



## MOLLUSCS OF SELECTED WATER BODIES IN WARSAW

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**ABSTRACT:** Malacofauna of lakes: Powsinkowskie, Wilanowskie and Czerniakowskie is composed of a similar number of taxa (14–16), but the species composition differs considerably. Mollusc densities are low, frequencies of individual species mostly do not exceed 25%, dominance structure, not very well marked in the deposits, is very clear among the few molluscs living on emerged macrophytes and macrophytes with floating leaves. Species diversity (Shannon-Weaver index) is higher in the bottom deposits, compared to macrophytes. Taxonomic composition of empty shells found in the bottom deposits, indicates that a few dozen year ago the malacofauna of the lakes was richer and similar between the lakes. It appears that the present composition of the malacofauna is affected, among others, by the character of the bottom deposits, transformations of littoral vegetation, level of pollution and trophy of the lakes; the influence of all these factors varies between species.

**KEY WORDS:** molluscs, empty shells, oxbows, agglomeration, anthropopressure

### INTRODUCTION

Molluscs are essential for assessment of the quality of aquatic habitats, which results among others from their long and entirely aquatic life cycle, varied ecological requirements and the presence of shells which are deposited in the sediments and allow an estimate of changes in species composition through time. Some mollusc species are used in water quality assessment systems (SLADEČEK 1973, PIECHOCKI 1979, TUROBOYSKI 1979, PIECHOCKI & DYDUCH-FALNIOWSKA 1993). It has been shown (PIECZYŃSKA et al. 1999) that with increasing trophy in lakes of the Mazurian Lakeland the proportion of snails in abundance of the macrophyte-dwelling macrofauna decreases, with accompanying changes in the dominance structure and impoverishment of species diversity.

About a hundred water bodies of different size and origin are located within the Warsaw agglomeration (KOŁODZIEJCZYK 1996). They were floristically studied by GRZYCKA (1969) and POLESIAK (1970) – the results are to a considerable degree out-dated, if only because of the disappearance of many water bodies

described by these authors. KOŁODZIEJCZYK (1976) presented ecological characteristics of the eulittoral of four water bodies. However, biology of urban water bodies is rather poorly known. Being usually rather small ecosystems, they naturally become increasingly shallow and then disappear. This is accompanied by pollution, littering with rubbish, and sometimes too intense regulation measures, as well as artificial decrease in ground water level. As a result, they are only rarely subject to biological studies. KOŁODZIEJCZYK (1996) summarised information on the effect of the Warsaw agglomeration on life in water bodies, and (1999) presented biological characteristics of Czerniakowskie Lake.

The objective of this study was a comparison of the malacofauna of three water bodies located within different distance from the city centre and subject to anthropopressure of different character and intensity. We studied the occurrence of molluscs and, based on empty shells, estimated changes in the taxonomic composition.



## STUDY AREA

The studies included lakes: Powsinkowskie, Wilanowskie and Czerniakowskie (Fig. 1). Located in the southern part of left-bank Warsaw, on the Vistula floodplain (Taras Praski), they originated as oxbows. They are fairly small, 8.50–19.70 ha in area, and shallow, of maximum depth ranging from 3.0 to 5.7 m (Table 1). They are located in different surroundings, have different shores, composition and abundance of aquatic vegetation, and are to different extent used as recreational places.

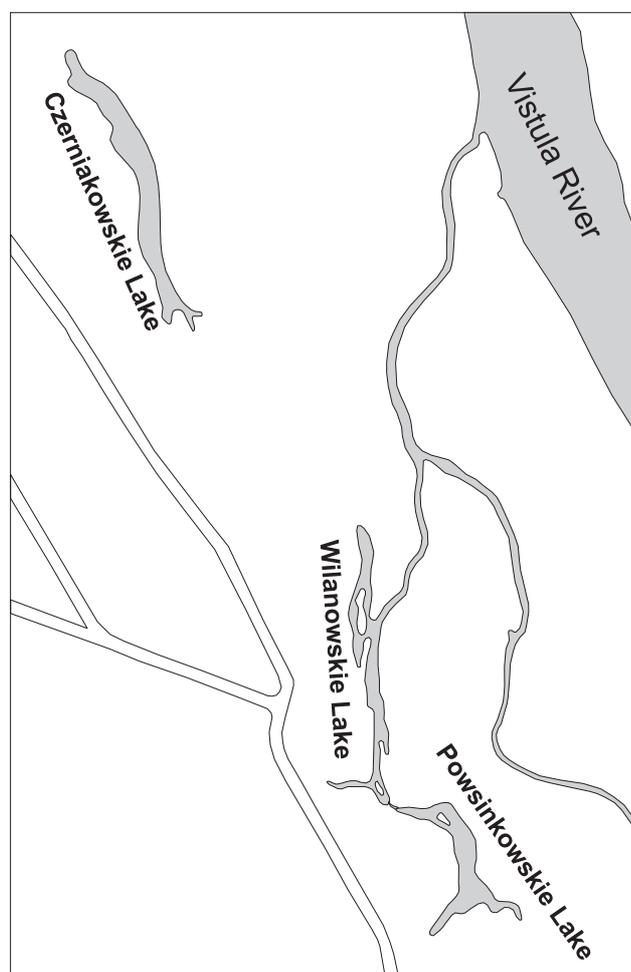


Fig. 1. Study area – investigated lakes in Warsaw

Table 1. Characteristics of the studied lakes

Lake	Surface area [ha]	Mean depth [m]	Maximum depth [m]	Shore line length [m]
Powsinkowskie	8.50	–	3.0	–
Wilanowskie*	12.76	1.6	4.3	3.300
Czerniakowskie**	19.70	2.6	5.7	4.200

\*according to MALANOWSKI et al. (1974); \*\*according to GUMIŃSKI et al. (1925)

Powsinkowskie Lake is the most remote from the city centre. Sewage and rubbish get into the lake from some small houses located on its western shore; on the eastern side it is adjoined by meadows, pastures, allotment gardens and cultivated fields with few tree clumps. Canals Natoliński and Powsinkowski, draining the surrounding area, open into the lake, while a short canal flowing out of it feeds Wilanowskie Lake. The shores are mostly low, partly marshy, and the bottom is muddy. The rich and varied emerged vegetation includes *Phragmites australis* (Cav.) Trin. ex Steudel and *Glyceria aquatica* (L.) Wahlb., plants of floating leaves are dominated by *Nuphar luteum* (L.) Sm., while the dominant submerged plant is *Elodea canadensis* Rich. The lake includes a bathing place, and numerous anglers penetrate the shores.

Wilanowskie Lake is located next to Powsinkowskie Lake, north of it, and is fed by a short canal from that lake. The other sources of water are: a discharge from the machinery centre, and from a pond in the Wilanowski Park; the main source is strongly polluted stream Potok Służewiecki. The Wilanówka River flowing out of the lake joins the Vistula; the former northward outlet to Czerniakowskie Lake does not exist any more. On the western side the lake is adjoined by the Wilanowski Park, on the eastern side by orchards and cultivated fields, and the Morysinek Park of a riverine forest character; on the northern side there are marshy meadows. The shores for a great part are reinforced with wooden poles and spiling, over a small section (west) they are covered with concrete. The bottom is muddy. Emerged plants (*P. australis*, *Typha latifolia* L. and *G. aquatica*) cover only few short sections of the shore. Small tufts of *N. luteum* are scattered all over the lake, and in places *E. canadensis* occurs. The eastern shore is intensely penetrated by anglers.

Czerniakowskie Lake is located to the north-west of Wilanowskie Lake, 6 km from the city centre; it is a nature reserve of landscape type (MOŚiZN enactment of 1987). It is the largest natural water body of Warsaw, at present completely closed. It is surrounded by allotment gardens, meadows and suburban housing estates of varied character. The lake is crossed (bridge) by a busy street toward the thermoelectric power plant Siekierki which is 1 km away. The lake is joined by drainage ditches and municipal sewage canals; periodically certain quantities of water are discharged from the power plant. The shores are low, only the south-western shore is an escarpment ca. 3 m high, which is an edge of the Vistula floodplain. Trees and shrubs grow singly or in clumps near the shores. The bottom is muddy and sandy. The shores are abundantly covered by *P. australis*, as well as less abundant *T. latifolia*, *G. aquatica* and sedges. Among plants with



floating leaves *N. luteum* dominates; *Nymphaea alba* L. is also present; submerged plants are represented by *E. canadensis* and *Potamogeton* spp. The lake is in-

tensely used for recreation (beech with a bathing place and boat rental).

## METHODS

The lakes were studied in 1990. In June from each lake water samples were taken in three sites, depth ca. 0.5 m, ca. 1 m from the shore; physico-chemical analysis was performed directly after sampling. Water pH was measured with H-5122 pH-meter, electrolytic conductivity – with OK-102/1 conductometer, dissolved oxygen concentration – with Winkler's method, chloride concentration ( $\text{Cl}^-$ ) – with argentometric titration, phosphates ( $\text{P}_{\text{PO}_4}$ ) – with molybdate method, ammonia nitrogen ( $\text{N}_{\text{NH}_4}$ ) – with direct nesslerisation method (JUST & HERMANOWICZ 1976). Chlorophyll a and phaeophytine were determined with acetone colorimetric method (GOLTERMAN & CLYMO 1969).

Molluscs samples from each lake were taken in five sites in May, June and September – from the bottom deposits, emerged plants (*P. australis* or *G. aquatica*), from plants with floating leaves (*N. luteum*), and in some sites also from submerged plants (*E. canadensis*) and filamentous algae – on each occasion two samples from each substratum available in the site. Deposit samples were taken with bottom scraper of ca. 0.2 m<sup>2</sup> area, ca. 1 m from the shore. Each sample of emerged plants included 8–12 submerged sections of stems (ca. 20 cm long), sample of *N. luteum* – 5 floating and submerged leaves with petioles, sample of *E. canadensis* – 4–6 shoots ca. 20 cm long. Samples of filamentous algae were taken with bottom scraper.

A total of 248 samples were taken, from 72 to 91 from each lake. The most numerous were the bottom deposit samples, then samples of emerged plants and plants with floating leaves; samples of *E. canadensis* and filamentous algae were the least numerous; filamentous algae were only sporadically observed in June and September.

The material was stored at –16°C; after defrosting it was washed on a sieve of 1 mm mesh, macroscopically sorted; the molluscs were isolated, and from deposits also empty shells. The material was preserved in 4% formaldehyde. The macrophytes were dried and weighed. Snails were identified using PIECHOCKI's (1979) key, bivalves – with URBAŃSKI's (1957) key, based on conchological characters; they were identified to species level except subgenera *Radix* and *Galba*, and Sphaeriidae.

Taxonomic composition of molluscs, their total density per 1 m<sup>2</sup> bottom or 100 g dry mass of plants, frequency of individual species, dominance structure and species diversity  $\bar{H}$  (Shannon-Weaver) were determined. Similarity of the malacofauna was estimated with the species composition similarity index *S* according to MARCZEWSKI & STEINHAUS (1959), and similarity of dominance structure *Re* (%) – Renkonen's index.

## RESULTS

### PHYSICO-CHEMICAL CHARACTERISTICS OF WATER

Water pH of all the lakes was slightly basic (Table 2), electrolytic conductivity somewhat lower in Powsinkowskie Lake, compared to the other water bodies. Dissolved oxygen content, generally rather high, was the highest in Czerniakowskie Lake (13.2 mg dm<sup>-3</sup>), the lowest in Wilanowskie Lake (8.4 mg dm<sup>-3</sup>). Concentra-

tion of  $\text{Cl}^-$  ions was the lowest in Powsinkowskie Lake (60.0 mg dm<sup>-3</sup>), over twice higher in Wilanowskie Lake and nearly three times higher in Czerniakowskie Lake. Concentration of ammonia ions was similar between the studied lakes, but there were large differences in phosphate concentration (Table 2), with the maximum value in Powsinkowskie Lake. With respect to the content of chlorophyll a and phaeophytine the lakes were in a similar order.

Table 2. Physico-chemical characteristics of water of the studied lakes

Lake	pH	$\mu\text{S cm}^{-2}$	$\text{O}_2$ [mg dm <sup>-3</sup> ]	$\text{Cl}^-$ [mg dm <sup>-3</sup> ]	$\text{N}_{\text{NH}_4}$	$\text{P}_{\text{PO}_4}$	Chlorophyll a [ $\mu\text{g dm}^{-3}$ ]	Phaeophytine [ $\mu\text{g dm}^{-3}$ ]
Powsinkowskie	7.6	880	10.8	60.0	0.40	738.5	90.6	25.7
Wilanowskie	8.3	1.160	8.4	134.0	0.45	292.3	80.1	14.4
Czerniakowskie	8.5	1.030	13.2	156.0	0.40	92.3	51.3	11.9

## GENERAL CHARACTERISTICS OF MALACOFAUNA

A total of 744 mollusc specimens were collected (708 snails and 36 bivalves) – the greatest number in Powsinkowskie Lake (345), the fewest in Wilanowskie Lake (155). Most molluscs were found in samples of macrophytes with floating leaves (299) and emerged macrophytes (265). Fewer animals were collected from the bottom deposits (151), and the fewest from submerged macrophytes (12) and filamentous algae (17). Consequently, molluscs found on the last two substrata are included only in a part of the analyses presented below.

The molluscs represent 23 taxa – 18 snails and 5 bivalves (Table 3); the lakes were found to harbour similar numbers of taxa (14–16), but the taxonomic composition varied considerably. Representatives of only six common taxa were present in all the studied lakes (*Viviparus viviparus*, *Bithynia tentaculata*, *Lymnaea stagnalis*, *Lymnaea (Radix)* sp., *Lymnaea (Galba)* sp., *Anisus vortex*, *Acroloxus lacustris*, *Unio pictorum* and sphaeriid bivalves). As many as 11 species were found

Table 3. List of mollusc taxa collected in the studied lakes

Taxon	Powsinkowskie Lake	Wilanowskie Lake	Czerniakowskie Lake
<i>Viviparus viviparus</i> (L.)	+	+	+
<i>Viviparus contectus</i> (Mill.)	+		
<i>Valvata cristata</i> O. F. Müll.	+		
<i>Valvata piscinalis</i> (O. F. Müll.)	+		+
<i>Valvata naticina</i> Mke.		+	
<i>Bithynia tentaculata</i> (L.)	+	+	+
<i>Physella acuta</i> (Drap.)		+	
<i>Lymnaea stagnalis</i> (L.)	+	+	+
<i>Lymnaea (Radix)</i> sp.	+	+	+
<i>Lymnaea (Galba)</i> sp.	+	+	+
<i>Planorbis planorbis</i> (L.)		+	
<i>Planorbis carinatus</i> O. F. Müll.			+
<i>Anisus vortex</i> (L.)	+	+	+
<i>Gyraulus albus</i> (O. F. Müll.)	+		
<i>Armiger crista</i> (L.)	+	+	
<i>Segmentina nitida</i> (O. F. Müll.)	+		
<i>Planorbarius corneus</i> (L.)	+	+	
<i>Acroloxus lacustris</i> (L.)	+	+	+
<i>Unio tumidus</i> Philipsson			+
<i>Unio pictorum</i> (L.)	+	+	+
<i>Anodonta anatina</i> (L.)			+
<i>Anodonta cygnea</i> (L.)			+
Sphaeriidae	+	+	+

in one lake only (Table 3). Consequently, values of species similarity index between the lakes were rather low: Lakes Wilanowskie/Czerniakowskie 0.47, Lakes Powsinkowskie/Czerniakowskie 0.50 and Lakes Powsinkowskie/Wilanowskie 0.58.

## DIFFERENTIATION OF MALACOFAUNA BETWEEN SUBSTRATA

The total density of molluscs was rather low. Converted to 1 m<sup>2</sup> bottom, it was on an average from 5 in Czerniakowskie Lake to 12 in Powsinkowskie Lake. On the macrophytes it ranged from 22 per 100 g dry weight in Czerniakowskie Lake to 42 on emerged macrophytes and 36 on macrophytes with floating leaves in Powsinkowskie Lake.

The numbers of mollusc taxa in the bottom deposits (Table 4) were similar between the lakes (12–13). A much lower number was found on emerged macrophytes (Lakes Wilanowskie and Czerniakowskie) and on macrophytes with floating leaves (all the water bodies). The malacofauna of submerged macrophytes and filamentous algae in all the lakes was composed of only 1–3 species.

The similarity of species composition was the lowest for molluscs of the bottom deposits: 0.32 for Lakes Czerniakowskie and Wilanowskie, 0.41 for Lakes Powsinkowskie and Wilanowskie, and 0.47 for Lakes Powsinkowskie and Czerniakowskie. It was higher for molluscs collected from emerged macrophytes and macrophytes with floating leaves in Lakes Wilanowskie and Czerniakowskie – 0.80 for each guild, lower for Lakes Wilanowskie and Powsinkowskie (0.42 and 0.57, respectively) and Lakes Powsinkowskie and Czerniakowskie (0.33 and 0.50, respectively).

The frequency of individual taxa was low on each of the studied substrata (Table 4), and mostly did not exceed 25%. In bottom deposits only *Segmentina nitida* in Powsinkowskie Lake and *Viviparus viviparus* in Czerniakowskie Lake reached frequency of 26–50%. The only constant species on emerged plants (frequency >50%) was *Acroloxus lacustris* in Czerniakowskie Lake. Also on the yellow waterlily *A. lacustris* was constant in Lakes Wilanowskie and Powsinkowskie, while in Czerniakowskie Lake – *Lymnaea (Radix)* sp.

The dominance structure of molluscs on the studied substrata was varied (Table 5). In the bottom deposits of Powsinkowskie Lake co-dominants were *Anisus vortex* and *Segmentina nitida*, in Wilanowskie Lake – Sphaeriidae and *Viviparus viviparus*, and in Czerniakowskie Lake – *V. viviparus*, *Lymnaea (Radix)* sp. and Sphaeriidae. The dominance structure on emerged macrophytes was similar between the lakes – in all *Acroloxus lacustris* dominated, though different species were subdominants: in Powsinkowskie Lake *A. vortex*, Wilanowskie – *Lymnaea (Radix)* sp. and *Lymnaea (Galba)* sp., and in Czerniakowskie Lake – *Lymnaea (Radix)* sp. On macrophytes with floating leaves in



Table 4. Frequency of mollusc taxa on different substrata in the studied lakes; A – deposits, B – emerged macrophytes, C – macrophytes with floating leaves; frequency: \* – >0–25%, \*\* – 26–50%, \*\*\* – 51–75%

Taxon	Powsinkowskie Lake			Wilanowskie Lake			Czerniakowskie Lake		
	A	B	C	A	B	C	A	B	C
<i>Viviparus viviparus</i>	*	*					**		
<i>Viviparus contectus</i>		*							
<i>Valvata cristata</i>	*								
<i>Valvata piscinalis</i>	*						*		
<i>Valvata naticina</i>				*					
<i>Bithynia tentaculata</i>	*	*		*			*		*
<i>Physella acuta</i>				*					
<i>Lymnaea stagnalis</i>	*	*	*	*	*	*		*	*
<i>Lymnaea (Radix) sp.</i>	*	**	*	*	**	*	*	**	***
<i>Lymnaea (Galba) sp.</i>		*	**	*	*	*	*	*	*
<i>Planorbis planorbis</i>				*					
<i>Planorbis carinatus</i>							*		
<i>Anisus vortex</i>	*	**	**		*		*		
<i>Gyraulus albus</i>			*						
<i>Armiger crista</i>		*	*	*					
<i>Segmentina nitida</i>	**	*							
<i>Planorbarius corneus</i>	*	*		*					
<i>Acroloxus lacustris</i>	*	**	***		**	***	*	***	**
<i>Unio tumidus</i>							*		
<i>Unio pictorum</i>	*			*			*		
<i>Anodonta anatina</i>							*		
<i>Anodonta cygnea</i>							*		
Sphaeriidae	*	*		*			*		

Table 5. Dominance structure [%] of molluscs of the studied lakes on different substrata; lakes: P – Powsinkowskie, W – Wilanowskie, C – Czerniakowskie

Taxon	Deposits			Emerged macrophytes			Macrophytes with floating leaves		
	P	W	C	P	W	C	P	W	C
<i>Viviparus viviparus</i>	6	25	23						
<i>Valvata cristata</i>	6								
<i>Valvata piscinalis</i>	9								
<i>Bithynia tentaculata</i>	6	12	6						
<i>Lymnaea stagnalis</i>	9	12							
<i>Lymnaea (Radix) sp.</i>	6	6	19		21	43	9	13	50
<i>Lymnaea (Galba) sp.</i>					21		6	8	7
<i>Anisus vortex</i>	20			30			6		
<i>Segmentina nitida</i>	20			22					
<i>Acroloxus lacustris</i>	6			39	41	51	71	77	35
<i>Anodonta anatina</i>			11						
<i>Anodonta cygnea</i>			8						
Sphaeriidae		27	16						
Others (<5%)	12	18	16	12	11	6	7	1	8

Lakes Powsinkowskie and Wilanowskie *A. lacustris* clearly dominated, and in Czerniakowskie Lake – *Lymnaea (Radix) sp.* (*A. lacustris* was subdominant there). The proportion of dominant species varied between the substrata: from 20% in the deposits of Powsinkowskie Lake to 77% on macrophytes with floating leaves in Czerniakowskie Lake. The similarity of dominance structure (Table 6) was the lowest for molluscs inhabiting the bottom deposits, especially in Lakes Powsinkowskie and Wilanowskie, as well as Lakes Powsinkowskie and Czerniakowskie. Higher values (maximum 87% for Lakes Powsinkowskie and Wilanowskie) were found when comparing dominance structure of molluscs on emerged macrophytes and macrophytes with floating leaves.

The diversity of the malacofauna (Shannon-Weaver index) was the highest (from 0.87 to 0.94) in the bottom deposits, and on macrophytes of floating leaves it was only 0.31 to 0.53.

#### EMPTY SHELLS

The total number of empty shells found in the bottom deposits of the studied lakes was 1,152: 755 snail and 397 bivalve shells. The most numerous shells (757) were found in Czerniakowskie Lake. Besides shells of many species which lived in the water bodies during the studies, some species represented only by shells were found (Table 7). These included 10 snail and 4 bivalve species; in individual lakes 4 to 6 snail and 1–3 bivalve species were represented by shells only. In all the studied lakes *Valvata pulchella* was found only as empty shells. In the bottom deposits of Czerniakowskie Lake shells of *Dreissena polymorpha* were very numerous.

Considering the empty shells, the total number of mollusc taxa was 27; in Powsinkowskie Lake 23, in Lakes Wilanowskie and Czerniakowskie 21 each. The species composition similarity index of Marczewski and Steinhaus, calculated jointly for live molluscs and empty shells, exceeded 0.60, which indicates a considerable similarity in species composition (MARCZEWSKI & STEINHAUS 1959), and amounted to 0.75 for Lakes Powsinkowskie and Wilanowskie, 0.75 for Lakes

Table 6. Similarity of dominance structure of the malacocoenoses in the studied lakes on different substrata (Renkonen's index, %)

Lake	De- posits	Emerged macro- phytes	Macro- phytes with floating leaves
Powsinkowskie/Wilanowskie	35	49	87
Powsinkowskie/Czerniakowskie	27	45	55
Wilanowskie/Czerniakowskie	55	76	56

Table 7. Mollusc taxa collected in the studied lakes as empty shells only

Taxon	Powsin- kowskie Lake	Wila- nowskie Lake	Czernia- kowskie Lake
<i>Valvata cristata</i>			+
<i>Valvata pulchella</i> Stud.	+	+	+
<i>Valvata piscinalis</i>		+	
<i>Valvata naticina</i>	+		+
<i>Planorbis carinatus</i>	+	+	
<i>Anisus sp.*</i>			+
<i>Gyraulus albus</i>		+	+
<i>Gyraulus sp.**</i>	+	+	
<i>Segmentina nitida</i>		+	+
<i>Unio tumidus</i>	+		
<i>Anodonta anatina</i>	+		
<i>Anodonta cygnea</i>	+	+	
<i>Dreissena polymorpha</i>			+
Number of taxa			
snails	4	6	6
bivalves	3	1	1

\**A. spirorbis* (L.) or *A. leucostomus* (Mill.); \*\**G. acronicus* (Fér.) or *G. rosmaessleri* (Auersw.). All these species are impossible to identify based on shell

Powsinkowskie and Czerniakowskie, and 0.62 for Lakes Wilanowskie and Czerniakowskie.

#### DISCUSSION

Because of their location and character of surrounding areas, the studied water bodies (Fig. 1) are subject to anthropopressure of different intensity. The character of the catchment area, shore and littoral vegetation indicate that the anthropopressure in Powsinkowskie Lake is moderate. The littoral of Wilanowskie Lake is strongly transformed and almost devoid of vegetation; Czerniakowskie Lake has the most varied littoral, relatively the least affected by hu-

man activity (KOŁODZIEJCZYK 1976). In Powsinkowskie Lake high content of phosphates, chlorophyll a and phaeophytine (Table 2) indicate a considerable trophic level. The trophic level is clearly lower in Wilanowskie Lake and the lowest in Czerniakowskie Lake. According to the classification adopted for Mazurian lakes and based on phosphorus content (KAJAK & ZDANOWSKI 1983), the studied water bodies represent different groups (Lakes: Powsinkowskie – IV, Wilanow-

skie – III, Czerniakowskie – II). However, the higher electrolytic conductivity of water and high concentration of chlorides in Lakes Czerniakowskie and Wilanowskie indicate a greater municipal and industrial pollution of water, compared to Powsinkowskie Lake.

According to STAŃCZYKOWSKA et. al. (1983), in the bottom deposits of Mazurian lakes the number of mollusc taxa decreases with increasing phosphorus content. A decrease in the number of mollusc species (and abundance) on submerged macrophytes with increasing lake trophy was observed by PIECZYŃSKA et al. (1999). No such dependence was found in the studied lakes. In all of them the number of mollusc taxa was similar (Table 3). However, the number of snail species, everywhere clearly lower than in the well-studied eutrophic Mikołajskie Lake (KOŁODZIEJCZYK 1984), was 14 in the most eutrophicated Powsinkowskie Lake and decreased (Table 3) with decreasing trophy (Table 1). The number of species seems to decrease not with increasing trophy or increasing degree of littoral transformation, but with increasing pollution of water and decreasing distance from the city centre. In the studied lakes the malacofauna (including snails) of the bottom deposits (Table 4) was qualitatively clearly richer than on macrophytes; in Mikołajskie Lake (KOŁODZIEJCZYK 1984) the number of snail taxa in the bottom deposits was clearly lower than on plants. This may suggest that in urban water bodies the bottom zone has been relatively less degraded, compared to littoral vegetation. The same might be indicated by a much less „sharp” dominance structure in the bottom deposits (Table 5) and by the higher values of Shannon-Weaver index in these deposits.

Both qualitatively and quantitatively the macrophyte mollusc fauna was the most abundant in Powsinkowskie Lake, which may be associated with the greatest diversity of plants in this water body. Various authors (among others ÖKLAND 1969, HARMAN 1972, BRÖNMARK 1985) pointed to a positive dependence between mollusc species richness and diversity of plant substrata. The smallest pollution of waters in this lake may also be of importance. In Wilanowskie Lake macrophytes are few, and the water is chemically polluted, while Czerniakowskie Lake, besides a considerable water pollution, is characterised by floristic monotony.

Mostly species typical of the  $\beta$ -mesosaprobic zone were found in the studied lakes (SLADEČEK 1973), the only mollusc typical of the  $\alpha$ - $\beta$ -mesosaprobic zone being *Planorbis carinatus* (Czerniakowskie Lake), and the only species which tolerates water pollution ( $\beta$ -mesosaprobic zone) is *Physella acuta*, an invasive species typical of heated waters, which is sporadically found in Wilanowskie Lake. Rare and endangered species, according to PIECHOCKI (2002), are *Planorbis carinatus* and *Valvata naticina*, the latter snail found in Wilanowskie Lake. The poverty of bivalves (Table 3) in Lakes

Powsinkowskie and Wilanowskie (only *Unio pictorum* and Sphaeriidae) may result both from the bottom character (muddy, with large quantities of decaying plants), and the small depths of the reservoirs, which makes it impossible to migrate for winter. Conversely, as many as four unionid species were found in bottom deposits of Czerniakowskie Lake, including a rare and endangered (PIECHOCKI & DYDUCH-FALNIOWSKA 1993) *Anodonta cygnea*, which constituted 25% abundance of all molluscs. Its presence may be favoured both by the sandy bottom and the greatest depth of the lake.

Despite the small distance between the lakes, the existing (Fig. 1) or past connections between them, the same limnological type and common origin, the similarity in the taxonomic composition of their present malacocoenoses was slight, and the similarity in their dominance structure not much higher (Table 6). The situation may result from different anthropopressure, eliminating different species. Unfortunately, data on the past malacofauna of these lakes are scarce. In Powsinkowskie Lake, compared to the 1980 data (KOŁODZIEJCZYK unpublished), the species composition of molluscs on macrophytes did not change essentially. Only *Physa fontinalis*, common at that time, was not found, while *Valvata cristata* and *Segmentina nitida* (the latter species very abundant in 1990) had not been recorded 10 years earlier. Till the 1980s in Powsinkowskie Lake *Lymnaea stagnalis* occurred in masses and *Viviparus* was very numerous; 10 years later their abundance was much lower. In Czerniakowskie Lake the abundance of *Viviparus viviparus* in summer 1964 reached 51.2 individuals per 1m<sup>2</sup> bottom (SAMOCHWALENKO & STAŃCZYKOWSKA 1972); in 1990 the mean density of the entire malacofauna in that lake was ten times lower.

Interpretation of species composition of the empty shells is difficult, because shells of some species which are present in the lakes were not found in the deposits. It may be an effect of the low density of these molluscs or interspecific differences in time of shell decomposition. JANKOWSKI (1933) listed from Czerniakowskie Lake six species not found (alive) during this study: *Myxas glutinosa*, *Gyraulus albus*, *Physa fontinalis*, *Valvata cristata*, *Bithynia leachi* and *Dreissena polymorpha*. At least two of them – *M. glutinosa* and *P. fontinalis* – have shells so delicate and brittle that it is practically impossible for them to be preserved in littoral bottom deposits. Of the remaining species, in the bottom deposits of Czerniakowskie Lake only numerous shells of *D. polymorpha* were found.

Disappearance of *D. polymorpha*, which is regarded as characteristic of the  $\alpha$ - $\beta$ -mesosaprobic zone (SLADEČEK 1973) may indicate an increase in environment pollution within the last several dozen years. A rapid decrease in abundance of this species, associated with accelerated eutrophication, was observed by STAŃCZYKOWSKA (1961, 1964) and STAŃCZYKOWSKA

et al. (1983) in Mazurian lakes. In Czerniakowskie Lake it may be associated with construction of the power plant Siekierki, which has for a long time emitted considerable quantities of dust settling on the bottom of the lake and may have a very adverse effect on this filtrationist. The absence of the species in Lakes Powsinkowskie and Wilanowskie may result both from their high fertility combined with small depth and muddy bottom with no hard substrata which are necessary for the zebra mussel, and from the large distance from the Vistula – the source of the colonising mussels. Czerniakowskie Lake, deeper and connected with the Vistula till the beginning of the 20th c. during great floods (GUMIŃSKI et al. 1925), was easier for the species to invade.

*Anodonta cygnea* (Table 7) has disappeared from Lakes Powsinkowskie and Wilanowskie, and is still pres-

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ent only in Czerniakowskie Lake (Table 3). In Powsinkowskie Lake another two species of unionids were represented only by empty shells (Table 7). Empty shells of *Valvata naticina* were found in deposits of Lakes Powsinkowskie and Czerniakowskie (Table 7), live individuals – only in Wilanowskie Lake (Table 3).

Considering both live individuals and empty shells, the similarity of taxonomic composition between the studied lakes was clearly higher than that based only on live specimens. This clearly indicates that several dozen years ago the species composition of the malacofauna of the lakes was still similar, and the great differences observed at present result from differentiated occurrence of species, probably as a result of slightly different anthropopressure.

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