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Andrzej KOŁODZIEJCZYK

Department of Hydrobiology, Institute of Zoology, University of Warsaw

ECOLOGICAL CHARACTERISTICS OF THE EULITTORAL OF FOUR WATER BODIES IN WARSAW

ABSTRACT: The eulittoral of the following water bodies located in Warsaw was investigated: Czerniakowskie Lake, Kamionkowskie Lake, Wilanowskie Lake and a clay pit Moczydło. Studied eulittoral was small (depending on small variations of water level) and of strong anthropogenic transformation. In the submerged eulittoral low oxygen concentrations were found, low content of organic matter in sediments, scarce flora and fauna. The degree of anthropogenic transformation of investigated water bodies depends on the way of their management and on the kind of surrounding area.

Contents

1. INTRODUCTION

The increase of the influence of human activities on natural ecosystems results from the development of urbanization and industrialization, intensification of chemization of agriculture and from the increasing tourism. This is accompanied by growing interest in different approaches of environmental studies. Investigations of urban environments are especially important. Studies carried out on areas of most intensive anthropogenic pressure could answer many theoretical and practical questions.

Especially intensive studies of urban environments are carried out by botanists. In Warsaw, among the others, there were studies of lichens as indicators of environment disturbance

(Zimny and Kucińska 1974), studies on the influence of atmospheric pollution on soils and cumulation of heavy metals in plants (Konecka-Betley et al. 1974, Czarnowska 1974). Also the influence of greens on urban environment and its climate was studied (Szczepanowska 1974, Okołowicz and Kossowska 1974).

Zoological studies of urban environments deal mainly with birds. To new papers on this subject, with ecological approach, belongs among the others a paper by Okulewicz (1971), where the influence of human penetration on avifauna is underlined. Strawiński (1971) divided the town into zones on the basis of birds occurrence. Research on synantropism of avifauna in towns was also made (Strawiński 1963, 1970, 1971, Tomiałojć 1970).

Hydrobiological studies in towns deal mainly with large lakes located close to the cities, usually heavy polluted. Smaller water bodies located within the town area, very often quite frequent, are investigated rarely and to a smaller extent.

Sukopp (1971) investigated in the West Berlin an influence of intense recreation on macrophytes of town water bodies. This author showed a strong reduction of macrophytes due to treading down and to landing of boats, and compiled the literature data on the influence of human activity on particular species of macrophytes.

In Warsaw the Czerniakowskie Lake was studied as far as bathymetry, thermics and flora were concerned (Sumiński, Jasińska and Kobendza 1925). Gryczka (unpubl.)[1] and Polesiak (unpubl.)[2] carried out phytosociological studies on several water bodies in Warsaw. Rutine data on the purity of water are gathered among the Warsaw water bodies for Wilanowskie Lake (Malanowski et al. 1974). Similar studies in other towns are also made, eg. on lake Malta in Poznań (Rosochowicz et al. unpubl.).

Present paper aimed at the characteristics of eulittoral of four water bodies located in Warsaw. The eulittoral was chosen for studies, as this zone is under the strong and direct influence of the surrounding areas. This zone is poorly known, except for the seas. Pieczyńska (1972), analysing the hydrological, physico-chemical and biological factors for lakes of Masurian Lakeland and the literature data summarized ecological studies of lake eulittoral.

In the present paper the eulittoral is defined (after Pieczyńska 1972) as a border zone between the water body and surrounding land, covering the area between the shore lines of yearly maximal and minimal water level, and the neighbouring area splashed or exposed during wave action. The area of this zone is conditioned by changes of water level and by the configuration of the shore terrace and near shore zone.

2. TERRAIN AND METHODS

There are numerous water bodies within Warsaw (about 70 with stagnant and about 10 with flowing water). They differ as far as their area, origin, age and way of their management are concerned. Natural water bodies (alongated oxbows located in the flood area of the Vistula River) and artificial (clay pits and amelioration ditches) can be distinguished.

[1] Gryczka T. 1969 – Plants and flora of water bodies of left bank Warsaw – Department of Systematics and Plant Geography, University of Warsaw, M. Sc. Thesis, 62 pp.

[2] Polesiak H. 1970 – Macrophytes associations of the area of Warsaw-Praga Południe – Institute of Botany, University of Warsaw, M. Sc. Thesis, 36 pp.

The studies were carried out in the eulittoral of four water bodies (Table I). Three of them, i.e. Czerniakowskie, Wilanowskie and Kamionkowskie Lakes are old oxbows of the Vistula River. Moczydło is an old clay pit presently made shallow and managed.

Table I. Characteristics of the investigated water bodies

Name	Surface area (ha)	Depth (m)		Length of the shore line (m)	Shore line development
		mean	maximum		
Czerniakowskie Lake	19.70*	2.61*	5.7*	4,200*	2.66*
Wilanowskie Lake	12.76**	1.62**	4.0**	3,300	2.79
Kamionkowskie Lake	6.35	–	2.1***	1,750	1.96
Clay pit Moczydło	0.75	–	–	690	2.25

*Acc. to Gumiński, Jasińska and Kobendza (1925); **acc. to Malanowski et al. (1973); ***acc. to Polesiak (unpubl.).

Wilanowskie Lake is characterized by a considerable flow. Czerniakowskie and Kamionkowskie Lakes have some inflowing amelioration ditches. Moczydło has no inflows.

For the evaluation of the influence of town agglomeration on these water bodies, their character and the area of surrounding lands were estimated. The area of their eulittoral was estimated. On the basis of measurement of changes of water level and translocation of the shore line the area of their eulittoral was estimated. The oxygen content was analysed in waters of the submerged eulittoral. Content of the organic matter in sediments and the distribution and biomass of macrophytes, and the composition, numbers and biomass of fauna were analysed in the whole eulittoral.

The data were collected between May 1973 and February 1974.

In each of the water bodies 10 sampling sites were established where samples were collected at three stations: on the shore line, in the submerged eulittoral and in emergent one, two latter one metre from the shore line. Water temperature was measured in the submerged part in the water column of 5–10 cm, also oxygen samples for Winkler method (Just and Hermanowicz 1964) were collected, two at each station 1–2 m apart. The sediments were collected by means of tubular sampler 5 cm wide in the submerged eulittoral, and by means of a 3 cm wide metal tube in the emergent one and on the shore line. Sediments were sampled to the depth of 10 cm.

Collected samples were subsampled for the determination of organic matter by ashing in a muffle furnace at 550°C for 5 h (Rybak 1969). The rest of sample was washed on a sieve with mesh size 0.42 mm, preserved in 4% formalin, sorted in macroscopic way, and all animals were determined and counted. Fresh weight of particular groups of organisms was estimated. Numbers and fresh weight of organisms were calculated per 1 m^2 of the eulittoral area.

In the eulittoral of Czerniakowskie Lake the meiobenthos (a size group of benthic organisms, differing from zoomicrobenthos by lack of *Protozoa* and *Rotatoria*) was also analysed. Samples for this purpose were collected at the same stations as macrobenthos samples. In the emergent eulittoral and on the shore line the samples were taken with a metal

tube 0.9 cm wide (to the depth of 4 cm)[3]. In the submerged eulittoral the macrobenthic samples were subsampled. Samples were preserved with formalin, washed on bolting cloth mesh size 50 μm, and organisms were counted under the microscope.

Macrophytes were sampled from frame (0.25 by 0.25 m) on each station of sampling site (4 samples). The overground parts were cut, the species determined, air dried and weighed. The biomass was calculated per 1 m^2 of the area.

A total of 120 macrobenthic samples, 25 meiobenthic and 68 samples of macrophytes were analysed, also 107 analyses of organic matter in sediments and 240 oxygen determinations were made.

3. RESULTS

3.1. Environmental studies

Lands surrounding the investigated water bodies are very differentiated (Fig. 1). There are parks, lawns, allotments, abandoned lands, buildings and even arable fields. The parks by themselves are considerably differentiated as shown by Strawiński (1971). The old parks with high trees, young ones recently established and lawns similar to grasslands can be distinguished. These areas differ in their influence on neighbouring water bodies (eg. in amount of leaf fall, degree of shading the water surface etc.). Also the intensive penetration of parks by people should be underlined.

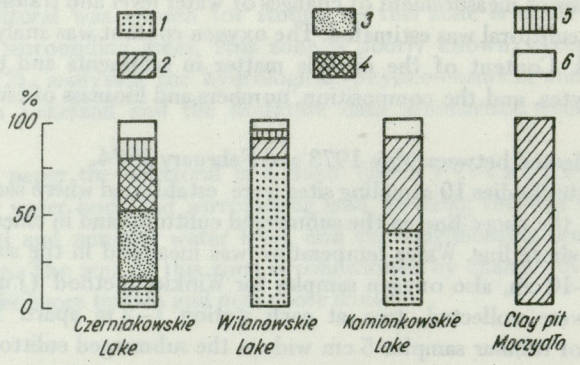

Fig. 1. The differentiation of lands surrounding investigated water bodies (in per cent of the shore line contacting various kinds of land cover)
1 – park, high trees, *2* – lawn, *3* – fields, *4* – allotments, *5* – abandoned lands, *6* – buildings

The area surrounding the Czerniakowskie Lake is the most differentiated. All kinds of distinguished land cover are there. The most uniform is the surrounding area of a clay pit Moczydło (lawn) (Fig. 7).

[3] As results from the literature data, about 90% of meiobenthic organisms occur in the upper 4 cm of sediments (Stańczykowska 1966, Prejs unpubl.).

The shores of studied water bodies contact the buildings only to a small extent (Fig. 1), however there is a possibility of the influence of even further settlements by surface and ground runoff, and mainly by intensive penetration of shores by inhabitants. This is clearly seen for such a small water body as Moczydło, surrounded by recently established park located within large residential area, and in the case of Kamionkowskie Lake located in the town centre.

Three of studied water bodies receive the wastes. Wilanowskie Lake is under their strongest influence, as there is a concentrated inflow from a small factory and an inflow from a polluted Powsinkowskie Lake (M a ł a n o w s k i et al. 1974).Czerniakowskie Lake has two inflows of communal sewage. Kamionkowskie Lake receives a small inflow from a coffee house.Moczydło does not receive any sewage.

The eulittoral of studied water bodies although changable, is less differentiated than the eulittoral of lakes situated out of towns (eg. Masurian lakes). Common types of lake eulittoral as eg. masses of dead reeds and near shore pools were not found. Stony eulittoral is sporadic in Kamionkowskie Lake and in the clay pit Moczydło. Eulittoral with great accumulation of detritus occurred only in Czerniakowskie Lake. In eulittoral of other lakes detritus occurrence was sporadic, it was not found in the eulittoral of Moczydło (Table II).

Table II. Types of the eulittoral of the investigated water bodies (in per cent of the length of the shore line)

Name	Eulittoral		Vegetation in the submerged eulittoral and on the shore line			Substratum			
	natural	transformed*	lack	scarce	dense	sand and clay	stones	mud	detritus
Czerniakowskie Lake	95	5	5	15	80	20	–	–	80
Wilanowskie Lake	5	95	15	65	20	1	–	90	9**
Kamionkowskie Lake	40	60	60	40	–	50	3	45	2**
Clay pit Moczydło	–	100	70	30	–	98	2	–	–

*Embankments of concrete, asphalt and logs; **values at station under the trees.

Also emergent vegetation, an important factor differentiating eulittoral, occurred scarcely only in the submerged parts of eulittoral of Czerniakowskie Lake.

Instead of being natural eulittorals, the shores of studied water bodies are changed by man: embankments are made of logs, concrete or asphalt.

An amplitude of water level changes for Polish lakes (without direct human influence) is for many years period within 30–50 cm (M i k u l s k i 1965). In studied area this amplitude was from 15 cm (Moczydło) to 33 cm (Czerniakowskie Lake) for the period June 1973–February 1974. Wilanowskie Lake, although the one with the greatest flow, has an amplitude of 21 cm (Fig. 2). Observations made in other periods allow to state that although presented values are for the shorter period than one year, they characterize well yearly changes of the water level. Considerable changes of the water level of studied water bodies suggest differentiated hydrological regime of areas of their localization.

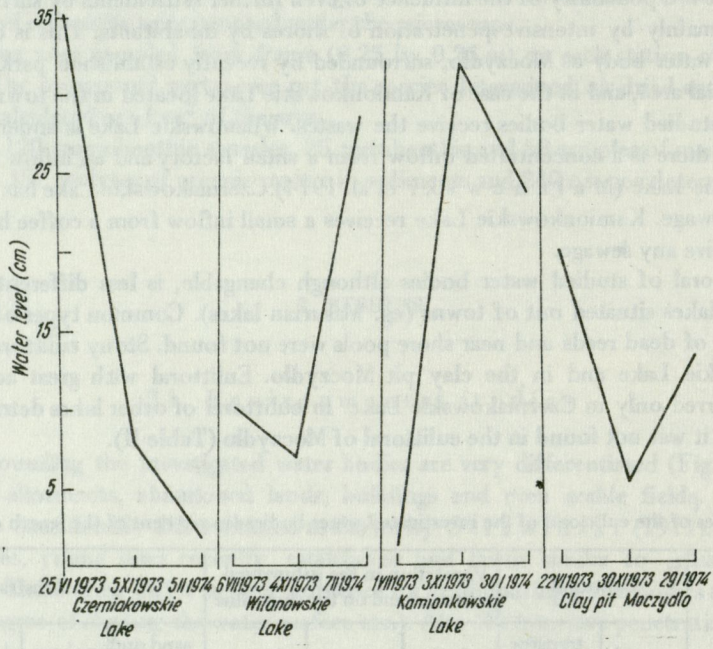

Fig. 2. Changes of water level in the investigated ater bodies

Changes of the water level and the configuration of shores and near shore zone result in movements of the shore line, thus decide directly about the area of eulittoral. On the east flat shores of Czerniakowskie Lake the shore line moved 2 to 4 m for the period June–November 1973, for Kamionkowskie Lake < 1 to 1.5 m. In other water bodies those changes were insignificant or not observed due to small changes of the water level (Moczydło) and shore embankments (Wilanowskie Lake and Moczydło).

Oxygen concentration in water is significantly controlled by biological processes (photosynthesis and respiration) and can be an index of these processes. Oxygen depletions are also indicators of water pollution.

The differences between the littoral as well as eulittoral zone and the other parts of a water body as far as oxygen concentrations are concerned, which in the near shore zone are differentiated even for short periods and especially in space, is often underlined. The smallest differentiation of the oxygen concentration in studied water bodies was found in autumn. Slightly higher differentiation and much lower oxygen concentrations were found in winter. During the summer oxygen concentrations were highly differentiated (Fig. 3). Especially strong differentiation occurred in the submerged eulittoral of Czerniakowskie and Wilanowskie Lakes. The lowest oxygen content, about 1 mg O_2/l occurred in Wilanowskie Lake in summer under a dense mat of pleuston plants over the bottom with thick layer of leaf litter. Great differences in the oxygen content in the eulittoral during the summer, in places 1–2 m apart, was characteristic for Czerniakowskie Lake, the one with eulittoral most differentiated and least transformed by man (Table II).

Investigated sediments are highly transformed by human activities. They are usually quite condensed. This in the emergent eulittoral results among the others from intense treading

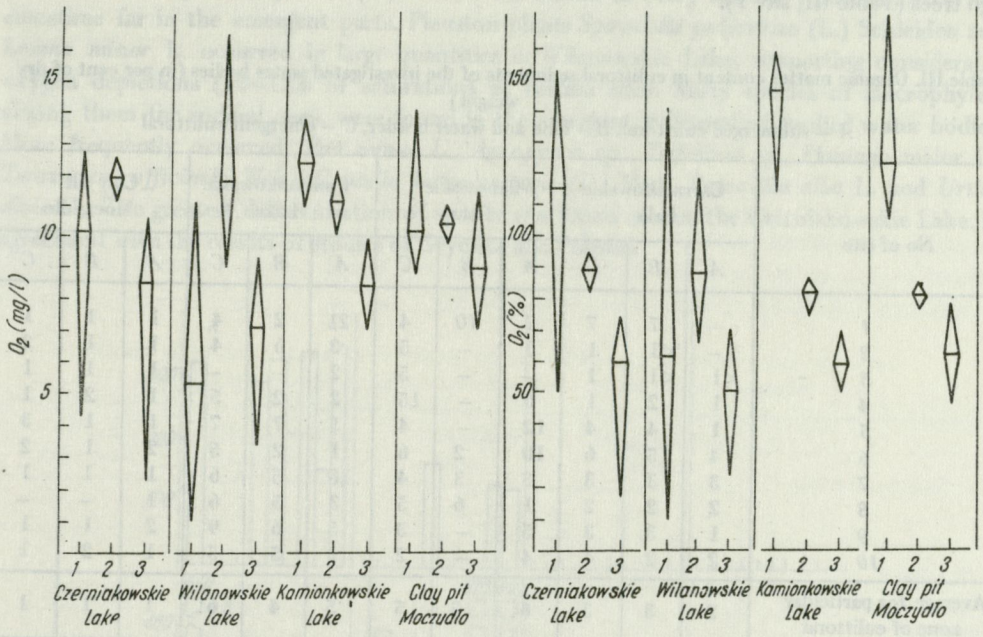

Fig. 3. Oxygen content (in mg/l) and oxygen saturation (%) in waters of submerged eulittoral at various sites in the investigated water bodies (average and range of variations)
1 – summer, *2* – autumn, *3* – winter

down, as also noticed by Gryczka (unpubl.). Some anthropogenic debris was frequently noticed in sediments: small bits of coal, glass, bricks and plaster, and large quantities of coal dust from chimney emission. R o s o c h o w i c z et al. (1965) also found the occurrence of coal dust in tripton of lake Malta, studied for pollution control in Poznań. Sediments with a major contribution of anthropogenic debris were found especially frequently in the eulittoral of Kamionkowskie Lake and Moczydło. Large quantities of plant origin detritus were found only in the submerged eulittoral of Czerniakowskie Lake, on the area overgrown by reeds. However, it forms there only a thin layer on the sandy substratum. Accumulation of leaf litter and tree branches was observed in the submerged eulittoral of Kamionkowskie and Wilanowskie Lakes in places with high trees growing close to water. It should be noticed that accumulation of debris of terrestrial and aquatic plants in the emergent eulittoral and on the shore line, common for Masurian lakes (P i e c z y ń s k a 1972) was never noticed. This results from small quantities of plants in eulittoral, limited wave action (due to small area of water body) and from periodical sweeping of shores in parks.

The content of organic matter in eulittoral sediments is very low and varies from < 1 to 21% of dry weight (Table III). For 32% of examined samples it was 1% or below that. High figures, found in eulittoral of Masurian lakes (P i e c z y ń s k a 1972) were never found. This is related with the lack or limited accumulation of organic matter, discussed above, and with the input of mineral products of human activities. The highest values of the organic matter content were found in Wilanowskie and Kamionkowskie Lakes (Table III). This could be due to the input of

allochthonous matter (leaf litter) from old densly overgrown parks. The maximum value (21%) was found in submerged eulittoral of Kamionkowskie Lake close to the shores overgrown by high trees (Table III, site *1*).

Table III. Organic matter content in eulittoral sediments of the investigated water bodies (in per cent of dry weight)
A – submerged eulittoral, *B* – land and water border, *C* – emergent eulittoral

No of site	Czerniakowskie Lake			Wilanowskie Lake			Kamionkowskie Lake			Clay pit Moczydło		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
1	–	7	7	7	10	4	21	2	4	1	1	1
2	–	<1	1	3	–	5	3	6	4	1	1	2
3	<1	<1	1	–	–	5	2	–	–	1	1	1
4	1	2	1	6	–	15	2	2	5	1	2	1
5	1	4	4	12	–	4	5	7	7	1	1	3
6	4	5	6	10	2	6	1	2	5	2	1	2
7	3	3	3	3	3	4	10	5	6	1	1	1
8	2	2	2	1	6	5	3	5	6	1	–	–
9	1	3	3	5	–	3	5	6	9	2	1	1
10	2	2	4	4	–	2	1	5	5	1	2	1
Average for particular zone of eulittoral	2	3	3	6	5	5	5	4	6	1	1	1
Average for the whole eulittoral	3			5			5			1		

The content of organic matter below 1% of dry weight was found in sandy eulittoral of Czerniakowskie Lake and in clay and sandy one of Moczydło. Low values in sediments at site *8* in Wilanowskie Lake and site *6* in Kamionkowskie Lake are due to the influence of flowing waters (from Powsinkowskie Lake and from Gocławski Canal), which does not allow the sedimentation of light organic debris.

The lowest content of organic matter was found in the eulittoral of a clay pit Moczydło. This is a recently established water body, artificialy made shallow with loads of ruins, without significant input of allochthonous matter (surrounded by lawn) (Fig. 1), and with small amounts of autochthonous organic matter(scarce macrophytes in the eulittoral). Czerniakowskie Lake has low content of organic matter in sediments apart from relatively small transformation of eulittoral overgrown with macrophytes (small part of afforested eulittoral and sandy substrate of river origin) (Gumiński, Jasińska and Kobendza 1925).

3.2. Biological studies

Gryczka and Polesiak (unpubl.) carried out phytosociological studies of Warsaw water bodies. Their results show the greatest abundance of macrophytes in Czerniakowskie Lake (36 species in five associations), smaller in Kamionkowskie Lake (18 species in four associations), and poor in Wilanowskie Lake (6 species in two associations). Clay pit Moczydło was not included in the above studies.

Analysis of sites in the eulittoral and shallow littoral of Czerniakowskie Lake showed frequent occurrence of *Phragmites communis* Trin., not found in other, more changed by man, water bodies. *Glyceria aquatica* (L.) Wahlb. was found in every studied eulittoral, occurring sometime far in the emergent parts. Pleuston plants *Spirodella polyrrhiza* (L.) Schleiden and *Lemna minor* L. occurred in large quantities in Wilanowskie Lake, supporting considerable oxygen depletions (10–12% of saturation) at certain sites. Many species of macrophytes, among them the ruderal ones, were found in the emergent eulittoral of studied water bodies. More frequently occurred: *Poa annua* L., *Agropyron* sp., *Trifolium* sp., *Plantago* maior L., *Taraxacum officinale* Web., *Capsella bursa-pastoris (L.)* Med., *Potentilla alba* L. and *Urtica dioica* L. The greatest differentiation of species was found around the Czerniakowskie Lake, in agreement with the results of studies of Gryczka and Polesiak.

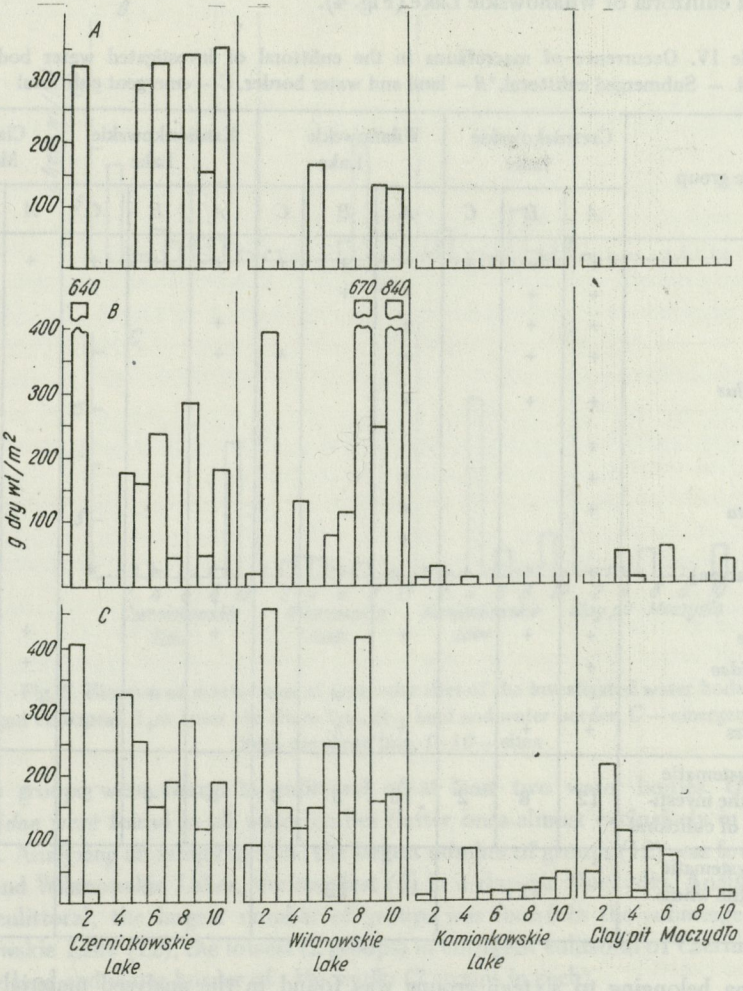

Fig. 4. Biomass of macrophytes at particular sites of the investigated water bodies
A – submerged eulittoral, 1 m from the shore line, *B* – land and water border, *C* – emergent eulittoral, 1 m from the shore line, *1–10* – sites

Macrophytes overgrow studied eulittoral unevenly. There is a complete lack of a dense belt of them in emergent eulittoral and on the shore line of Moczydło, Czerniakowskie Lake has 80% of its shore line overgrown by dense vegetation (Table II). But even there the anglers and sun bathers getting to water, or people landing boats made numerous paths among the reeds.

Plant biomass at particular sites is highly differentiated within each water body and among all of them. The lowest biomass was found in the eulittoral of Kamionkowskie Lake and of a clay pit Moczydło (Fig. 4). There is a lack of emergent vegetation in the submerged eulittoral of these water bodies, maximum biomass on the border line of land and water was 75 g/m^2 , in the emergent eulittoral – 217 g/m^2. The highest biomass was found at some sites in Czerniakowskie Lake (250 g/m^2 in submerged eulittoral) and in Wilanowskie Lake (470 g/m^2 in emergent eulittoral and 670 g/m^2 on the shore line). But in these lakes there are also places without vegetation: on sandy substratum in Czerniakowskie Lake, and on majority of sites in the submerged eulittoral of Wilanowskie Lake (Fig. 4).

Table IV. Occurrence of macrofauna in the eulittoral of investigated water bodies
A – Submerged eulittoral, *B* – land and water border, *C* – emergent eulittoral

Systematic group	Czerniakowskie Lake			Wilanowskie Lake			Kamionkowskie Lake			Clay pit Moczydło		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
Oligochaeta	+	+	+	+	+	+	+	+	+	+	+	+
Hirudinea	+	+		+	+							
Bivalvia	+	+		+			+					
Gastropoda	+	+		+		+	+		+			
Isopoda (Asellus aquaticus)	+	+		+								
Gammaridae	+											
Zygoptera	+			+								
Ephemeroptera	+			+								
Neuroptera				+								
Coleoptera (larvae)	+	+	+		+	+		+	+			
Trichoptera							+					
Chironomidae	+	+		+			+			+		
Ceratopogonidae	+									+	+	
Tipulidae					+			+	+			+
Diptera, others	+	+		+	+			+	+			+
Number of systematic groups in the investigated part of eulittoral	12	8	2	10	5	3	5	4	5	3	2	3
Number of systematic groups in the whole eulittoral	12			12			8			5		

Macrofauna belonging to sixteen groups was found in the analysed material (Table IV). *Oligochaeta* were met most frequently (in the whole eulittoral in each water body), *Gammaridae* and *Neuroptera* most seldom (former in submerged eulittoral of Czerniakowskie Lake, latter in submerged eulittoral of Wilanowskie Lake). Animals belonging to other

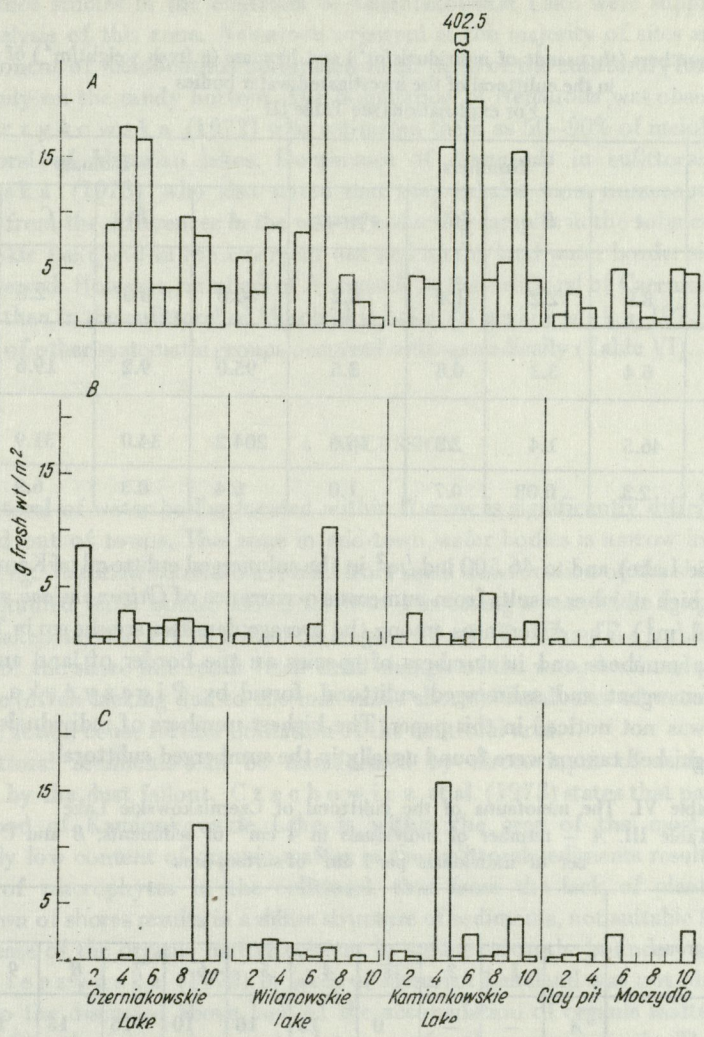

Fig. 5. Biomass of macrofauna at particular sites of the investigated water bodies
A – submerged eulittoral, 1 m from the shore line, *B* – land and water border, *C* – emergent eulittoral, 1 m from the shore line, *1–10* – sites

systematic groups were found in eulittoral of at least two water bodies. *Oligochaeta* and *Chironomidae* were found in all water bodies (latter ones almost exclusively in the submerged eulittoral). Analysing all sampling sites, the largest number of groups (12) was found in Czerniakowskie and Wilanowskie Lakes, the smallest (5) in a clay pit Moczydło. Analysing particular parts of eulittoral, the largest number of groups was found in the submerged eulittoral of Czerniakowskie Lake (12), the lowest (2 groups) in emergent eulittoral of Czerniakowskie Lake and on the land and water border of Moczydło (2 groups in each).

Macrofauna of eulittoral is highly differentiated within each of studied water bodies and among all of them (Fig. 5, Table V). The average numbers vary from 80 ind./m^2 of the eulittoral surface area (land-water border of Moczydło) to 8,900 ind./m^2 (submerged eulittoral

Table V. Average numbers (thousands of individuals/m^2) and biomass (g fresh weight/m^2) of macrobenthos in the eulittoral of the investigated water bodies
For explanations see Table III

Name	Numbers				Biomass			
	A	*B*	*C*	average	*A*	*B*	*C*	average
Czerniakowskie Lake	8.9	2.2	1.4	4.2	36.0	8.6	2.8	15.8
Wilanowskie Lake	6.4	3.3	0.8	3.5	95.0	9.2	19.6	41.3
Kamionkowskie Lake	46.5	1.4	2.8	16.6	204.2	34.0	31.9	90.0
Clay pit Moczydło	2.3	0.08	0.7	1.0	6.4	0.3	6.9	4.5

of Czerniakowskie Lake) and to 46,500 ind./m^2 in the submerged eulittoral of Kamionkowskie Lake. The latter high number results from numerous occurrence of *Chironomidae* at one of the sites (400,000 ind./m^2). The differences among the average densities are shown in Table V. An increase in fauna numbers and in numbers of species on the border of land and water, as compared with emergent and submerged eulittoral, found by Pieczyńska (1972) for Masurian lakes, was not noticed in this paper. The highest numbers of individuals and largest number of distinguished taxons were found usually in the sumberged eulittoral.

Table VI. The meiofauna of the eulittoral of Czerniakowskie Lake
A, *B*, *C* as in Table III. *A* – number of individuals in 4 cm^3 of sediments, *B* and *C* – number of individuals per 1 dm^2 of surface area

Systematic group		Site									
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Nematoda	*A*	–	–	0	15	10	10	15	15	10	0
	B	0	0	96	1,600	0	320	320	480	800	160
	C	0	0	0	160	3,360	4,800	3,360	4,320	5,280	2,560
Oligochaeta	*A*	–	–	0	0	0	0	0	0	0	0
	B	0	0	220	0	0	0	160	320	0	160
	C	0	0	0	0	0	320	160	0	0	0
Chironomidae	*A*	–	–	0	0	0	0	0	0	0	0
	B	0	0	32	0	0	0	0	0	0	0
	C	0	0	0	0	96	0	320	160	0	0
Tardigrada	*A*	–	–	0	0	0	0	0	0	0	0
	B	0	0	860	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0
Ostracoda	*A*	–	–	0	0	5	0	0	0	0	0
	B	0	0	0	0	0	0	160	0	0	160
	C	0	0	0	0	0	0	0	0	0	0

Meiobenthos studies in the eulittoral of Czerniakowskie Lake were supplementary to the faunistic analysis of this zone. *Nematoda* occurred at the majority of sites and being often a single component of meiobenthos dominated in all parts of the eulittoral (Table VI). They did not occur only on the sandy bottom. The domination of *Nematoda* was observed by Prejs and Stańczykowska (1972) who estimated them as 50–90% of meiobenthos numbers in the littoral of Masurian lakes. Dominance of *Nematoda* in eulittoral was found by Wasilewska (1973) who also stated that they inhabit most numerously the emergent parts. Apart from the differences in the way of collecting samples in the submerged eulittoral of Czerniakowskie Lake and in the emergent one and on the land-water border similar regularities could be observed. However, numbers of *Nematoda* in the eulittoral of Czerniakowskie Lake are much lower than in the eulittoral of Mikołajskie Lake (Wasilewska 1973).

Members of other systematic groups occurred only sporadically (Table VI).

4. DISCUSSION

The eulittoral of water bodies located within Warsaw is significantly different from one of lakes located out of towns. This zone in mid-town water bodies is narrow in the contrary to eulittoral of eg. Masurian lakes. This results from small translocation of the shore line, which in the case of studied water bodies moves for 0 to 4 m during a year, while in eg. Lake Śniardwy (Masurian Lakeland) for 1.9 to 296 m (average – 53 m) (Pieczyńska 1972). This small movements of the shore line result from small changes of the water level and poorly developed shore terrace (often lacking due to the man-made shores). Small area of water bodies and thus limited wave action couse further limitation of the eulittoral area.

The eulittoral sediments can be transformed by direct input of anthropogenic waste materials or by the dust fallout. Czechowicz et al. (1973) states that part of town in the neighbourhood of Kamionkowskie Lake is within the area of the most intense fallout. Exceptionally low content of organic matter in the eulittoral sediments results from a limited occurrence of macrophytes in the eulittoral, thus from the lack of plant detritus input. Treading down of shores results in a dense structure of sediments, not suitable for fauna.

The increase of the organic matter content in sediments on the boundary of land and water found by Pieczyńska (1972) in lakes of Masurian Lakeland was not observed. This can be related to the discussed above lack of the accumulation of organic matter in this part of eulittoral and to the input of mineral substances of anthropogenic origin. The eulittoral with concrete, asphalt or log embankments is an example of most intense anthropogenic influence on this part of a water body.

The best known kind of negative influence of human activity on a water body is an introduction of sewage there. According to Malanowski et al. (1974) the Wilanowskie Lake receives 67 m^3 per day of the industrial sewage with average BOD_5 of 650 mg O_2/dm^3 and with the load of 170 mg of solids/dm^3. Polluted waters flow also to the Wilanowskie Lake from Powsinkowskie Lake, which is polluted by Natoliński Canal (amelioration waters and sewage from town Natolin, purified by biological treatment plant). It was found that pollution of Wilanowskie Lake in 1973 was higher than permitted level (Malanowski et al. 1974). This results in the fact that waters of Wilanowskie Lake are most polluted as compared with other water bodies in Warsaw (Czechowicz et al. 1973).

Pollution of waters by organic substances causes a decrease of their oxygen content. The highest concentrations of oxygen in water (over 140% saturation) occurred more seldom in the

investigated water bodies than in the eulittoral of Masurian lakes (Pieczyńska 1972). Generally low oxygen concentrations in studied waters can result from limited wave action and small amounts of plants. This could also result from the inflow of allochthonous matter from the surrounding areas (although a distinct drop of the oxygen content in eulittoral close to sewage outlets was not observed).

The large differentiation of plant biomass on particular sites and frequent lack of macrophytes in the eulittoral results from treading down and mowing in park areas and from destruction by anglers and canoiests. This influence is significant, as boat renting is located by these water bodies (with exception of Wilanowskie Lake). Similar phenomena were observed by Sukopp (1971) for Lakes Havel in the zone of West Berlin, utilized for recreation. Transformation of sediments by inputs of large quantities of solid substances also limiting the occurrence of plants.

The eulittoral fauna is similarly to plants influenced by human activity. As the emergent eulittoral is best accessible for people, and here human activities are most concentrated (mowing, treading down etc.), macrofauna numbers and biomass were much lower in the emergent eulittoral and on the land water border than in the submerged parts.

The eulittoral transformed to the smallest extent among the studied water bodies was found in the Czerniakowskie Lake, the biggest one and located the farest from the city centre, and thus facing the weakest anthropogenic pressure. Lakes Wilanowskie and Kamionkowskie are located in old, frequently visited parks, and their eulittorals are strongly transformed. Clay pit Moczydło is a recently established water body of a small area, intensely used for recreation, with considerable transformation of eulittoral.

5. SUMMARY

The eulittorals of following water bodies located in Warsaw were studied: Lakes Czerniakowskie, Wilanowskie and Kamionkowskie and a clay pit Moczydło. The water temperature and oxygen content, organic matter content in sediments were studied, macrophytes, macrobenthos and meiobenthos were also analysed. Microbathymetric measurements were done and the surrounding area were characterized.

The oxygen saturation of waters (Fig. 3) and organic matter content in eulittoral sediments of studied water bodies (Table III) were much lower than in the eulittoral of Masurian Lakeland investigated by Pieczyńska (1972). Also a great variation of generally low biomass of macrophytes was found (Fig. 4). Macro- and meiobenthos were low in numbers and not much differentiated (Tables IV–VI, Fig. 5) in comparison with data for Masurian lakes. The eulittoral of studied water bodies was poorly differentiated, without a range of habitats typical for not transformed eulittorals in our climatic zone. Small translocations of the shore line result in a small area of studied zone.

The above mentioned features which differ the midtown water bodies from not transformed ones result from small area of the former and from the influence of surrounding areas highly transformed and utilized by man. Factors influencing the character of eulittoral are: treading down of soil which changes its structure, treading down and mowing of vegetation, sewage inflow, and enrichment of sediments with mineral substances, by-products of building, and with dusts of chimney emission. Utilization of water bodies for recreation causes an increase of the degree of eulittoral penetration by man. Old parks supply large quantities of leaf litter and branches which as allochthonous matter changes the character of sediments and of water layer above them.

Comparing particular water bodies a dependence of the degree of anthropogenic transformation of eulittoral on the area of these waters and on their location in relation to urbanized areas can be noticed. It was found, that the eulittoral of Czerniakowskie Lake, the largest one and located the farest from town centre has the eulittoral transformed to the smallest degree. The strongest transformation of eulittoral was found in a clay pit Moczydło, a small artificial water body highly controled and adjusted for recreation purposes (100% of man-made shores, made shallow with loads of ruins, with mowing of eulittoral vegetation).

6. POLISH SUMMARY (STRESZCZENIE)

Badaniami objęto pobrzeże następujących zbiorników wodnych położonych na terenie Warszawy: Jeziora Czerniakowskiego, Jeziora Wilanowskiego, Jeziora Kamionkowskiego i Glinianki Moczydło. W ich pobrzeżu prowadzono pomiary temperatury i zawartości tlenu w wodzie, zawartości materii organicznej w osadach, analizę makrofitów oraz makrobentosu i meiobentosu. Prowadzono pomiary mikrobatymetryczne oraz charakteryzowano tereny otaczające.

W porównaniu z pobrzeżem jezior Pojezierza Mazurskiego badanym przez Pieczyńską (1972) w pobrzeżu badanych zbiorników stwierdzono niższe stężenie tlenu w wodzie (fig. 3) i znacznie niższe zawartości materii organicznej w osadach (tab. III). Stwierdzono również duże wahania i ogólnie niskie wartości biomasy makrofitów (fig. 4). Makro- i meiobentos charakteryzują się niskimi liczebnościami i małym zróżnicowaniem (tab. IV–VI, fig. 5) w porównaniu z bentosem pobrzeża jezior mazurskich. Samo pobrzeże badanych zbiorników jest słabo zróżnicowane, brak w nim szeregu środowisk typowych dla nie przekształconych pobrzeży jezior naszej strefy klimatycznej. Niewielkie przesunięcia linii brzegowej sprawiają, że zasięg strefy pobrzeża w badanych zbiornikach jest niewielki.

Wymienione cechy, różniące pobrzeże zbiorników śródmiejskich od pobrzeża zbiorników nie przekształconych, są wynikiem zarówno niewielkich rozmiarów zbiorników, jak i wpływu otaczających terenów, silnie przekształconych i użytkowanych przez człowieka. Do rodzajów działalności mających wpływ na charakter pobrzeża badanych jezior zaliczamy: deptanie gleby, zmieniające jej strukturę, wydeptywanie i koszenie roślinności, doprowadzanie ścieków, wprowadzanie do osadów substancji mineralnych pochodzących z działalności budowlanej i emisji kominowej. Użytkowanie zbiorników dla celów rekreacji powoduje wzrost stopnia penetracji pobrzeża. Tereny starych parków są dostarczycielami dużych ilości materii allochtonicznej w postaci liści i gałęzi drzew, które zmieniają charakter osadów i warstwy wody nad nimi.

Porównując poszczególne zbiorniki zauważamy zależność stopnia antropogenicznego przekształcenia pobrzeża od wielkości zbiornika i od jego położenia w stosunku do terenów zurbanizowanych. Stwierdzono, że największe i położone najdalej od centrum Jezioro Czerniakowskie ma pobrzeże najsłabiej przekształcone. Pobrzeże przekształcone najsilniej występuje w Gliniance Moczydło, niewielkim, sztucznym zbiorniku silnie zmienionym i dostosowanym do potrzeb rekreacji (w 100% uregulowane brzegi, wypłycenie przez zsypanie gruzu, koszenie roślinności w pobrzeżu).

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Paper prepared by J. Stachowiak

AUTHOR'S ADDRESS:
Mgr Andrzej Kołodziejczyk
Zakład Hydrobiologii
Instytut Zoologii
Uniwersytet Warszawski
ul. Nowy Świat 67
00–048 Warszawa
Poland.