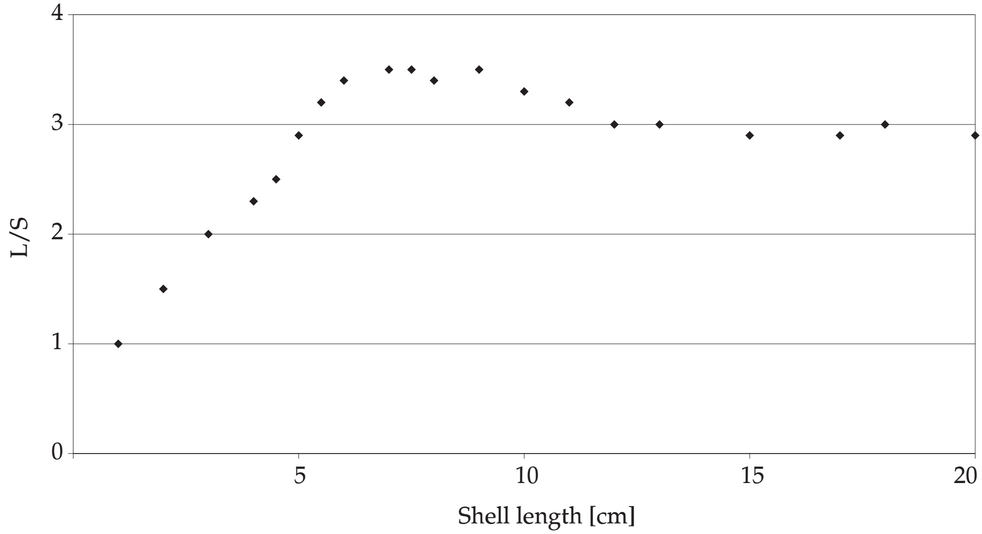

Fig. 2. Relationship between length (L) and width (S) of shells of the mussel *A. woodiana* from the Konin channels.

In the opinion of Sadykhova (1972), in order to obtain reliable results reflecting the weight-growth ratio, the equation parameters have to be calculated for every population living in particular conditions. In cases when there is a change at the various ontogenetic stages from allometric to isometric growth, or *vice versa*, it is appropriate to calculate the coefficients for different size groups. Based on this, the decision was made to calculate the relationship between the sizes and weights of the mussel population from the Konin channels separately for groups up to 6 cm and for the larger individuals. It was found that an increase in shell width and height in relation to shell length for individuals of up to 5-6 cm results in an exponential coefficient value greater than three. The slowing of shell growth in larger individuals leads to a decrease in the coefficient value to below three (Table 1). In early developmental stages before the final formation of the interior organs, there is an increase of shell width and volume. As the mussel grows, the most intensive increase in tissue liquid weight occurs. In other words, an increase of shell weight precedes the growth of soft body tissues, and the animal wet weight, i.e. the body and shell weight together with the liquid of the mantle cavity, increases less intensively than does live weight (body + shell).

TABLE 1

Equations of allometry of the growth parameters of *A. woodiana* from the heated channels of the Konin lakes system

Function	N	L [cm]	Equation	SD	V
S f(L)	99	0.9 - 21	$S = 0.7215 + 0.318\ L$	4.23	6.5%
S f(L)	19	0.9 - 5.9	$S = 0.0252\ L^{1.6}$	1.01	5.6%
S f(L)	80	7 - 21	$S = 3.1845 + 3.098\ L$	1.49	8.2%
H f(L)	99	0.9 - 21	$H = 0.8056\ L^{0.937}$	5.96	5.4%
Wl f(L)	99	0.9 - 21	$Wl = 0.04\ L^{3.23}$	5.78	7.8%
Wl f(L)	28	0.9 - 5.9	$Wl = 0.029\ L^{3.647}$	1.23	8.2%
Wl f(L)	99	6.5 – 21	$Wl = 0.305\ L^{2.523}$	2.89	3.8%
Ws f(L)	68	6.5 – 21	$Ws = 0.046\ L^{2.757}$	1.25	4.8%
Wt f(L)	65	6.5 – 21	$Wt = 0.800\ L^{1.574}$	8.27	7.8%
Wf f(L)	68	6.5 – 21	$Wf = 0.051\ L^{2.928}$	1.79	4.4%
Ww f(L)	68	6.5 – 21	$Ww = 0.411\ L^{2.149}$	1.44	1.4%

SD - standard deviation; V - variation coefficient; Wl - live weight; Ws - shell weight; Ww - wet weight; Wt - soft tissue weight; Wf - weight of liquid contained in the mantle cavity

The Ludwig von Bertalanffy equation is a reliable way to describe the growth relationships of mussels:

$$Lt = L\ (1 - e^{-kt}) \qquad (1)$$

where:

Lt - animal length after time t,

L – maximal theoretical animal length,

k - growth constant,

e - variable.

By analyzing the equation parameters using the k coefficient, various characteristics can be deduced such as the maximal theoretical size of the mussel and the time needed to attain it. The basic data for the graphic determination of the von Bertalanffy growth coefficients (Walford 1946) are shown in Fig. 3. The adaptation of this method for use with mussels can be found in Sadykhova (1972), Alimov (1981, 1989) and Kiss (1995). This method does not require analyzing all the annual rings on the mussel shells; it is sufficient to describe the mussel length (Lt, Lt +1 etc.) as it corresponds to a few distinct and consecutive rings (Hancock 1965). The maximal theoretical length of the mussel is shown by the crossing point of the straight lines (Fig. 3). The growth constant is calculated using the equation:

$$K = ln\ tg\ a \qquad (2)$$

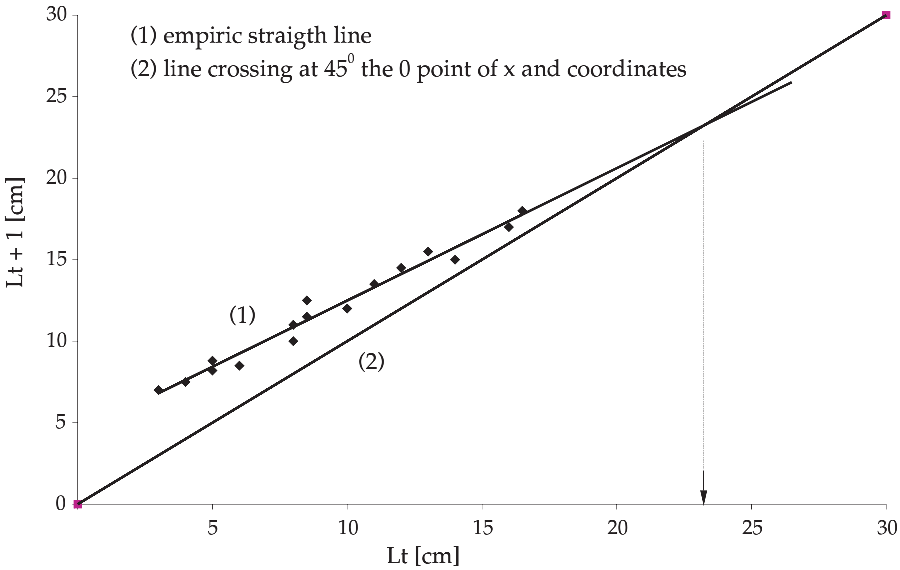

Fig. 3. Maximal theoretical size of mussels according to the Walford's method (1) empiric straight line; (2) line crossing at 45° the 0 point of x and y coordinates.

where:

a is the sloping angle of the empiric straight line Lt = f (lt + 1).

The empiric growth of the analyzed mussels (Table 2) is approximated by the equation:

$$Lt + 1 = 4.756 + 0.795\ Lt \quad (3)$$

At a growth constant of 0.227, the theoretical maximal size of the mussels in the Konin channels should not exceed 23 cm.

TABLE 2

Range of average shell lengths and annual growth increases of the mussel *A. woodiana* from the channels of the Konin lakes system

L	N	Average length in cm (SD)	Average growth increase in cm (SD)
L1	47	4.58 (0.18)	3.38 (0.20)
L2	48	8.05 (0.18)	3.40 (0.28)
L3	48	11.27 (0.29)	2.48 (0.19)
L4	38	13.88 (0.35)	1.67 (0.10)
L5	28	15.72 (0.34)	1.23 (0.23)
L6	17	16.48 (0.49)	-

L - values corresponding to the consecutive distinct rings; N - number of measurements; SD - standard deviation

The theoretical life span of mussels from the Konin channels can be determined by transforming the von Bertalanffy equation:

$$T\ max = (ln\ L - ln\ (L - Lmax)\ /\ k \qquad (4)$$

where:

L - maximal theoretical animal length,

Lmax – the largest length of mussel shell noted in a given environment,

k - growth constant.

The largest observed *A. woodiana* individuals during the 1993-1996 study period were 21 cm in length. The maximal theoretical life span did not exceed 10 years. On the basis of colony size structure analysis, the life cycle of *A. woodiana* in the warm channels of the Konin lakes system can be described. As in other related species, mussel reproduction occurs in this system in the fall (Stadnichenko 1984). The expulsion of invasive glochidia occurs at the beginning of summer. This is followed by a stage of parasitism which may last from 12 to 80 days (Herbers 1913, Ivanchik 1970) depending on environmental conditions and water temperature. The parasitism stage for *A. woodiana*, which was determined experimentally, varied from 220 to 250 grade-days (Kiss 1995). The small aggregations of tiny mussels (0.9-2.5 cm) with flattened, fragile shells that were observed in July and August indicated that they belonged to that year's new mussels. The presence of a ring in mussels less than 2 cm long was weakly discernable. The first ring was clearly visible only at a mussel length of 5.5 cm. Mussels from 4-6 cm were one year old and had settled in the early fall of the previous year.

CONCLUSIONS

In the early developmental stages of mussels, there was distinct allometry of growth directed towards the increase of shell volume, which was probably related to sexual maturation. Shell growth in sexually mature individuals was isometric. The average maximal life duration of *A. woodiana* of the Konin channels was seven years, with the theoretical maximal being ten years. Theoretically, these mussels can attain a size of 23 cm and a corresponding weight of 850 g.

The values of average annual growth increases indicated that the most intensive growth is characteristic for younger individuals with a shell length up to 8 cm, equaling from 2.5 to 3.4 cm annually. In older mussels, it does not exceed 2 cm. Typical colonies of *A. woodiana* consisted of three to five year old individuals between 11 and 16 cm in length. Individuals younger than one year were encountered only sporadically.

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STRESZCZENIE

WZROST I STRUKTURA POPULACJI *ANODONTA WOODIANA* (LEA, 1834) (*BIVALVIA, UNIONIDAE*) W SYSTEMIE PODGRZANYCH JEZIOR KONIŃSKICH

Przeprowadzono analizę struktury wymiarowo-wiekowej i właściwości wzrostu chińskich małży *Anodonta woodiana* (Lea, 1834) zasiedlających kanały systemu podgrzanych zbiorników konińskich. *A. woodiana* charakteryzuje się wyraźnym wzrostem allometrycznym we wczesnych stadiach rozwojowych do długości muszli 5-6 cm, a w zakresie 6-21 cm wyraźną izometrią wzrostu (tab. 1, rys. 1 i 2). Wynika to prawdopodobnie z tego, że małże zwiększały objętość narządów wewnętrznych w związku z przygotowaniem do rozrodu. Wydzielono 4 grupy wielkościowe: osobniki młodociane o długości muszli do 5 cm, drobne do 10 cm, średnie do 15 cm i duże powyżej 15 cm długości. Najbardziej typowe skupiska tworzyły osobniki 3-5 letnie. Wartości średnich przyrostów rocznych wykazały, że najintensywniejszy wzrost był charakterystyczny dla osobników młodszych o długości muszli do 8 cm i wynosił 3,4-2,5 cm rocznie, a w przypadku starszych nie przekraczał 2 cm (tab. 2). Określono maksymalny czas życia, który wyniósł 10 lat i maksymalną długość muszli 23 cm (rys. 3).

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