FOLIA MALACOLOGICA Vol. 8(3): 239–244
ISSN 1506-7629
The Association of Polish Malacologists
& Faculty of Biology, Adam Mickiewicz University
Poznań 2000

AGE STRUCTURE AND SEX RATIO OF *ANODONTA WOODIANA* (LEA, 1834) (BIVALVIA: UNIONIDAE) FROM KONIN RESERVOIRS (C POLAND)

Marianna Soroka

Department of Genetics, University of Szczecin, al. Piastów 40b, 71-065 Szczecin, Poland
(e-mail: Marianna.Soroka@sus.univ.szczecin.pl)

Abstract: Age structure, sex ratio and shell mass of a recently introduced bivalve *Anodonta woodiana* (Lea) were analysed in three sampling sites at its only locality in Poland – the cooling system of two power plants near Konin (C Poland). The youngest population is that in the lake Licheńskie, the oldest individual (6+) was found in the population inhabiting the warmest canal. In the material examined, the most numerous individuals were those aged three years (43%), followed by four years (33%) and five years old (12%) individuals. The shell mass (Sm) was positively correlated with the individual age, the highest shell mass increment being observed in specimens aged 2+, 3+ and 4+. No dependence was found between the Sm parameter and sex. The shell mass varied widely (V% > 30). The highest Sm values were found in individuals from the initial cooling reservoir, the lowest in those from the lake Licheńskie, the respective water temperatures during the summer stagnation being 33 and 30°C. Except for the population from the lake Licheńskie, the sex ratio was 1:1.

Key words: bivalves, *Anodonta woodiana*, introduction, age structure, sex ratio

INTRODUCTION

A freshwater Chinese bivalve *Anodonta woodiana* (Lea, 1834) has been recently introduced in Poland and then acclimatised (Piechocki & Riedel 1997).

First mentions of one (or two) introduced species date from 1994; the species was found in a system of heated lakes near Konin in C Poland (Protasov et al. 1994, Zdanowski 1996). Initially, the bivalves were identified by J. I. Starobogatov as *Sinanodonta gibba* (Benson) and *S. orbicularis* (Heude) (Zdanowski 1996, Afanasjev at al. 1997). Later, Piechocki (personal communication) classified the bivalves from the lake Licheńskie as *Anodonta woodiana*, which corresponds to *S. gibba*, whereas the individuals from warm canals and initial cooling reservoirs remained unclassified, and still described as a Chinese *Anodonta sp.* (Zdanowski 1996, Afanasjev at al. 1997, Zdanowski et al. 1997). Bivalves from various sites in the cooling water system of the Konin power plants displayed a varied shell shape (Soroka 1998a, b, Soroka & Piotrowski 1999a, b). Genetic studies with the use of isoenzyme electrophoresis revealed that all the morphological forms of *Anodonta* represented *A. woodiana* (Soroka & Skotarczak 1999a, b).

A. woodiana originates from the far East, from the basins of the rivers Amur and Yangtse (Kiss 1995). It spread to European countries mainly from China, due to introduction of the Chinese carp that started in 1962 (Petró 1985, after Kiss 1995). Since then, its presence in several Asian and European countries has been observed: in the Indonesian Archipelago, France, Romania, Great Britain, the former Yugoslavia, Hungary and, within the last few years, also in Poland (Negus 1966, Kiss 1995, Piechocki & Riedel 1997). *A. woodiana* occurs in masses in fish ponds in Hungary (Kiss 1995). It was most probably through Hungary that, at the beginning of the 80ies, the species got to Poland with imported fish stocking material of the silver carp and the bighead (Zdanowski 1996, Afanasjev at al. 1997, Zdanowski et al. 1997). It is expected that its distribution range will soon cover whole Europe (Kiss 1995).

A. woodiana, a new species in the Polish waters, is now present only in one locality: a system of heated lakes near Konin which, since 1958, has become an open system of water cooling for the power plant Konin and, since 1970, for the power plant Pątnów. The system includes five natural lakes (Gosławskie, Pątnowskie, Licheńskie, Ślesińskie and Wąsowsko-Mikorzyńskie), three canals of water intake by the power plants (total length 6 km) and a network of discharge canals (total length 26 km) (ZDANOWSKI 1996).

Till now, young populations of *A. woodiana* in Poland have exerted a positive effect on aquatic ecosystems, through accumulation of biogenic substances, thus contributing to the improvement of water quality (PROTASOV et al. 1994, 1997, SINICYNA at al. 1997, ZDANOWSKI 1996, ZDANOWSKI et al. 1997). In Poland ecological studies on the newly introduced species have just started and are among very few such studies in Europe and the world, while the studies on its age structure and sex ratio are the first of this kind (KISS & PEKLI 1988, PROTASOV et al. 1993, 1994, 1997, KISS 1992, 1995, ZDANOWSKI 1996, SINICYNA at al. 1997, ZDANOWSKI et al. 1997).

The aim of the study was the analysis of age structure of populations of *A. woodiana* from three sites within the cooling water system of the power plants Konin and Pątnów, and an estimation of the diversity within and between the studied sites. The presence of individuals of varied age suggested an adaptation, growth and reproduction of the bivalves in the new habitat. Another objective of the analysis was determination of the sex ratio of the bivalves in the studied sites. The shell mass was analysed with respect to its differentiation depeding on age and sex.

MATERIAL AND METHODS

The material was collected in September 1998 in the lake Licheńskie and the adjacent canal and initial cooling reservoir, all being part of the cooling water system of the power plants Konin and Pątnów. The lakes and the water cooling system were described by ZDANOWSKI (1994). The water temperature of the system is increased compared to other water bodies of the same climatic zone. Among the five lakes of the cooling system, the lake Licheńskie is the most heated, the temperature during the summer stagnation being 30°C. The temperature in the remaining lakes is lower, during the warmest period on an average by 3°C, while in the canals and reservoirs it is by 3°C higher compared to the lake Licheńskie (ZDANOWSKI 1994).

Specimens of *A. woodiana* were collected at three sites: the lake Licheńskie – 29 specimens (Group I), the warmest canal – 27 (Group II) and the initial cooling reservoir – 23 (Group III). The total number of specimens was 79. The material was collected by Prof. BOGUSŁAW ZDANOWSKI from the Institute of Inland Fishery in Olsztyn.

Live individuals of *A. woodiana* were transported to the Department of Genetics, University of Szczecin, where they were kept during eight months. They were fed every other day with dried *Daphnia*, and the water in the aquaria was aerated.

The individual age was estimated based on annual growth lines visible on the shell.

In the spring and summer 1999, sex of the bivalves was determined. For this purpose wet preparations were made of the gonad of each specimen and analysed in light microscope (Carl Zeiss Jena, Jenaval, SH 250) at 400× magnification. The presence of oocytes was regarded as indicating female sex, their absence – male sex. Sex was determined in the individuals that survived in the laboratory till that time.

The shells were weighed (Sm) as dry, after removing the body when the experiments had been concluded; analytical balance was used, the accuracy being 0.01 g. To estimate statistical significance of the differences in the shell mass between and within the age classes, t-Student test was used. The analysis of distribution of male and female specimens within the shell weight classes was based on Chi^2 test.

RESULTS

The shell mass (Sm) of the analysed specimens of *A. woodiana* ranged from 10 to 154 g. The mean values within groups I, II and III amounted to 43, 59 and 86 g, respectively (Table 1). The variability coefficient (V%) of the shell mass in all the three studied groups was high (over 25%), characteristic of an asymmetrical distribution (Table 1). Based on t-Student test, statistically significant differences were found in Sm between the three analysed groups. The mean value of the parameter for all the material examined was 60 g and was the closest to the mean value for group II. The Sm values varied depending on the individual age (Table 2).

The three analysed groups of *A. woodiana* differed in their age structure (Table 2). Individuals aged 3 and 4 years were present in all the groups. In group

III there were no individuals aged 2 years, and individuals aged 5 years were absent from group I. The only individual aged 6 years was found in group II. In groups I and II the highest proportion was constituted by individuals aged 3 years (68% and 41%, respectively), and in group III individuals aged 4 years dominated (52%), the percentage of individuals aged 3 years being the lowest and individuals of 2 and 6 years being absent (Table 2). In the whole analysed material individuals aged 3 years dominated (43%), followed by specimens of 4 (33%) and 5 years (12%, Table 2).

A positive correlation was found between the individual age and shell mass(Table 2, Fig. 1). The highest shell mass values in all the age classes were observed in group III, except for individuals aged 2 years, which were absent from that group. For individuals at that age, the mean values of the parameter amounted to 27 g in group I and 18 g in group II (Table 2). For all the individuals aged 2+, the mean value of Sm was 21 g, for 3+ – 46 g, for 4+ – 77 g and for 5+ – 95 g. The shell mass values differed statistically significantly between the age classes, except for the individuals of classes 4+ and 5+. The age class 6+ was not included in any statistical analysis since it was represented by a single individual.

The correlation between the individual age and the shell mass was the strongest in group II, where the

Table 1. Basic statistics of shell mass (Sm) in three groups of *A. woodiana*

Sm [g]	Group I	Group II	Group III	All groups
N	28	27	21	76
$\overline{X}$	42.59	59.20	85.76	60.42
SD	16.86	24.95	26.65	28.58
PU	6.25	9.41	11.40	6.43
V%	39.58	42.14	31.07	47.31
X_{min}	19.26	9.64	43.74	9.64
X_{max}	88.92	101.08	153.76	153.76

Table 2. Percentage of individuals, mean and extreme values of shell mass (Sm) in age classes of three groups of *A. woodiana*

	Age	% individuals	Sm [g] $\overline{X}$	Sm [g] X_{min}–X_{max}
Group I	2+	10.70	27.21	19.26–39.23
	3+	67.86	37.51	25.26–59.41
	4+	21.43	66.39	46.95–88.92
	5+	–	–	–
	6+	–	–	–
Group II	2+	18.52	18.04	9.64–28.69
	3+	40.74	58.09	37.77–83.68
	4+	29.63	74.58	62.18–90.51
	5+	7.41	85.78	79.78–91.78
	6+	3.70	101.08	101.08
Group III	2+	–	–	–
	3+	14.29	58.87	43.74–83.13
	4+	52.38	84.34	55.03–126.76
	5+	33.33	97.92	69.52–153.76
	6+	–	–	–
All groups	2+	10.53	21.48	9.62–39.28
	3+	43.42	46.31	25.26–83.68
	4+	32.89	77.35	46.95–126.76
	5+	11.84	95.22	69.52–153.76
	6+	1.32	101.08	101.08

correlation coefficient was the highest (r = 0.8), followed by group I (r = 0.7) and group III, where the correlation was poor, with r = 0.4 (Fig. 1).

Sex was determined in 54 individuals which survived in the laboratory till the end. In group I, among 25 individuals, there were 21 females and 4 males, which was 84% and 16%, respectively. In group II, among 18 individuals, there were 8 females (44.44%) and 10 males (55.56%). In group III, of 11 specimens, 6 were female (54.54%) and 5 male (45.46%). The results were analysed with Chi^2 test, assuming the expected sex ratio as 1:1. Such a sex ratio was observed in groups II and III, while the actual sex ratio in group I departed significantly from the expected proportion ($p = 0.001$).

No dependence was found between the sex of the bivalves and their shell mass (Sm), except group I which departed from 1:1 sex ratio.

DISCUSSION

Anodonta woodiana is characterized by a large shell size and considerable weight. The biomass of its population in Great Britain in the river Thames reached 3,000 kg/ha (NEGUS 1966). In Hungary, bivalves of this species are the largest of native bivalves, and their biomass in the river Körös was 75% total bivalve biomass, which constitutes ca. 20–25 thousand kg/ha (KISS 1992). The growth rate of the Hungarian population is surprizing; the species invaded Hungary about 1962 (KISS 1995). However, the growth of *A. woodiana* is not linear. During hot summer periods it may be even twice faster compared to cooler months (KISS 1995). Because of the higher water temperature in the Konin lakes, it should be expected that the growth rate of *A. woodiana* and their proportion in the aquatic ecosystem might be comparable to that in the Hungarian populations. Such a change in the composition of the bottom fauna may considerably affect the ecological equilibrium. Such phenomena were repeatedly observed among molluscs, other invertebrates and vertebrates (HEBERT et al. 1989, BORCHERDING 1991, STRAYER 1991, MAY & MARSDEN 1992, SPIDLE et al. 1994, MARSDEN et al. 1996, GOLDSCHMIDT 1999, LEE 1999).

The analysis of the shell mass (Sm) revealed a very wide variation in all the three studied groups of *A. woodiana*, as evidenced by very high values of the variability coefficient. The high variation within each group results most probably from the age structure. This is supported by the positive correlation between the age and shell mass (r ranging from 0.447 to 0.844). However, differences in calcium carbonate concentration in the environment, as well as individual differences in its accumulation in the shell can not be excluded, the latter possibility being more likely because of the uniform character of the habitats of the analysed bivalves.

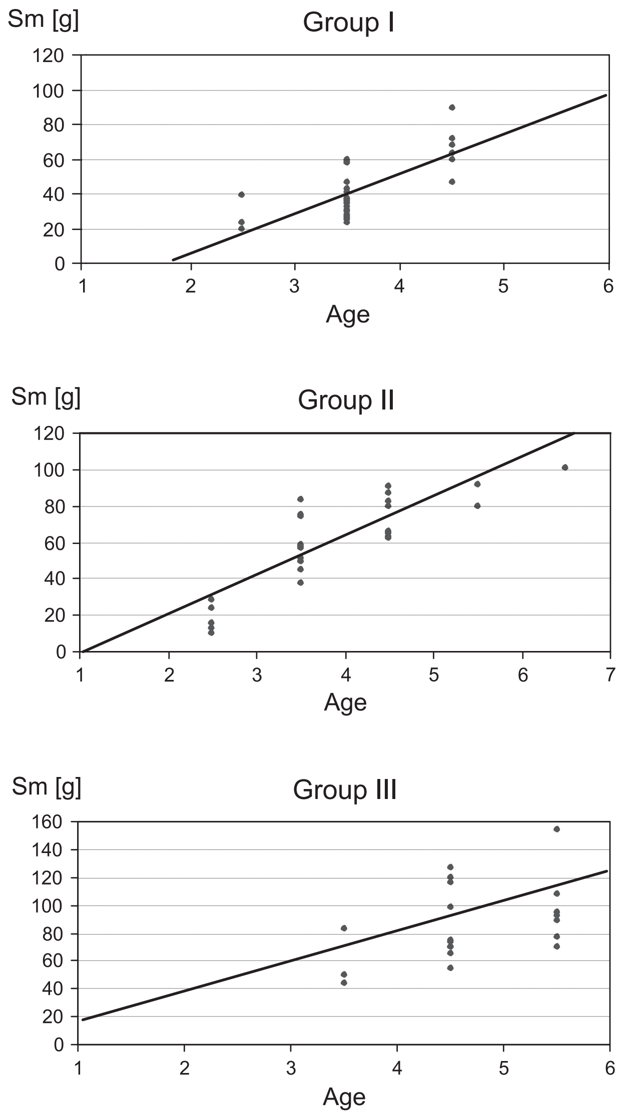

Fig. 1. Correlation between the age classes and shell mass (Sm) in three groups of *Anodonta woodiana*

There was no dependence between the shell mass (Sm) and the sex of the bivalves. The dependence found in group I was not considered because of the sex ratio departing from 1:1.

The observed differences in the shell mass between the age classes were statistically significant, except individuals aged 4 and 5 years. This may result from a very intense growth, including increment in shell mass, in young *A. woodiana*, i.e. individuals aged 2, 3 and 4 years. The increase in body mass of individuals aged 4+ and 5+ is already similar. A very intense growth of young individuals of the species was observed in Hungarian populations (KISS 1995). The bivalves from the warmest canal and from the initial cooling reservoir (groups II and III, respectively) had the highest mean values of the shell mass, both in the group and in particular age classes. The sites where these bivalves were collected were characterized by a water temperature by 3°C higher compared to the lake Licheńskie (group I). The results confirm the earlier studies of KISS (1995) who found that in warmer waters the mass increase of *A. woodiana* was higher. The large differences in the biomass between the Hungarian and British populations of the species may result, among others, from different habitat conditions (NEGUS 1966, KISS 1992).

The three analysed groups of bivalves differed in their age structure. The oldest individuals were present in the highest proportion in groups II and III, i.e. in the canal and reservoir. The population from the lake Licheńskie was the youngest. The oldest individual of *A. woodiana* comes from the warmest canal of the cooling water system near Konin and has lived since 1993. The observed age differentiation in the analysed groups of bivalves indicates their adaptation to the new habitat conditions and the ability to grow and reproduce there (GELLER et al. 1994). The date 1993 as the purported date of introduction of *A. woodiana* in the warm canals of the Konin lake complex is too late, though compatible with respect to the locality, compared to the first mentions of the presence of the species in Poland. PROTASOV et al. (1994) and ZDANOWSKI (1996) reported finding in 1993, at the depth of 3 m under fish bins located in the discharge canal of the power plant Pątnów, large aggregations of Chinese bivalves (up to 50–70 kg/m^2), able to filter as much as 1,600 l water per hour. Unfortunately, the age of those individuals was not estimated. Such large populations observed in 1993 could not be founder populations. Based on this, it can be suspected that the first individuals of *A. woodiana* appeared in the area prior to 1993, and the studied animals were descendants of the introduced founder bivalves. The first individuals invaded the canals and reservoirs of the system, and the lakes were invaded only later.

Bivalves of the genus *Anodonta* show no sexual dimorphism, only in few cases females are more convex (PIECHOCKI & DYDUCH-FALNIOWSKA 1993). In this study, the sex determination was based on microscopic examination of the gonads: the presence of ova in female specimens. In two of the analysed groups of *A. woodiana* (II and III), the sex ratio was close to the expected 1:1 proportion. However, in group I the ratio considerably departed from the expected value. The sex ratio estimated by KISS (1995) for Hungarian populations of *A. woodiana* was 60% females and 40% males. In groups II and III, the sex ratio did not differ statistically ($p>0.05$) from that observed in the Hungarian populations (KISS 1995). No hermaphroditic individuals were found in the studied groups of *A. woodiana* and in the Hungarian populations, though such individuals were observed in various populations, e.g. Chinese and French (KISS 1992, 1995). Perhaps the ability of *A. woodiana* to change its reproductive mode could be the reason for the biased sex ratio in the bivalves of group I (84% females and 16% males), or it is accidental. The technique of sex determination based on the presence of ova in female individuals did not include observation of spermatozoa in male or hermaphroditic individuals. Thus, it can not be excluded that some hermaphroditic specimens were present in the analysed material, especially in group I, where the sex ratio was biased towards females. In order to solve the problem it is necessary to perform a histochemical analysis of the gonads – a study already started by DOMAGAŁA (personal communication, Department of Zoology, University of Szczecin).

ACKNOWLEDGEMENTS

My sincere thanks are due to Prof. B. ZDANOWSKI from the Institute of Inland Fishery in Olsztyn for collecting the material.

REFERENCES

AFANASJEV S. A., SZATOCHINA A. V., ZDANOWSKI B. 1997. Some aspects of thermal tolerance of *Anodonta* from heated Konińskie lake. Archives of Polish Fisheries 5: 5–11.

BORCHERDING J. 1991. The annual reproductive cycle of the freshwater mussel *Dreissena polymorpha* Pallas in lakes. Oekologia 87: 208–218.

GELLER J. B., CARLTON J. T., POWERS D. A. 1994. PCR-based detection of mtDNA haplotypes of native and invading mussel on the northeastern Pacific coast: latitudinal pattern of invasion. Mar. Biol. 119: 243–249.

GOLDSCHMIDT T. 1999. Darwin's dreampond. Drama in Lake Victoria (in Polish). Wyd. Prószyński i S-ka, Warszawa.

HEBERT P. D. N., MUNCASTER B. W., MACKIE G. L. 1989. Ecological and genetic studies on *Dreissena polymorpha* (Pallas): a new mollusc in the Great Lakes. Can. J. Fish. Aquat. Sci. 46: 1491–1587.

KISS A., PEKLI J. 1988. On the growth rate of *Anodonta woodiana* (Lea, 1834) (Bivalvia: Unionacea). Bull. Univ. Agric. Sci. Gödöllô 1: 119–124.

KISS A. 1992. *Anodonta woodiana* Lea, 1834 (Bivalvia: Unionacea) in Hungary. Lavori S. I. M. 24: 171–176.

KISS A. 1995. The propagation, growth and biomass of the Chinese huge mussel (*Anodonta woodiana woodiana* Lea, 1834) in Hungary. Univ. Agric. Sci. Gödöllô, Tropical and Subtropical Department, Private Edition, Second ed.: 1–33.

LEE C. E. 1999. Rapid and repeated invasions of freshwater by the copepod *Eurytemora affinis*. Evolution 53: 1423–1434.

MARSDEN J. E., SPIDLE A., MAY B. 1996. Review of genetic studies of *Dreissena* spp. Amer. Zool. 36: 259–270.

MAY B., MARSDEN J. E. 1992. Genetic identification and implications of another invasive species of Dreissenid Mussel in the Great Lakes. Can. Fish. Aquat. Sci. 49: 1501–1506.

NEGUS C. 1966. A quantitative study of growth and production of unionid mussel in the River Thames at Reading. J. Anim. Ecol. 35: 513–532.

PIECHOCKI A., DYDUCH-FALNIOWSKA A. 1993. Mięczaki (Mollusca). Małże (Bivalvia). Fauna Słodkowodna Polski. Vol. 7A, PWN, Warszawa.

PIECHOCKI A., RIEDEL A. 1997. Mollusca. In: Wykaz zwierząt Polski (RAZOWSKI J., ed.), 4, pp. 104–121, Instytut Systematyki i Ewolucji Zwierząt PAN, Kraków.

PROTASOV A. A., AFANASJEV S. A., ZDANOWSKI B. 1993. Naturalne systemy samooczyszczania wód jezior konińskich. Komun. Ryb. 6: 6–9.

PROTASOV A. A., AFANASJEV S. A., SINICYNA O. O., ZDANOWSKI B. 1994. Composition and functioning of benthic communities. Archives of Polish Fisheries 2: 257–284.

PROTASOV A. A., ZDANOWSKI B., SINICYNA O. O., AFANASJEV S. A., TUNOWSKI J. 1997. Structure and functioning of zooperiphyton and benthos communities of the channels of heated lakes of konińskie district. Archives of Polish Fisheries 5: 77–99.

SINICYNA O. O., PROTASOV, A. A., AFANASJEV S. A., TUNOWSKI J., ZDANOWSKI B. 1997. The role of *Anodonta* sp. in organic matter destruction, in various zones of the channels of konińskie lakes system. Archives of Polish Fisheries 5: 109–116.

SOROKA M. 1998a. Zmienność konchiologiczna i genetyczna małży z rodzaju *Anodonta* w jeziorach konińskich. XIV Krajowe Seminarium Malakologiczne, Wólka Milanowska 22–25 IV 1998, Stowarzyszenie Malakologów Polskich, Wrocław: 63–65.

SOROKA M. 1998b. Conchological and genetic variation of *Anodonta* (Bivalvia: Unionidae) in the Konin Lakes. Folia Malacologica 6: 81.

SOROKA M., PIOTROWSKI S. 1999a. Analysis of metric shell characters in *Anodonta sp.* from heated Konin Lakes (C Poland). Folia Malacologica 7: 271.

SOROKA M., PIOTROWSKI S. 1999b. Analiza cech metrycznych muszli *Anodonta sp.* z podgrzanych akwenów koło Konina. XV Krajowe Seminarium Malakologiczne, Łódź 23–25 IX 1999, Uniwersytet Łódzki, Łódź: 61–62.

SOROKA M., SKOTARCZAK B. 1999a. Genetic identification of morphologically diverse bivalves of the genus *Anodonta*. Folia Malacologica 7: 271.

SOROKA M., SKOTARCZAK B. 1999b. Genetyczna identyfikacja morfologicznie zróżnicowanych form małży z rodzaju *Anodonta*. XV Krajowe Seminarium Malakologiczne, Łódź 23–25 IX 1999, Uniwersytet Łódzki, Łódź: 59–61.

SPIDLE A. P., MARSDEN J. E., MAY B. 1994. Identification of Great Lakes Quagga Mussel as *Dreissena bugensis* from the Dniepr River, Ukraine, on the basis of allozyme variation. Can. J. Fish. Aquat. Sci. 51: 1485–1489.

STRAYER D. L. 1991. Projected distribution of zebra mussel, *Dreissena polymorpha*, in North America. Can. J. Fish. Aquat. Sci. 48: 1389–1395.

ZDANOWSKI B. 1994. Characteristic of heated Konin lakes, pollution sources, main results and conclusions. Archives of Polish Fisheries 2: 139–160.

ZDANOWSKI B. 1996. Nieznana szczeżuja (*Anodonta sp.*) w podgrzanych Jeziorach Konińskich. XII Krajowe Seminarium Malakologiczne, Łódź 25–27 IV 1996, Uniwersytet Łódzki, Łódź: 7.

ZDANOWSKI B., ŚWIĄTECKI A., AFANASJEV S.A., TUNOWSKI J. 1997. Chińskie małże *Anodonta* w Jeziorach Konińskich – rozmieszczenie i rola w oczyszczaniu wód. XVII Zjazd Hydrobiologów Polskich, Poznań 8–11 IX 1997: 212–213.

received: May 25th, 2000
accepted: August 15th, 2000