FOLIA MALACOLOGICA
Vol. 9(3): 137–147
ISSN 1506-7629
The Association of Polish Malacologists
& Faculty of Biology, Adam Mickiewicz University
Poznań 2001

LONG-TERM CHANGES AND SPATIAL VARIABILITY OF MOLLUSC COMMUNITIES IN A LOWLAND RESERVOIR (ZEGRZYŃSKI RESERVOIR, C POLAND)

EWA JURKIEWICZ-KARNKOWSKA

Academy of Podlasie, Department of Ecology and Environment Protection, Prusa 12, 08-110 Siedlce, Poland (e-mail: phkarnk@astercity.net)

ABSTRACT: Studies on spatial diversity in species composition, dominance patterns and abundance of malacocenoses in the Zegrzyński Reservoir were carried out in the late 1990s, and changes since the 80s were assessed. The malacocenoses of the reservoir in the 90s were characterized by a considerable structural diversity and varied abundance. The species diversity was higher in the littoral while the abundance was generally higher in habitats located farther from the shore. After a period of rapid development of the 80s, in the 90s the malacofauna stabilised at a lower level of abundance and species richness, while the dominance patterns became more pronounced. The phenomenon could be related to progressive eutrophication as well as ageing of the reservoir. Compared to other dam reservoirs the mollusc fauna of the Zegrzyński Reservoir is still quite rich in terms of both abundance and number of species.

KEY WORDS: dam reservoir, malacocenoses, long-term changes, spatial diversity

INTRODUCTION

Succession of macrobenthic taxocenoses, including malacocenoses, beginning in newly-created dam reservoirs, depends on formation and changes of environmental conditions. As a rule, during the first years of the reservoir's existence, the macrobenthos develops rather rapidly (PATERSON & FERNANDO 1969, PETR 1972, VOSHELL & SIMMONS 1984), which is followed by a stabilisation of abundance (and/or biomass) at a level depending mainly on the trophic status of the reservoir (BAXTER 1977, STAŃCZYKOWSKA & JURKIEWICZ-KARNKOWSKA 1983). When an influx of nutrients is limited, benthos impoverishment may take place (MORDUKHAY-BOLTOVSKOY 1961, 1971, PODDUBNAYA 1966, SOKOLOVA 1971, HRUSKA 1973, ARMITAGE 1977), though nowadays the impoverishment is usually only transitory, because of strong eutrophication resulting from human activity. Benthos development is stimulated by increasing trophy (e.g. KRZYŻANEK et al. 1986, DUSOGE 1989, DUSOGE et al. 1990, PEROVA & SHCHERBINA 1998), but excessive eutrophication causes reduction in the density and biomass of the bottom organisms, decreasing their diversity and changing the dominance patterns (e.g. BUTORIN 1978, BORODICH & LYAKHOV 1983, KRZYŻANEK 1986, KRZYŻANEK et al. 1986, JURKIEWICZ-KARNKOWSKA 1998).

Temporal changes in environmental conditions are influenced not only by eutrophication, but result also from reservoir's ageing associated with increasing thickness of the bottom sediment layer and its spatial differentiation. The shallows are the first to show ageing symptoms (ZIMBALEVSKAYA et al. 1984): in habitats where the flow is the slowest, a thick layer of fine-grained sediment develops. In such habitats the most drastic reduction of malacocenoses was observed (e.g. JURKIEWICZ-KARNKOWSKA 1998). The direction of macrozoobenthos succession may change as a result of severe disturbances of hydrological regime, such as floods or a considerable drop in the water table, followed by its return to a normal level. In such situations an increase in the abundance of bottom fauna was observed (e.g. GIZIŃSKI & WOLNOMIEJSKI 1982, DUSOGE et al. 1985, JURKIEWICZ-KARNKOWSKA 1986, 1989, KRZYŻANEK et al. 1986, PODDUBNAYA 1988).

The aim of this study was an analysis of spatial diversity in species composition, abundance and dominance patterns of malacocenoses of the Zegrzyński Reservoir in the late 90s, as well as an assessment of changes which have taken place since the period of rapid development of malacocenoses in the 80s.

STUDY AREA AND METHODS

The Zegrzyński Reservoir, established in 1962 through damming of the Narew and Bug rivers, is one of the largest dam reservoirs in Poland. Its surface area is 33 km^2, and capacity – 100 mln m^3. It is relatively shallow (mean depth ca. 3.5 m, maximum depth at dam up to 9 m), with mean retention time from 1 to 15 days. The resevoir was an object of numerous studies. Data on environmental conditions were reviewed by KAJAK & DUSOGE (1989) and KAJAK (1990). The water, as well as the bottom sediments of the reservoir, contain much phosphorus, oxygen conditions vary and periodical oxygen deficits may occur. Data on the quality of the reservoir environment indicate that its trophic status still remains at high level (RAPORT 1997).

Samples of bottom molluscs were taken three times in 1997 (May, July, September) and July 1999, within 8 transects located in various parts of the reservoir (Fig. 1), using Ekman-Birge's grab with catching area of 225 cm^2, and a dredge (working side length 35 cm) which was pulled along a fixed distance of bottom (semi-quantitative samples, particularly useful when investigating big molluscs). The samples were washed on a sieve of 0.5 mm mesh. Parallelly, qualitative investigations of the malacofauna were carried out, especially of macrophyte-associated molluscs. The molluscs were preserved with 4% formaldehyde solution and 75% ethanol. They were identified according to PIECHOCKI (1979) and PIECHOCKI & DYDUCH-FALNIOWSKA (1993), and counted. After drying at 105°C, they were weighed with the accuracy of 0.01 g. Frequency (F) of particular species in the reservoir was calculated as percentage of the samples containing a given species in the total number of samples. The data were statistically analysed with Statistica software.

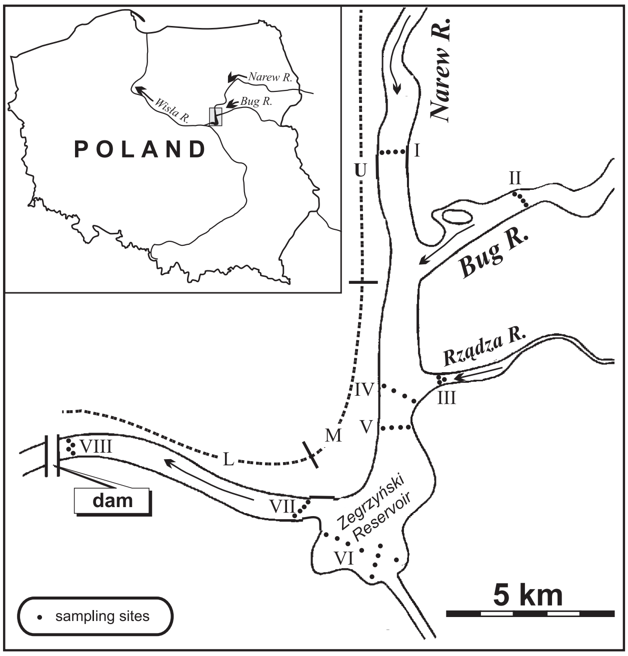

Fig. 1. Location of transects (I–VIII) and sampling sites in the Zegrzyński Reservoir

RESULTS

SPECIES COMPOSITION

In the quantitative samples 21 mollusc species were found, and further 8 species, mainly pulmonate snails, were recorded during supplementary qualitative studies. In total, 15 snail species (4 of them prosobranchs) and 14 bivalve species were recorded (Table 1). The number of species was the highest in the mid part of the reservoir which is the most diverse (Fig. 2A). A comparison of malacocenoses of particular transects revealed that the malacofauna of the mouth sections of the rivers Narew (transect I), Bug (transect II) and Rządza (transect III), and the section Zegrzynek-Rynia in the mid part of the reservoir (transect IV) was relatively rich (Fig. 2B).

In the littoral zone the species richness of the malacofauna (28 species) was higher than in habitats located farther from the shore (18 species). This pertains to each part of the reservoir, especially mid and lower ones (Fig. 2A). Within the transects the difference was not pronounced in all cases, and in the mouth section of the Bug river (section II) the maximum species number was even higher in the central zone (Fig. 2B).

In the mid, widest part of the Zegrzyński Reservoir differences in species richness of malacofauna of habitats influenced by the Bug river (left shore of the reservoir) and the Narew river (right shore) were observed (Fig. 2C). Generally, in habitats of the left shore, especially in the littoral zone and in the stag-

Table 1. List of species found in the Zegrzyński Reservoir in 1997–1999, in quantitative (+) and qualitative (×) samples

No	Species	Parts of the reservoir		
		upper	middle	lower
	Gastropoda:			
	Prosobranchia:			
1.	*Theodoxus fluviatilis* (Linnaeus, 1758)	×	–	–
2.	*Viviparus viviparus* (Linnaeus, 1758)	+	+	+
3.	*Valvata piscinalis* (O. F. Müller, 1774)	+	+	–
4.	*Bithynia tentaculata* (Linnaeus, 1758)	×	+	+
	Pulmonata:			
5.	*Lymnaea (Lymnaea) stagnalis* (Linnaeus, 1758)	+	+	×
6.	*L. (Radix) peregra* (O. F. Müller, 1774)	+	+	+
7.	*L. (R.) auricularia* (Linnaeus, 1758)	–	+	+
8.	*L. (Stagnicola) corvus* (Gmelin, 1791)	–	×	–
9.	*L. (S.) turricula* (Held, 1836)	–	×	–
10.	*Planorbis planorbis* (Linnaeus, 1758)	–	×	–
11.	*Anisus (Disculifer) vortex* (Linnaeus, 1758)	–	+	–
12.	*Gyraulus albus* (O. F. Müller, 1774)	–	×	–
13.	*Planorbarius corneus* (Linnaeus, 1758)	–	+	+
14.	*Ancylus fluviatilis* O. F. Müller, 1774	×	–	–
15.	*Acroloxus lacustris* (Linnaeus, 1758)	–	×	–
	Bivalvia:			
16.	*Unio pictorum* (Linnaeus, 1758)	+	+	–
17.	*U. tumidus* Philipsson, 1788	×	+	–
18.	*Anodonta anatina* (Linnaeus, 1758)	+	+	+
19.	*A. cygnea* (Linnaeus, 1758)	+	+	×
20.	*Sphaerium (Sphaerium) corneum* (Linnaeus, 1758)	+	+	+
21.	*S. (Sphaeriastrum) rivicola* (Lamarck, 1818)	+	+	+
22.	*S. (Cyrenastrum) solidum* (Normand, 1844)	+	+	–
23.	*Musculium lacustre* (O. F. Müller, 1774)	–	×	–
24.	*Pisidium (Pisidium) amnicum* (O. F. Müller, 1774)	+	+	–
25.	*P. (Galileja) henslowanum* (Sheppard, 1823)	+	+	–
26.	*P. (G.) subtruncatum* Malm, 1855	+	+	–
27.	*P. (G.) nitidum* Jenyns, 1832	+	–	–
28.	*P. (G.) casertanum* (Poli, 1791)	+	+	–
29.	*Dreissena polymorpha* (Pallas, 1771)	+	+	+
		20	26	11

nant environment (transect VI), the malacocenoses were poorer in species compared to the right shore. In the stagnant environment and the right shore of the reservoir, the number of species was higher in the littoral zone than in the habitats located more centrally. The spatial diversity of species richness, though in some cases distinct, generally was statistically insignificant (LSD test, $p<0.05$).

Among molluscs found in the Zegrzyński Reservoir only few species were common. The highest frequency was reached by *Viviparus viviparus* (80.4%) and *Dreissena polymorpha* (64.3%); relatively frequent species included *Sphaerium rivicola* (50.1%), *Anodonta anatina* (42.1%), *Sphaerium corneum* (36.8%) and *Bithynia tentaculata* (32.0%). Many species occurred sporadically, e.g. *Theodoxus fluviatilis*, *Lymnaea turricula*, *L. corvus*, *Anisus vortex*, *Planorbis planorbis*, *Gyraulus albus*, *Ancylus fluviatilis*, *Acroloxus lacustris*. Most of them are pulmonates associated with macrophytes and/or typical for small water bodies.

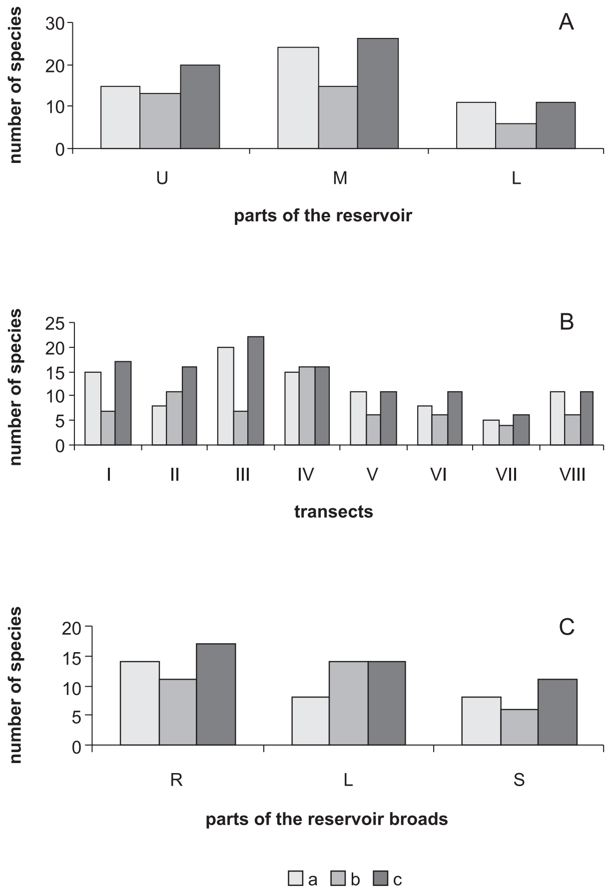

Fig. 2. Number of species in particular parts of the Zegrzyński Reservoir (A), transects (B) and different parts of the reservoir broads (C). U, M, L – upper, middle and lower part of the reservoir, respectively; I–VIII – transects (for the location see Fig. 1); R, L, S – right, left and stagnant part of the reservoir broads; a, b, c – data for the littoral zone, central zone and both zones together

Theodoxus fluviatilis and *Ancylus fluviatilis*, found only during qualitative investigations in the mouth section of the Narew river, are snails limited to habitats with running water.

DOMINANCE PATTERN

In 1997–1999 the main dominants in the malacofauna of the Zegrzyński Reservoir were *V. viviparus* and *D. polymorpha*. The former species was common in the whole reservoir, the latter in its mid and lower parts. In habitats with abundant occurrence of *D. polymorpha*, the proportion of the mussel in the whole malacocenosis was up to several times higher compared to that of *V. viviparus*.

The average proportion of each of the dominant species in the malacofauna of the reservoir exceeded 30% (for *D. polymorpha* the value was slightly higher). The proportion of *V. viviparus* was somewhat higher in the littoral than in the habitats located more centrally; the reverse was true in the case of *D. polymorpha*. Except the above-mentioned species, small bivalves of the family Sphaeriidae constituted a significant component of the malacofauna (24%). The proportion of unionid bivalves exceeded 4%.

A considerable diversity in the dominance pattern was observed along the reservoir. In its upper part *V. viviparus* dominated, especially in the littoral zone (Fig. 3A). In the other parts dominance of *D. polymorpha* was strongly pronounced, while the proportion of Sphaeriidae ranged from 3 to 14% and decreased towards the dam.

The dominance pattern was heterogenous also within particular parts of the reservoir and transects (Fig. 3A, B). In the upper part, a clear difference was observed between the malacocenoses of the mouth sections of the Narew and Bug rivers, especially in the current zone (Fig. 3A, B). Malacocenoses of the transects of the mid part of the reservoir also varied in this respect. Different dominant patterns were found in the habitats influenced by the Bug river, where a clear dominance of *D. polymorpha* was evident, and those affected by the Narew river, with the dominance of *V. viviparus* (Fig. 3C). When the stagnant habitat (transect VI), with its unusually high abundance of *D. polymorpha*, is excluded from the comparison, the dominance pattern on both sides of the mid part of the reservoir becomes more similar (Fig. 3C). The proportion of Sphaeriidae in the zone influenced by the Bug river was considerable and higher than such proportion in the habitats influenced by Narew. In the lower part of the reservoir differences in the dominance pattern between the two investigated transects were clear only in the littoral (Fig. 3B).

ABUNDANCE AND BIOMASS

The mean mollusc densities approached 900 indiv./m^2, but the abundance varied widely both between the parts of the reservoir and within the transects. Statistically significant differences in the mean abundance were found between the upper and lower parts of the reservoir, as well as between its mid and lower parts (LSD test, $p<0.005$ and $p<0.02$, respectively). Differences in the mean density of molluscs within the transects were statistically significant only in 36% cases (Table 2) and concerned mainly transects VI and VII. Generally, the mean abundance increased downstream the reservoir (Fig. 4A, B), though the tendency was less clear and the values of density lower along the right shore (Fig. 4C). Differences in the mean abundance of molluscs between the littoral and the central zone were insignificant in the upper part of the reservoir; in the mid and lower parts they were greater but still statistically insignificant (Fig. 4A, B). Higher densities were observed in centrally located habitats compared to the littoral zone in the upper and mid parts of the reservoir, while in its lower part the malacofauna was more abundant closer to the shore.

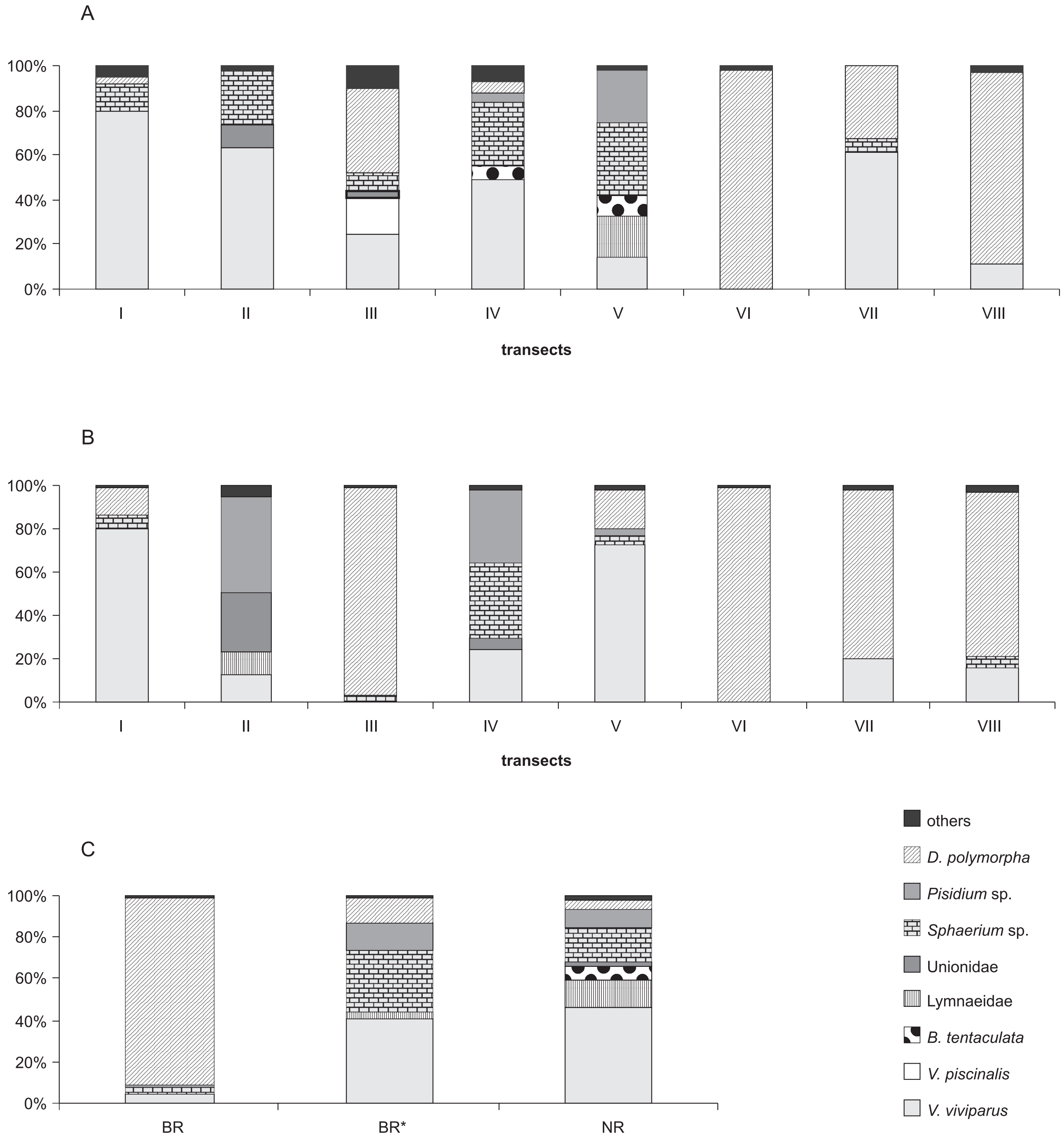

Fig. 3. Proportion (%) of the abundant molluscs in the total density of malacofauna in the littoral zone (A), central zone (B), habitats influenced by the Bug and Narew rivers (C). I –VIII – see Fig. 1; BR – habitats influenced by the Bug River, BR* – BR excluding stagnant habitat (section VI), NR – habitats influenced by the Narew River

The highest mollusc density (on an average from 1,500 to over 2,000 indiv./m^2) was observed in habitats where *D. polymorpha* dominated (transects VI, VII), and the lowest (on an average several dozen indiv./m^2) – in the mouth section of the Bug river (Fig. 4B). Within other transects the mean density was of the order of several hundred indiv./m^2 bottom area. In spite of differences in abundance between the littoral and central zones (though statistically insignificant), there was no homogenous tendency in this diversity within partcular transects, however, in general, the mollusc density in deeper habitats was higher than or equal to the respective values in the littoral zone (except transect VIII). The maximum mollusc abundance was observed in the stagnant habitat (transect VI – 6,940 indiv./m^2) and near the dam (transect VIII – 3,640 indiv./m^2); the minimum – (several dozen indiv./m^2) in some habitats in the upper and mid parts of the reservoir.

Table 2. Spatial diversity of mollus abundance and biomass along the investigated transects of the Zegrzyński Reservoir. LSD test; p. – significance level; ns – non-significant differences; I–VIII – transects, see Fig. 1

BIOMASS	ABUNDANCE							
	I	II	III	IV	V	VI	VII	VIII
I		ns	ns	ns	ns	0.0165	ns	0.0029
II	ns		ns	ns	ns	0.0055	ns	0.0017
III	ns	ns		ns	ns	0.0067	ns	0.0019
IV	ns	ns	ns		ns	0.0092	ns	0.0028
V	ns	ns	ns	ns		0.0017	ns	0.0004
VI	ns	ns	ns	ns	0.0163		ns	ns
VII	ns	ns	ns	ns	ns	ns		ns

The mean mollusc biomass in the Zegrzyński Reservoir amounted to 285 g dry weight/m^2; the highest value was observed in the lower part of the reservoir, while in its upper and mid parts the values were similar (Fig. 5A, B). This pertained also to each of the two zones: littoral and central. Statistically significant differences in the mean biomass were found between the upper and lower parts of the reservoir, and its mid and lower parts (LSD test, $p<0.05$ and $p<0.006$, respectively). A comparison of the mean biomass between the transects revealed statistically significant differences only in 18% cases (Table 2). The biomass in the centrally located habitats was higher than in the littoral zone (Fig. 5A, B).

The highest mean biomass (almost 600 g dry weight/m^2) was observed near the dam (transect VIII), the lowest (over 50 g dry weight/m^2) – in the mid part of the reservoir (transect IV). The maximum biomass was recorded in transect VIII (over 1,200 g dry weight/m^2), the minimum – 0.13 g dry weight/m^2 – in the stagnant habitat (transect VI), being also characterized by the widest range of biomass values. In most habitats, the biomass was of the order of several dozen to a few hundred g dry weight/m^2. The mean mollusc biomass in the mouth section of the Narew river (transect I) was significantly higher, compared to the mouth section of the Bug river (transect II), however in the mid and lower parts of the reservoir the biomass along the left shore, influenced by the Bug river was higher than along the right shore (Fig. 5C).

In particular parts of the reservoir and in the transects (except V) a statistically significant correlation was found between the mollusc abundance and biomass (Table 3).

Table 3. Correlations between the mollusc abundance and biomass in different habitats of the Zegrzyński Reservoir (significant at $p<0.05$). For the location of parts of the reservoir and transects see Fig. 1

Part of the reservoir	Zone	Correlation coefficient (r)	Transects	Correlation coefficient (r)
upper	littoral	0.96	I	0.85
	central	0.79	II	0.97
	whole	0.81		
middle	littoral	0.55	III	0.84
	central	0.84	IV	0.85
	whole	0.65	V	ns
			VI	0.88
lower	littoral	0.96	VII	0.98
	central	ns	VIII	0.78
	whole	0.75		

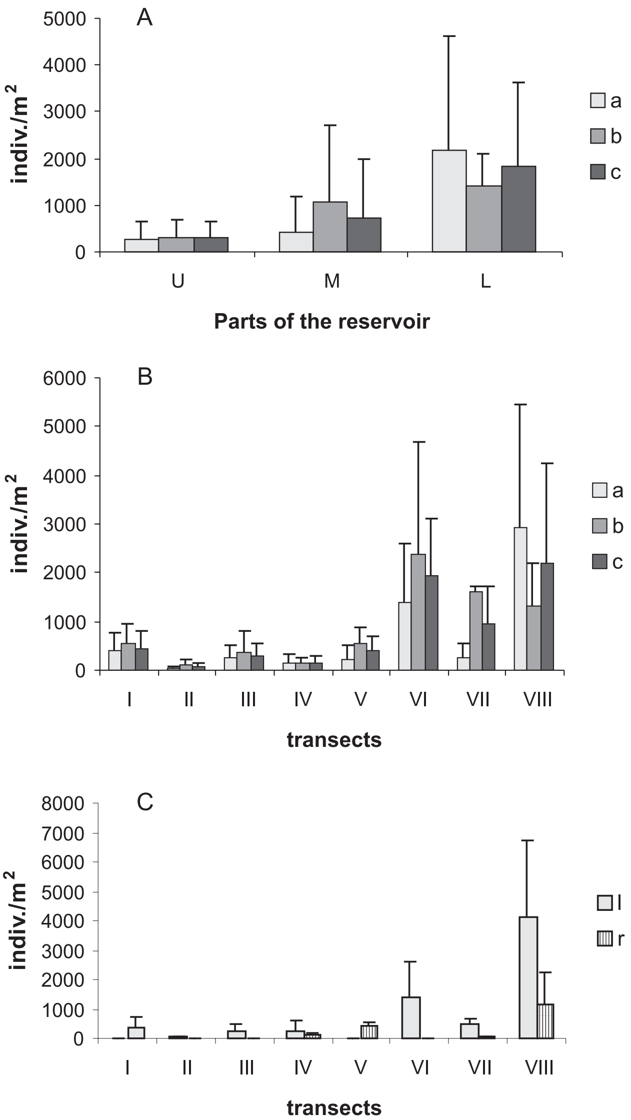

Fig. 4. Mean densities of molluscs (indiv./m^2) in particular parts of the Zegrzyński Reservoir (A), transects (B), left and right shores of the reservoir (C). U, M, L, I – VIII, a, b, c – see Fig. 2; l, r – left and right shores of the reservoir

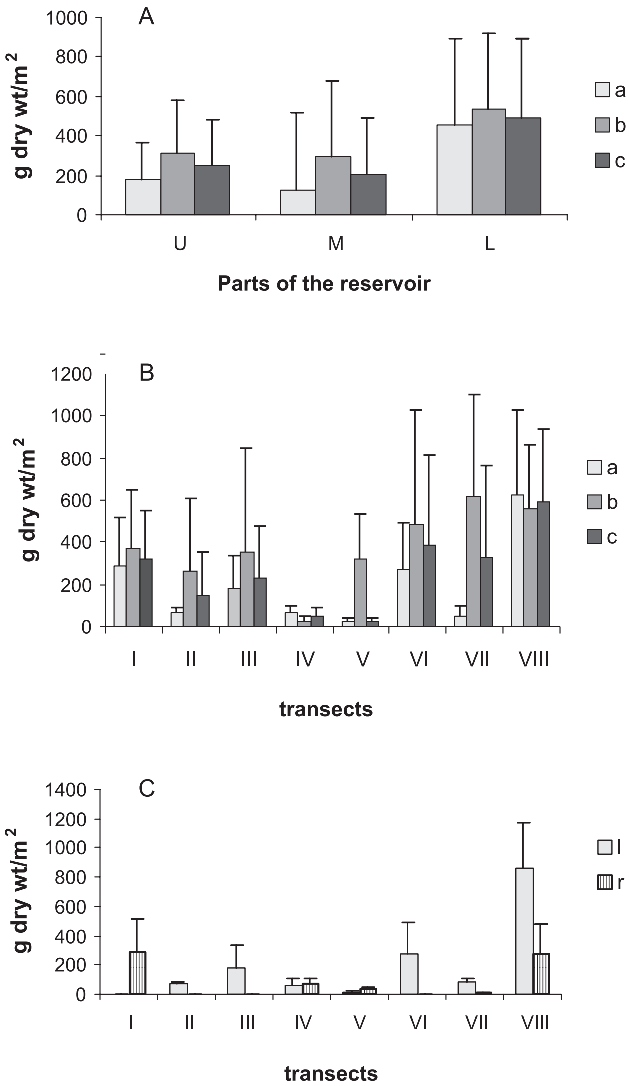

Fig. 5. Mean biomass of molluscs (g dry wt/m^2) in particular parts of the Zegrzyński Reservoir (A), transects (B) left and right shores of the reservoir (C). U, M, L, I – VIII, a, b, c, l, r – see Figs 2 and 4

DISCUSSION

Earlier data on the malacofauna of the Zegrzyński Reservoir, contained in the papers by JURKIEWICZ-KARNKOWSKA (1986, 1989, 1998), GRUŻEWSKI (1988), LEWANDOWSKI et al. (1989) and DUSOGE et al. (1990), make it possible to trace some of the changes in the malacocenoses since the period of their rapid development in the 80s.

In comparison with the 80s, an impoverishment in the mollusc species diversity is observed in the Zegrzyński Reservoir. During quantitative investigations ca. 50% species recorded by DUSOGE et al. (1990) in 1986–1988 were not found. Taking into consideration molluscs collected only in qualitative investigations, a decrease in the species number by ca. 30% is observed compared to the data from the early 80s (JURKIEWICZ-KARNKOWSKA 1989). In the 90s, molluscs preferring flowing water, such as *Lithoglyphus naticoides*, *Unio crassus*, *Anodonta complanata*, *Pisidium supinum*, *Valvata naticina*, *Theodoxus fluviatilis*, *Sphaerium solidum* became rare or were no longer recorded. The first four species have not been recorded from the reservoir since 1995 (JURKIEWICZ-KARNKOWSKA 1998). *V. naticina*, *S. solidum* and *Th. fluviatilis* were rare in 1995, and only single individuals were found. The reduction in species diversity may result from a considerable stabilisation of environ-

Table 4. Changes in the frequency of selected (most common in 1986–1987) mollusc species between 1986–1987, 1995 and 1997; a – littoral zone, b – central zone

Taxa	1980–1981	1986–1987	1995	1997		
	a	a+b	a	a	b	a+b
Vviparus viviparus	44.3	60.3	86.3	84.8	78.3	80.4
Lithoglyphus naticoides	51.7	21.8	11.1	0	0	0
Valvata piscinalis	42.5	37.8	19.4	17.6	21.7	19.3
Bithynia tentaculata	21.8	35.9	65.3	39.4	26.1	32.0
Anodonta anatina	22.4	27.6	41.8	38.2	47.8	42.1
Sphaerium rivicola	45.4	–	63.4	54.5	33.3	50.1
S. corneum	23.7	–	10.0	42.4	30.3	36.8
Sphaerium spp.	60.3	68.6	66.7	67.6	65.2	66.7
Pisidium spp.	70.1	50.6	12.5	23.5	30.4	26.3
Dreissena polymorpha	23.0	18.6	72.9	66.7	73.9	64.3

mental conditions associated with the lack of severe disturbances of the hydrological regime, increase in the bottom sediment thickness and ageing of the reservoir biocenosis. An important limiting factor may be eutrophication (KAJAK 1990, RAPORT 1997). Disappearance of many small bivalves of the genus *Pisidium,* which are sensitive to water pollution, e.g. increased trophy (PIECHOCKI & DYDUCH-FALNIOWSKA 1993, KRZYŻANEK 1994, PEROVA & SHCHERBINA 1998), may be attributed to eutrophication of their habitats. An increased proportion of *Anodonta* among the total number of unionids may also result from eutrophication; such a situation was reported e.g. by METCALFE-SMITH et al. (1998). A limiting effect of eutrophication on the mollusc species diversity was observed by various authors (e.g. HARMAN & FORNEY 1970, STAŃCZYKOWSKA et al. 1983, PIP 1987, MOUTHON 1996, HARMAN 1997, PIECZYŃSKA et al. 1999). The number of mollusc species found in bottom samples from the Zegrzyński Reservoir in 1997–1999 has not changed significantly since 1995 and thus it may indicate stabilisation of the malacofauna composition in the 90s at the level clearly lower than that observed 10 years earlier. The frequency of many molluscs that were common in the 80s has changed (Table 4). Since the beginning of the 80s the frequency of *V. viviparus* has increased and in mid 90s its range within the reservoir stabilised. At the same time, *D. polymorpha* has considerably expanded within the reservoir and its frequency increased till the end of the 90s. A slight increase in frequency of *A. anatina* was observed, compared to the data from the 80s. The frequency of bivalves of the genus *Sphaerium* has remained unchanged in spite of the reduced range of *S. rivicola* and *S. solidum*, because at the same time *S. corneum* has became more common in some of the habitats. The frequency of bivalves of the genus *Pisidium* has decreased considerably, many species were not found at all and the remaining ones were rare. Some snails common in many habitats of the Zegrzyński Reservoir in the 80s, such as *V. piscinalis* and *L. naticoides* (GRUŻEWSKI 1988, JURKIEWICZ-KARNKOWSKA 1989, DUSOGE et al. 1990) have decreased considerably in frequency or disappeared completely since the 80s (Table 4).

As a result of disappearance or decreased abundance of many species, followed by an increased proportion of *V. viviparus* and *D. polymorpha* in the malacocenoses, the dominance patterns have become more pronounced since the 80s. In the mouth sections of the Narew (both in the littoral and central zones) and Bug rivers (especially in the littoral), the dominance of *V. viviparus* has increased during the last 10 years. At the same time the contribution of unionids has remained at a similar level, whereas the proportion of *Sphaerium* has increased slightly in the littoral zone, because of the increased abundance of *S. corneum.* The proportion of *Pisidium* and *V. piscinalis* in the malacocenoses has decreased considerably, whereas *V. naticina* and *L. naticoides* have disappeared completely (empty shells, however, were found). In the mid part of the reservoir, the dominance of *D. polymorpha* has increased. At the same time the role of *V. viviparus* in the dominance relations has decreased, especially along the right shore where in 1995 the snail still constituted over 90% molluscs in the littoral zone (at present 50%). The percentage of Sphaeriidae and *V. piscinalis* has decreased as well. In the mouth section of the Rządza river, a noticeable proportion of Lymnaeidae was observed close to the shore. The dominance of *D. polymorpha* has increased also in the lower part of the reservoir. An abundant occurrence of this mussel within some habitats of this part of the reservoir was reported as early as in late 80s (GRUŻEWSKI 1988, DUSOGE et al. 1990). Since that period the increase in abundance of *D. polymorpha* has been so intense that the proportion of *V. viviparus* in the malacocenoses has decreased despite the development of its population. A significant development of *D. polymorpha* populations is often observed in lowland dam reservoirs of Europe (MITROPOLSKIY & LUFEROV 1966, GIZIŃSKI & WOLNOMIEJSKI 1982, BORODICH & LYAKHOV 1983, GIZIŃSKI et al. 1989, PEROVA & SHCHERBINA 1998).

The mean abundance of molluscs has decreased many times in the mouth section of the Bug river and several times in the mid parts of the reservoir (transects IV and V); a trend resulting from a considerable reduction in abundance of many small bivalves (Sphaeriidae) and prosobranchs (*L. naticoides*, *T. fluviatilis*, *V. piscinalis*, *V. naticina*). The decrease in abundance of one of the main dominants, *V. viviparus*, in the mid part of the reservoir (transects IV and V) may result from worse trophic conditions in comparison with the upper part where sedimentation of a considerable amount of seston carried by the river takes place (SIMM 1990) and the lower part of the reservoir supplied by plankton coming from stagnant habitats. The changes in mollusc abundance observed in the mouth sections of the Narew and Rządza rivers are small. In the stagnant habitat (transect VI) and the lower part of the reservoir the mollusc abundance has clearly increased, mainly due to the development of *D. polymorpha* population promoted by bottom character and favourable trophic conditions associated with considerable authochthonous plankton abundance (EJSMONT-KARABIN & WĘGLEŃSKA 1990, SIMM 1990). In the majority of sections, except the one located near the dam, a decrease in mollusc abundance has occurred in the littoral zone since late 80s, whereas in the habitats located centrally the tendency is less pronounced, or even a significant increase in abundance was observed. Investigations in the littoral zone in 1995 (JURKIEWICZ-KARNKOWSKA 1998) also revealed a less distinct reduction of abundance in habitats located closer to the current compared to stagnant ones. In the littoral zone, being characterized by slow water exchange, a greater inflow of surface run-off and intra-reservoir processes, disadvantageous effects of eutrophication and ageing of the reservoir are visible earlier than in habitats located more centrally (SINGH 1983, ZIMBALEWSKAYA et al. 1984, DENISOVA et al. 1985). The mean biomass of molluscs exhibits a smaller decrease compared to their abundance; this results from an increased abundance of large-sized species.

Despite the observed impoverishment, the malacofauna of the Zegrzyński Reservoir is still fairly abundant and species-rich compared with other lowland or submontane reservoirs (cf. MITROPOLSKIY & LUFEROV 1966, PODDUBNAYA 1966, 1988, FERRARIS & WILHM 1977, KRZYŻANEK 1977, 1979, BUTORIN 1978, SMERNOY & MITROPOLSKIY 1978, SOKOLOVA et al. 1980, BORODICH & LYAKHOV 1983, COOPER & KNIGHT 1985, KRZYŻANEK et al. 1986, ŻBIKOWSKI 1995).

CONCLUSIONS

1. Malacocenoses of the Zegrzyński Reservoir in the late 90s displayed a considerable spatial diversity of abundance and structure.
2. The species diversity of the malacofauna was higher in the littoral (pulmonate snails are associated mainly with this zone) while the abundance was generally higher in more centrally located habitats.
3. The dominance patterns have become more pronounced since the 80s; of all the species *D. polymorpha* displayed the most evident increase in proportion.
4. After the period of a rapid development in the 80s, the malacofauna stabilised in the 90s at a lower level of abundance and species richness; this may be related to progressive eutrophication as well as to ageing of the reservoir.
5. Compared to other dam reservoirs, the malacofauna of the Zegrzyński Reservoir is still quite rich in terms of abundance of number of species.

REFERENCES

ARMITAGE P. D. 1977. Development of the macroinvertebrate fauna of Cow Green Reservoir (Upper Teesdale) in the first five years of its existence. Freshwat. Biol. 7: 441–454.

BAXTER R. M. 1977. Environmental effects of dams and impoundments. Ann. Rev. Ecol. Syst. 8: 255–283.

BORODICH N. D., LYAKHOV S. M. 1983. Zoobentos. In: Kuybyshevskoye vodokhranilishche. Tr. Inst. Biol. Vnutr. Vod. AN SSSR 51: 131–148.

BUTORIN N. V. (ed.). 1978. Ivanovskoye vodokhranilishche i ego zhizn. Tr. Inst. Biol. Vnutr. Vod. AN SSSR 34: 1–304.

COOPER CH. M., KNIGHT L. A. 1985. Macrobenthos-sediment relationships in Ross Barnett Reservoir, Mississippi. Hydrobiologia 126: 193–197.

DENISOVA A. I., LEVITSKAYA N. V., SIDORENKO V. M. 1985. Sravnitelnaya kharakteristika gidrokhimicheskogo rezhima melkovodiy i glubokovodnykh zon dneprovskich vodokhranilishch. Gidrobiol. Z. 21: 57–64.

DUSOGE K. 1989. Distribution and structure of benthos in the lowland Zegrzyński Reservoir. Ekol. Pol. 37: 281–298.

DUSOGE K., BOWNIK-DYLIŃSKA L., EJSMONT-KARABIN J., SPODNIEWSKA I., WĘGLEŃSKA T. 1985. Plankton and benthos of man-made Lake Zegrzyński. Ekol. Pol. 33: 455–479.

DUSOGE K., LEWANDOWSKI K., STAŃCZYKOWSKA A. 1990. Liczebność i biomasa fauny dennej w różnych środowiskach Zbiornika Zegrzyńskiego. In: Funkcjonowanie ekosystemów wodnych, ich ochrona i rekultywacja. I. Ekologia zbiorników zaporowych i rzek (KAJAK Z., ed.), pp. 57–85, SGGW-AR, Warszawa.

EJSMONT-KARABIN J., WĘGLEŃSKA T. 1990. Zooplankton zbiornika Zegrzyńskiego – jego obfitość, struktura i rola w funkcjonowaniu ekosystemu. In: Funkcjonowanie ekosystemów wodnych, ich ochrona i rekultywacja. I. Ekologia zbiorników zaporowych i rzek (KAJAK Z., ed.), pp. 29–56, SGGW-AR, Warszawa.

FERRARIS C., WILHM J. 1977. Distribution of benthic macroinvertebrates in an artificially destratified reservoir. Hydrobiologia 54: 169–176.

GIZIŃSKI A., WOLNOMIEJSKI N. 1982. Zoobenthos of Koronowo Dam Reservoir in its 10th and 15th years of existence. Acta Univ. Nicolai Copernici. Prace Limnologiczne 13: 35–50.

GIZIŃSKI A., BŁĘDZKI L. A., KENTZER A., WIŚNIEWSKI R., ŻYTKOWICZ R. 1989. Hydrobiological characteristics of the lowland, rheolimnic Włocławek Reservoir on the Vistula River. Ekol. Pol. 37: 359–403.

GRUŻEWSKI M. 1988. Jakościowa i ilościowa charakterystyka występowania mięczaków dennych w Zbiorniku Zegrzyńskim. Masters Thesis, WSR-P Siedlce.

HARMAN W. N. 1997. Otsego Lake macrobenthos communities between 1968 and 1993: Indicators of decreasing water quality. J. Freshw. Ecol. 12: 465–476.

HARMAN W. N., FORNEY J. L. 1970. Fifty years of change in the molluscan fauna of Oneida Lake, New York. Limnol. Oceanogr. 15: 454–460.

HRUSKA V. 1973. The changes of benthos in Slapy Reservoir in the years 1960–1961. Hydrobiol. Studies 2: 213–247.

JURKIEWICZ-KARNKOWSKA E. 1986. Występowanie i rola mięczaków w wybranych rzekach i zbiornikach zaporowych Niziny Mazowieckiej. Ph. D. Thesis, IE PAN, Dziekanów Leśny.

JURKIEWICZ-KARNKOWSKA E. 1989. Occurrence of molluscs in the littoral zone of the Zegrzyński Reservoir and in the pre-mouth and mouth zones of supplying rivers. Ekol. Pol. 37: 319–336.

JURKIEWICZ-KARNKOWSKA E. 1998. Long-term changes in mollusc communities in shallow biotopes of a lowland reservoir (Zegrzyński Reservoir, Central Poland). Pol. J. Ecol. 46: 43–63.

KAJAK Z. 1990. Zegrzyński zbiornik zaporowy. Warunki Środowiskowe. In: Funkcjonowanie ekosystemów wodnych, ich ochrona i rekultywacja. I. Ekologia zbiorników zaporowych i rzek (KAJAK Z., ed.), pp. 7–20, SGGW-AR, Warszawa.

KAJAK Z., DUSOGE K. 1989. Temporal and spatial diversity of trophy-indicators in a lowland dam reservoir. Ekol. Pol. 37: 211–233.

KRZYŻANEK E. 1977. Bottom macrofauna of the dam reservoir of Goczałkowice in the years 1970–1975. Acta Hydrobiol. 19: 51–57.

KRZYŻANEK E. 1979. Bottom macrofauna of the dam reservoir at Rybnik remaining under influence of hot discharged waters from the hot power station. Acta Hydrobiol. 21: 243–259.

KRZYŻANEK E. 1986. Development and structure of the Goczałkowice reservoir ecosystem. XIV. Zoobenthos. Ekol. Pol. 34: 491–513.

KRZYŻANEK E. 1994. Changes in the bivalve groups (Bivalvia – Unionidae) in the Goczałkowice Reservoir (southern Poland) in the period 1983–1992. Acta Hydrobiol. 36: 103–113.

KRZYŻANEK E., KASZA H., KRZANOWSKI W., KUFLIKOWSKI T., PAJĄK G. 1986. Succession of communities in the Goczałkowice Dam Reservoir in the period 1955–1982. Arch. Hydrobiol. 106: 21–43.

LEWANDOWSKI K., GRACZYK T., STAŃCZYKOWSKA A. 1989. The occurrence of *Viviparus viviparus* (L.) in the Zegrzyński Reservoir. Ekol. Pol. 37: 337–446.

METCALFE-SMITH J. L., STATON S. K., MACKIE G. L., LANE N. M. 1998. Changes in the biodiversity of freshwater mussels in the Canadian waters of the Lower Great Lakes Drainage Basin over the past 140 years. J. Great Lakes Res. 24: 845–858.

MITROPOLSKIY V. I., LUFEROV V. P. 1966. Raspredelenie bentosa v volzhskom plese Rybinskogo vodokhranilishcha. Tr. Inst. Biol. Vnutr. Vod. AN SSSR 12: 10–15.

MOUTHON J. 1996. Molluscs and biodegradable pollution in rivers: studies into the limiting values of 11 physicochemical variables. Hydrobiologia 319: 57–63.

MORDUKHAY-BOLTOVSKOY F. D. 1961. Process formirovaniya donnoy fauny v Gorkovskom i Kuybyshevskom vodokhranilishchakh. Tr. Inst. Biol. Vodochr. 4: 49–77.

MORDUKHAY-BOLTOVSKOY F. D. 1971. Bentos krupnych vodokhranilishch na Volge. In: Volga 1 (DZYUBAN N. A., ed.), pp. 123–127, Oblast. tipogr. im Myagi, Kuybyshev.

PATERSON C. G., FERNANDO C. H. 1969. The macroinvertebrate colonisation of a small reservoir in Eastern Canada. Verh. Internat. Verein. Limnol. 17: 126–136.

PEROVA S. N., SHCHERBINA G. KH. 1998. Sravnitelnyi analiz struktury makrozoobentosa Rybinskogo vodokhranilishcha v 1980 i 1990 gg. Biol. Vnutr. Vod. ANR 2: 52–61.

PETR T. 1972. Benthic fauna of a tropical man-made lake (Volta Lake, Ghana 1965–1968). Arch. Hydrobiol. 70: 484–533.

PIECHOCKI A. 1979. Mięczaki (Mollusca). Ślimaki (Gastropoda). Fauna Słodkowodna Polski 7, PWN, Warszawa–Poznań.

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

PIECZYŃSKA E., KOŁODZIEJCZYK A., RYBAK J. I. 1999. The responses of littoral invertebrates to eutrophication-linked changes in plant communities. Hydrobiologia 391: 9–21.

PIP E. 1987. Species richness of freshwater gastropod communities in central North America. J. Moll. Stud. 53: 163–170.

PODDUBNAYA T. L. 1966. O donnoy faunie Cherepovetskogo vodokhranilishcha v pervye dva goda ego sushchestvovaniya. Tr. Inst. Biol. Vnutr. Vod AN SSSR 12: 21–33.

PODDUBNAYA T. L. 1988. Mnogoletnyaya dinamika struktury i produktivnost donnykh soobshchestv Rybinskogo vodokhranilishcha. Tr. Inst. Biol. Vnutr. Vod AN SSSR 55: 112–141.

RAPORT o stanie środowiska województwa stołecznego warszawskiego w 1996 r. 1997. WIOŚ, Biblioteka Monitoringu Środowiska, Warszawa.

SIMM A. 1990. Przestrzenne zróżnicowanie fitoplanktonu w zbiorniku Zegrzyńskim na tle wybranych parametrów fizyczno-chemicznych. In: Funkcjonowanie ekosystemów wodnych, ich ochrona i rekultywacja. I. Ekologia zbiorników zaporowych i rzek (KAJAK Z., ed.), pp. 21–29, SGGW-AR, Warszawa.

SINGH R. K. 1983. The role of the littoral (shallow) zone in reservoir productivity. Acta Hydrochim. Hydrobiol. 11: 101–107.

SMERNOY V. P., MITROPOLSKIY V. I. 1978. Zoobentos pribrezhnykh melkovodiy Rybinskogo vodokhranilishcha. Tr. Inst. Biol. Vnutr. Vod AN SSSR 39: 74–103.

SOKOLOVA N. J. 1971. Donnaya fauna i osobennosti ey formirovania v malykh vodokhranilishchakh bassena verkhney Volgi. Bjul. Mosk. Obsc. Ispyt. Prir. 76: 46–58.

SOKOLOVA N. J., IZVEKOVA E. I., LVOVA A. A., SAKHAROVA M. I. 1980. Sostav, raspredeleniye i sezonnaya dinamika chislennosti i biomassy bentosa. In: Bentos Uchinskogo vodokhranilishcha (WINBERG G. G., ed.), Tr. vsesoyuz. Gidrobiol. Obsc. 23: 24–39.

STAŃCZYKOWSKA A., JURKIEWICZ-KARNKOWSKA E. 1983. Bentos strefy przybrzeżnej zbiorników zaporowych. In: Ekologiczne podstawy zagospodarowania Wisły i jej dorzecza. pp. 489–509, PWN, Warszawa–Łódź.

STAŃCZYKOWSKA A., JURKIEWICZ-KARNKOWSKA E., LEWANDOWSKI K. 1983. Ecological characteristics of lakes in North-Eastern Poland versus their trophic gradient. X. Occurrence of molluscs in 42 lakes. Ekol. Pol. 31: 459–475.

VOSHELL J. R., SIMMONS G. M. 1984. Colonisation and succession of benthic macroinvertebrates in a new reservoir. Hydrobiologia 112: 27–39.

ZIMBALEVSKAYA L. N., DEKHTYAR M. N., LEGEYDA I. S., PLIGIN J. V., SIDORENKO V. M., KHOROSICH L. A. 1984. Melkovodya dneprovskikh vodokhranilishch i problemy ispolzovaniya ikh resursov. Vodnye Resursy AN SSSR 2: 14–22.

ŻBIKOWSKI J. 1995. Struktura populacji pelofilnego makrobentosu Zbiornika Włocławskiego. Ph. D. Thesis, UMK, Toruń.

received: January 15th, 2001
accepted: August 10st, 2001