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Original Research

Taxonomic Composition of Macroinvertebrates in the Liwiec River and its Tributaries (Central and Eastern Poland) on the Basis of Chosen Physical and Chemical Parameters of Water and Season

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Abstract

The taxonomic composition of macroinvertebrates in the Liwiec River and its tributaries situated in central and eastern Poland was studied during three seasons (spring, summer and autumn). Simultaneously, physical and chemical parameters of water were measured. Water parameters were different in each study period. Macroinvertebrates samples collected in summer and autumn were much more diversified than the samples collected in spring. In the spring samples a greater EPT diversity was observed, while in the samples collected in autumn *Odonata, Coleoptera* and *Heteroptera* were more diversified. The values of the BMWP-PL index were slightly higher for the summer and autumn samples than for the spring ones. Correlation between the concentration of oxygen in water and the number of individuals of *Plecoptera* and *Trichoptera* larvae was noted. The negative correlation between the values of BOD_5, the concentration of nitrate ions and conductivity, and the number of macroinvertebrate families was observed. A negative correlation also was noted between nitrate and phosphate ion concentrations and the number of individual insect larvae.

Keywords: macroinvertebrates, BMWP-PL biotic index, physical and chemical parameters, seasons, lowland rivers

Introduction

A review of biological methods used in the monitoring of rivers in different countries of the world reveals that biotic indices with the use of macroinvertebrates are widely used in the assessment of river quality [1-8]. Also, the Water Framework Directive [9] specifying water protection policy of the EU countries, introduced the obligation of surface water biomonitoring with the use of macroinvertebrates.

The taxonomic composition of macroinvertebrates depends on a number of factors, e.g. water purity [10-12] or the season in which samples are collected [13-15]. The lifecycle of macroinvertebrates changes with the seasons of the year; it depends on chosen abiotic factors (temperature, water oxygenation, salinity, etc.) which also change throughout the year [16]. The biotic index BMWP-PL, a modification of the British BMWP score [17], was developed for the assessment of Polish rivers [18]. In the index

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insects and their larvae make up 80% of all macroinvertebrate families used in the bioassessment of river quality. Their number varies by season.

Fleituch et al. [11] tested the occurrence of macroinvertebrates and physical and chemical parameters of water in relation to a gradient of human impact on 12 chosen rivers of Poland. They indicated that insect-related metrics are the most promising tool in water quality assessment and that they may be recommended for extended studies on large numbers of Polish rivers.

Biotic indices based on macroinvertebrates' taxonomic composition are related to conditions characteristic of a given geographical region [19, 20]. The BMWP-PL index was prepared on the basis of research carried out on 49 rivers in Poland. The families of macroinvertebrates characteristic of the studied rivers were identified [18] and scored 1-10. Taxa sensitive to pollution, for example *Ephemeroptera, Plecoptera, Trichoptera* larvae, received higher scores, while taxa tolerant of pollutions, for example *Oligochaeta*, some families of *Diptera* (*Chironomidae*, *Culicidae*), *Hirudinea* (*Erpobdellidae, Hirudinidae*), *Crustacea* (*Asellidae*), received lower scores. The final result, which is the sum of scores of all taxa, allows for the classification of water to one of five quality classes [21].

For the needs of the biomonitoring of river quality with the use of macroinvertebrates, the Framework Water Directive [9] recommends that samples should be collected once a year. Thus, choosing the best season (spring, summer or autumn) for collecting macroinvertebrate samples from lowland rivers of Poland seems significant.

The main aims of the paper were formulated on the basis of the studies of invertebrate macrofauna and of chosen physical and chemical water parameters of the Liwiec River and its chosen tributaries situated in central and eastern Poland, carried out in the Department of Ecology and Environmental Protection of the University of Podlasie, beginning from 1998. They are:

- the analysis of the taxonomic composition of macroinvertebrates on the basis of chosen physical and chemical parameters of water,
- specifying which season is the best for collecting macroinvertebrate samples from lowland rivers of Poland,
- finding the relationship between chosen water parameters and the occurrence of macroinvertebrates.

Materials and Methods

The Liwiec River (126.2 km) and its three tributaries: the Muchawka (29.7 km), the Kostrzyn (54.4 km) and the Osownica (44.9 km) were the object of the research. The catchment area of the Liwiec River is 2779 km^2. It is situated in South Podlasie and Central Mazovia [22]. The river-head is located 160 m a.s.l. and the mouth of the river lays 85 m a.s.l. The mean river gradient is 0.6 ‰. The river flows into the Bug River at 42.7 km. The Liwiec

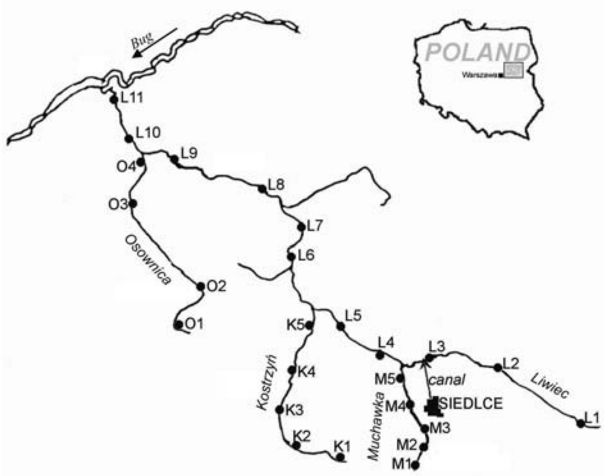

Fig. 1. Study area. L1–L12, O1–O4, M1–M5 – sampling sites.

is of the 4th order. According to the WFD the Liwiec River is classified to the 16th ecoregion. The catchment of the Liwiec River is classified as the big one [9]. It is located in agricultural areas, used mainly as pastures and arable lands. Grasslands comprise about 75% of watershed area, forests – 20% and wastelands – 5%. The land directly adjacent to the river is used mainly as meadows and pastures. The studies were carried out at 11 sampling sites at the Liwiec River, 5 sampling sites located at Kostrzyn and Muchawka and 4 located at Osownica. The sites located near the outlet of water from the sewage treatment plant were not taken into consideration in our studies. The bottom substrata at most of the studied sites was sandy or sandy-muddy, the mean depth from which the samples were collected did not exceed 0.5 m, and the flow velocity at most of the studied sites did not exceed 0.4m s^{-1}.

The Liwiec River was studied in 1998-2000 and 2002, the Muchawka and the Kostrzyn in 2005 and the Osownica in 2001. Biological samples and water for chemical analyses were taken at the same time, 3 times each year (in spring, summer and autumn); 58 samples were collected in each season. Totally, 174 samples of water for chemical analyses and 174 biological samples (macroinvertebrates) were taken.

In the water, according to the Polish standards, the following chemical parameters were determined: reaction, conductivity, dissolved oxygen, BOD_5, phosphate, nitrate, ammonium and calcium ion concentrations. Biological analyses included macroinvertebrate samples collected with semi-quantitative method, with a core sampler, from a bottom surface of about 1 m^2 (5 sub-samples were collected from each sampling site of a bottom surface of about 1m^2; each of the sub-samples from the surface of about 0.2m^2). The sampling procedure covered all the habitats at each site (including riffles, pools and different bottom substrata). The collected material was washed in a sieve of 0.5 mm mesh size. Taxonomic identification of macroinvertebrates was done to family, and in the case of *Oligochaeta* – to class. For taxonomic identification, various keys and guides were applied and consultations with authorities were carried out. The results of macroinvertebrate community analysis were used for biological assessment of the studied rivers' water quality, applying the BMWP-PL biotic index [18, 21].

To assess the differences between the parameters noted in each season the one-way analysis of variance (Anova) was applied. Statistically significant differences tested with Fisher's LSD (Least Significant Difference) test were accepted at $p<0.05$. Statistically significant differences between mean values of studied parameters were marked in the figures and tables with a, b and c letters. The relationship between physical and chemical, and biological metrics was evaluated with the use of Spearman's correlation coefficient. For statistical calculations *Statistica* (version 5.0) was used.

Results

Physical and chemical parameters of water changed in each study period. The lowest mean values: reaction (Fig. 2A), ammonium ion concentrations ($F=11.54$, $p<0.001$, Fig. 2E), and calcium ion concentrations (Fig. 2H), were noted in the autumn samples. The lowest mean values of oxygen concentration ($F=5.17$, $p=0.006$, Fig. 2C) and of BOD_5 ($F=4.43$, $p=0.013$, Fig. 2D), and the highest phosphate ion concentrations ($F=3.35$, $p=0.037$, Fig. 2G) were noted in the summer samples. The highest mean values of nitrate ion concentrations ($F=18.23$, $p<0.0001$, Fig. 2F) were noted in the spring samples.

The taxonomic composition of macroinvertebrates in the Liwiec River and its tributaries are presented in Tables 1A and 1B. 73 macroinvertebrate families and one *Oligochaeta* class were found. Macroinvertebrate samples collected in summer and autumn were much more diversified than the samples collected in spring ($F=3.47$, $p=0.033$, Fig. 3A). In spring samples the number of families found at each site ranged from 3 to 21 (the mean number of families – 11.0), in summer and autumn samples, respectively 4-23 and 3-24 families were noted (the mean number of families in each season were: 12.6 and 13.0). More individuals of macrofauna were found in the autumn samples than in the spring and summer ones; the differences were not statistically significant (Fig. 3B). Insects and their larvae outnumbered (61.9%) other individuals in the spring samples. In other study periods they comprised: 56.5% of all individuals in summer, 56.4% in autumn (Fig. 4). In biotic indices *Ephemeroptera, Plecoptera* and *Trichoptera* (EPT) larvae are given a relatively high number of scores. They comprised 33.7% of all insects and their larvae found in the spring samples, 22.0% found in the summer samples, and 27.0% noted in the autumn samples (Fig. 5). In the autumn samples lower numbers of *Ephemeroptera* and *Plecoptera*, and higher numbers of *Trichoptera* individuals were observed (Table 2). EPT were the least diversified in autumn ($F=7.16$, $p<0.001$, Fig. 3C), although *Ephemeroptera* larvae were the most varied in summer (Table 2). The number of insects and their larvae families (*Odonata, Heteroptera* and *Coleoptera*) was higher in autumn than in summer (statistically significant differences are given in Table 2). As far as other macrofauna taxa is concerned, a higher number of *Mollusca* families was found in autumn than in spring (differences in mean numbers were not statistically significant) (Table 3).

The families of macroinvertebrates dominant in number are shown in Tables 2 and 3. Their representatives were found at most of the study sites (Table 1A and 1B).

Values of the biotic index BMWP-PL were calculated on the basis of macroinvertebrate families. The following mean values of the BMWP-PL index were noted for each season: spring – 55.5±22.6, summer – 60.0±23.2, autumn – 60.8±20.5.

The occurrence of invertebrate macrofauna is determined by environmental conditions, e.g. chosen physical and chemical parameters of water. Calculated values of correlation coefficients (Table 4) show that the number of *Plecoptera* and *Trichoptera* larvae individuals was higher in the conditions of increased oxygenation. Increased values of BOD_5, concentration of NO_3^- and water salinity influenced negatively the number of macroinvertebrate families and lowered the values of the BMWP-PL index. Water salinity had statistically significant influence on the taxonomic diversity of insects and their larvae, e.g. *Ephemeroptera*. In the conditions of increased conductivity the families of *Insecta* and their larvae were less numerous. Statistically significant negative correlations between oxygen concentration and the number of *Hirudinea* and *Megaloptera* individuals were observed. The higher the concentration of calcium, the higher the number of *Hirudinea* individuals found in water.

Discussion

In order to assess the water of rivers with the use of macroinvertebrates it is important to collect samples typical of a given habitat, as well as to choose the season when macroinvertebrate fauna of a given river is the most diversified [14]). The community composition of macrofauna is determined by physical and chemical parameters of water (for example oxygenation, nitrate ion concentration) which undergo seasonal changes, and which might also be changed by the influx of pollution from the catchment [10, 16, 23, 24]. Taxonomic composition of macroinvertebrates, especially of insect larvae, in different seasons depends on the life-cycle of representative taxa. Natural (changing seasons) and antropogenic factors act together and influence benthic communities [16].

The analysis of physical and chemical parameters of waters of the studied rivers (Fig. 2) shows that the oxygenation of water is lower in summer when the temperature is higher than in other seasons. However, it is difficult to interpret changing values of other parameters of water in studied periods. They might be caused by the discharge of anthropogenic pollution from agricultural areas and nu-

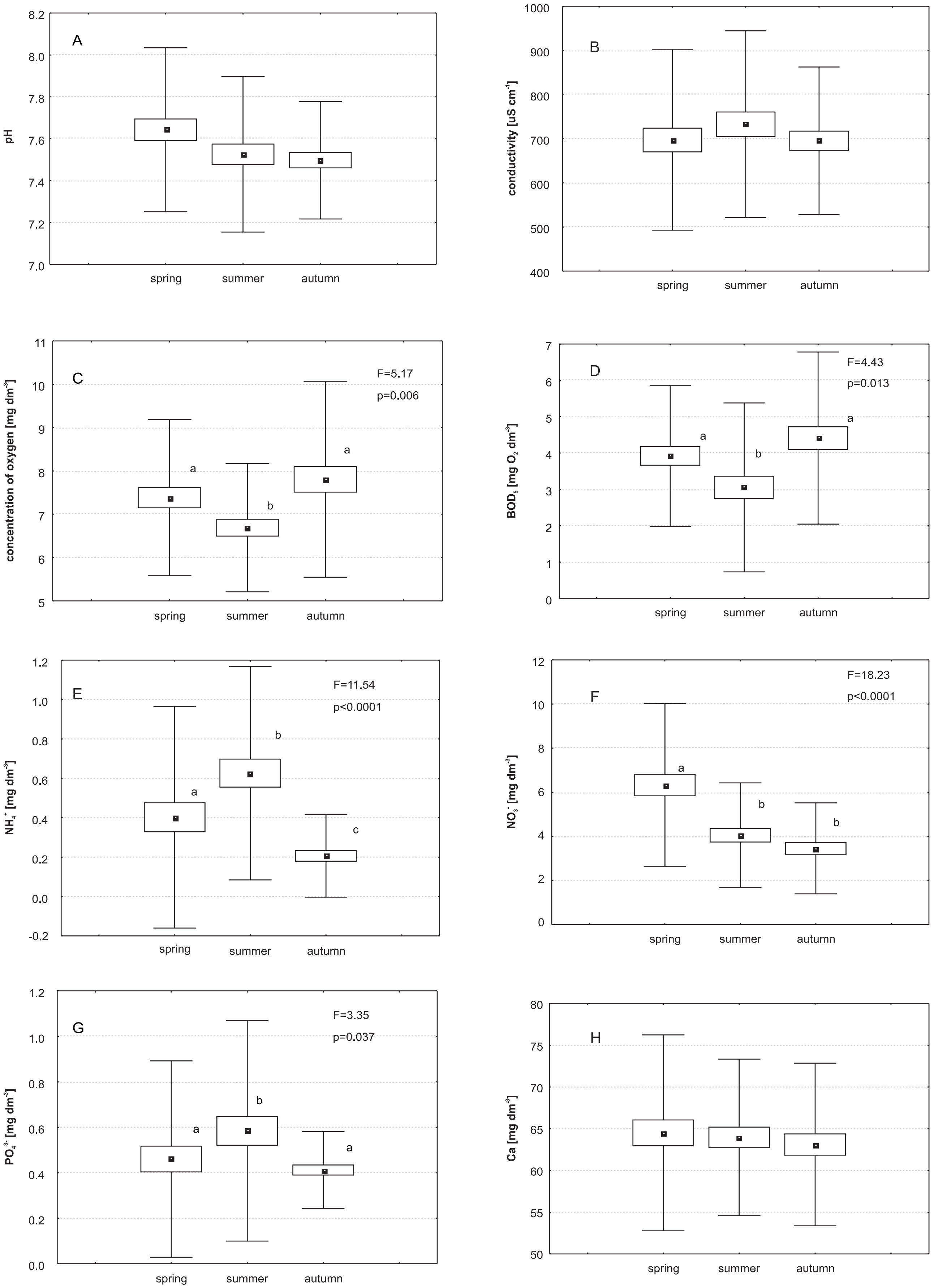

Fig. 2. Comparison of physical and chemical water quality parameters in three seasons. Each bar represents 58 samples (mean, SE and SD); (F – empirical value of F statistic, p – statistical probability).

Table 1A. Taxonomic composition of the Liwiec River water in 1998-2000 and 2002; (L1-L11 – sampling sites).

Taxa	Sites										
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
1	2	3	4	5	6	7	8	9	10	11	12
OLIGOCHAETA	+	+	+	+	+	+	+	+	+	+	+
HIRUDINEA											
Glossiphoniidae	+	+	+	+	+	+	+	+	+		
Erpobdellidae	+	+	+	+	+	+	+	+		+	+
Piscicolidae		+	+	+		+					
CRUSTACEA											
Asellidae	+	+	+	+	+	+	+	+	+	+	+
Gammaridae	+	+	+	+	+	+	+			+	+
Cambaridae		+		+	+	+	+				
INSECTA											
Ephemeroptera											
Siphlonuridae								+			
Ametropodidae		+									+
Baetidae	+	+	+	+	+	+	+	+	+		+
Heptageniidae					+		+	+	+	+	+
Caenidae	+	+	+	+	+		+	+	+	+	+
Leptophlebiidae	+	+	+				+		+	+	+
Ephemeridae	+	+	+			+	+	+			
Ephemerellidae		+						+	+	+	+
Potamanthidae						+					
Plecoptera											
Nemouridae	+	+					+	+	+		+
Perlodidae										+	
Odonata											
Calopterygidae	+	+	+	+	+	+	+	+	+	+	+
Lestidae						+					
Platycnemididae	+	+	+	+	+	+	+	+	+	+	+
Coenagrionidae			+	+			+	+			
Gomphidae				+	+	+	+	+	+	+	+
Aeshnidae				+		+					
Corduliidae	+		+		+	+	+				
Libellulidae				+			+				
Trichoptera											
Hydropsychidae	+	+	+	+	+	+	+	+	+	+	+
Polycentropodidae	+	+	+		+	+	+		+	+	+
Brachycentridae							+	+	+		+
Philopotamidae			+		+	+					+
Psychomyidae		+						+	+		
Limnephilidae	+	+	+	+	+	+	+	+	+	+	+
Goeridae	+	+									
Leptoceridae		+	+			+	+		+	+	+
Molannidae	+		+		+	+	+				
Odonatoceridae	+										
Sericostomatidae	+	+	+		+	+		+			

Table 1A. continued

Taxa	Sites										
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
1	2	3	4	5	6	7	8	9	10	11	12
Phryganeidae		+	+	+	+	+	+		+		
Hydroptilidae					+			+			
Megaloptera											
Sialidae	+	+	+	+	+	+	+	+	+	+	+
Coleoptera											
Donaciidae	+		+						+		
Dytiscidae	+	+	+	+	+	+	+	+	+	+	+
Gyrinidae	+	+	+	+	+	+			+	+	+
Helodidae	+										
Elmidae	+	+									
Haliplidae	+		+	+	+						
Hydrophilidae		+		+				+			
Curculionidae				+							
Heteroptera											
Notonectidae	+		+	+	+		+	+	+	+	+
Corixidae	+	+	+	+	+	+	+	+	+	+	+
Naucoridae		+			+						
Aphelocheiridae		+		+				+		+	
Nepidae			+	+	+	+	+	+	+	+	+
Veliidae					+						
Gerridae	+	+	+	+	+	+	+	+	+	+	+
Diptera											
Ephydridae								+			+
Athericidae						+		+	+	+	
Simuliidae		+	+	+	+			+	+	+	
Limoniidae		+							+	+	+
Tipulidae		+	+		+	+	+	+	+	+	+
Dixidae								+			
Muscidae		+									+
Tabanidae						+	+	+		+	+
Chaoboridae									+		
Chironomidae	+	+	+	+	+	+	+	+	+	+	+
MOLLUSCA											
Gastropoda											
Viviparidae	+		+								+
Valvatidae	+	+			+	+	+	+		+	
Bithyniidae	+	+	+	+	+	+	+	+	+	+	+
Physidae	+	+	+		+	+					
Ancylidae									+		
Lymnaeidae	+	+	+	+	+	+	+	+	+	+	+
Planorbidae	+	+	+	+	+	+	+				
Bivalvia											
Unionidae		+	+			+	+	+	+	+	+
Sphaeriidae	+	+	+	+	+	+	+	+	+	+	+

Table 1B. Taxonomic composition of the Muchawka (M1 – M5), Kostrzyn (K1 – K5) and Osownica (O1 – O5) rivers.

Taxa	Muchawka					Kostrzyn					Osownica			
	M1	M2	M3	M4	M5	K1	K2	K3	K4	K5	O1	O2	O3	O4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OLIGOCHAETA		+	+		+	+		+	+	+		+	+	+
HIRUDINEA														
Glossiphoniidae	+	+	+	+	+	+	+	+				+	+	
Erpobdellidae	+	+	+	+	+	+	+	+	+	+	+	+	+	+
CRUSTACEA														
Asellidae	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Gammaridae						+	+	+						+
INSECTA														
Ephemeroptera														
Baetidae	+					+			+	+		+	+	
Heptageniidae						+			+	+		+	+	+
Caenidae			+			+	+	+	+	+	+	+		+
Leptophlebiidae			+			+			+	+				+
Ephemeridae	+	+	+	+	+	+	+			+	+	+	+	
Plecoptera														
Nemouridae	+	+	+			+		+			+			
Odonata														
Calopterygidae		+	+		+	+		+	+	+	+	+	+	+
Platycnemididae				+					+	+				
Gomphidae					+			+	+	+	+	+	+	+
Corduliidae		+	+	+				+		+				
Trichoptera														
Hydropsychidae	+	+	+	+	+	+		+		+	+	+	+	+
Polycentropodidae				+	+			+	+	+			+	+
Psychomyidae	+												+	
Limnephilidae	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Leptoceridae											+			+
Molannidae	+	+	+	+	+					+				
Sericostomatidae				+		+							+	+
Phryganeidae		+	+		+	+								
Ryacophilidae				+										
Megaloptera														
Sialidae	+	+	+	+	+	+	+	+	+	+		+	+	
Coleoptera														
Donaciidae						+								
Dytiscidae	+	+	+	+	+	+				+				+
Gyrinidae						+		+	+	+			+	+
Helodidae													+	
Elmidae														+
Haliplidae									+					
Curculionidae												+		
Heteroptera														
Notonectidae										+				
Corixidae	+		+		+	+	+	+	+	+				

Table 1B. continued

Taxa	Muchawka					Kostrzyn					Osownica			
	M1	M2	M3	M4	M5	K1	K2	K3	K4	K5	O1	O2	O3	O4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aphelocheiridae	+	+	+	+	+			+		+		+		+
Nepidae				+			+		+					
Gerridae				+	+	+		+	+					
Diptera														
Athericidae											+		+	
Simuliidae						+			+		+	+	+	
Limoniidae				+		+					+	+	+	
Tipulidae					+			+			+		+	+
Tabanidae	+					+	+			+	+			+
Chironomidae	+	+		+	+	+		+	+	+	+	+	+	+
MOLLUSCA														
Gastropoda														
Viviparidae	+	+	+		+									
Valvatidae					+					+				
Bithyniidae	+	+	+	+	+				+					
Physidae	+	+	+	+	+				+				+	
Ancylidae						+			+					
Lymnaeidae	+	+		+	+	+		+		+	+	+	+	
Planorbidae	+	+	+	+	+									
Bivalvia														
Unionidae		+		+	+					+				
Sphaeriidae	+	+	+	+	+	+	+	+	+	+	+	+	+	+

merous villages located in the catchments of the studied rivers. Sites located near the outlet of water from sewage treatment plants (e.g. the site at the Liwiec River adjacent to Siedlce sewage treatment plant) [25] were not taken into consideration in this paper.

The studies showed that physical and chemical parameters are one of the factors which influence the composition of macroinvertebrates [10-12, 16, 26]. The occurrence of *Plecoptera, Trichoptera* and *Megaloptera* larvae was related to the oxygenation of waters. Increased salinity lowered the number of macroinvertebrate families, especially the number of insects and their larvae (Table 4) which comprise the dominant group of taxa in the BMWP-PL index applied for the assessment of river quality in Poland [18]. Higher temperatures in summer lower the oxygen concentration in water and, consequently, influence the number of "pure-water" taxa [14]. Thiëbaut et al. [12] showed that the taxonomic variety of macroinvertebrates, especially of EPT larvae, is strictly related to chemical parameters of waters. The three taxonomic groups of macroinvertebrates appeared to be more relevant to assess the influence of domestic pollution on river waters. In summer EPT larvae were the least numerous of all insect larvae of the studied rivers. Transformations experienced by insects larvae, e.g. *Ephemeroptera, Plecoptera, Odonata*, in summer make that in the samples collected in this season their number is reduced (Table 2). Thus, summer does not seem to be a good season to collect macroinvertebrate samples for biomonitoring [27]. In the studied lowland rivers the families of *Asellidae*, *Sialidae* and *Chironomidae* were quite numerous in summer. These taxa are not sensitive to low oxygen concentrations, which is confirmed by statistically significant correlation between the oxygen concentration and the number of *Sialidae*. The negative correlations between the oxygen concentration and the number of *Hirudinea* and between the calcium concentration and the number of *Hirudinea* were observed (Table 4), which is also confirmed by literature data [26] concerning environmental requirements of these taxa.

Chainho [16] describes a strong influence of water salinity on the occurrence of benthos macroinvertebrates. The results of this paper show that increased salinity of water lowers the number of families and the values of the BMWP-PL biotic index (Table 3). The number of insect larvae also lowers as values of nitrate and phosphate concentrations climb. Cao et al. [10], Fleituch et al. [11] and Harding et al. [24] had similar observations concerning

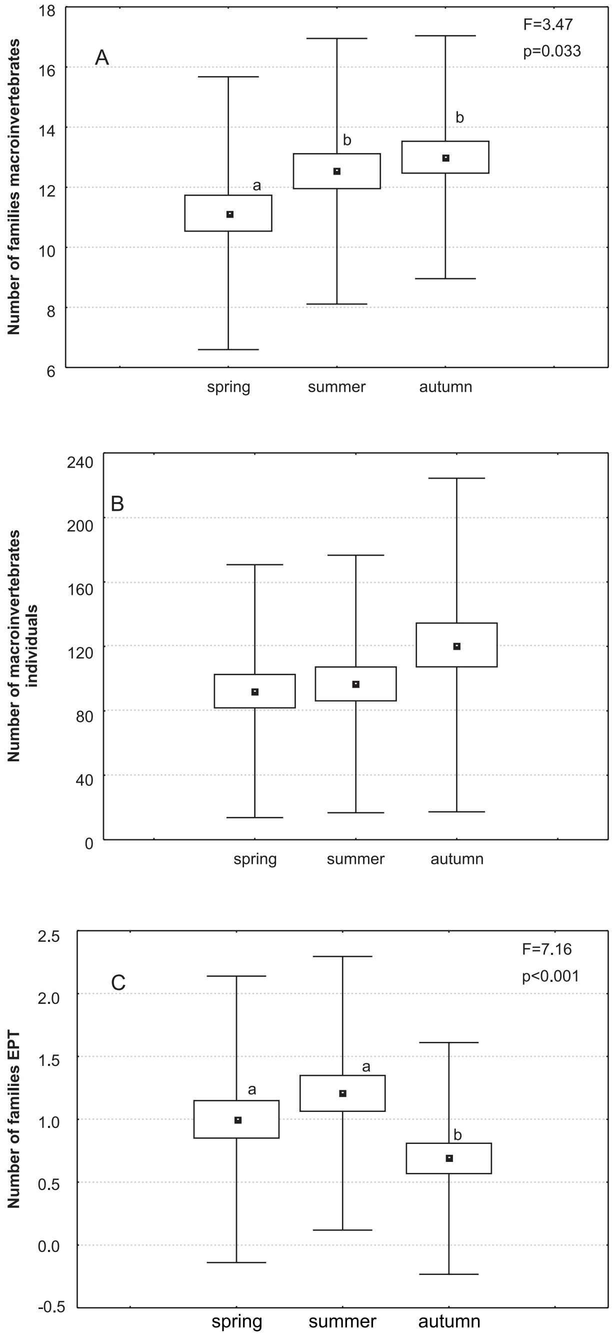

Fig. 3. Comparison of the number of families of macroinvertebrates (A), the number of individuals (B), the number of families of EPT (C) in three seasons. Each bar represents 58 samples (mean, SE and SD); (F – empirical value of F statistic, p – statistical probability).

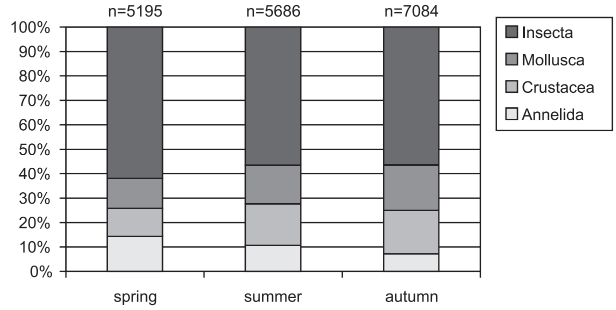

Fig. 4. Percentages of individuals in taxonomic groups in three seasons in the Liwiec River catchment.

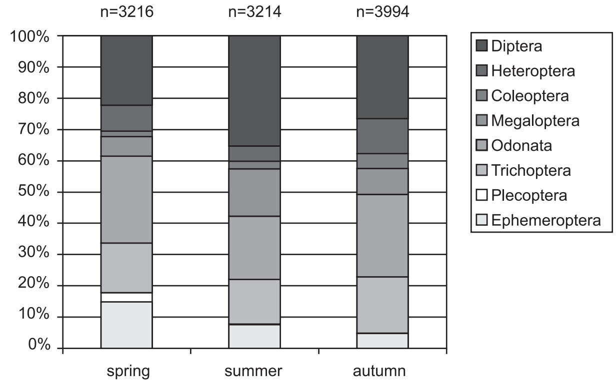

Fig. 5. Percentages of insect larvae individuals in three seasons in the Liwiec River catchment.

the influence of chemical pollution of waters on macroinvertebrates communities.

In the studied rivers the highest number of macroinvertebrates was noted in the samples collected in autumn (Fig. 3B), although the differences in numbers noted in various seasons were not statistically significant. Similarly, in the studies done by Cowell et al. [13] and Šporka et al. [14] macroinvertebrates were the most numerous in samples collected in autumn. Macroinvertebrates found in the autumn and summer samples collected for the needs of our research were more diversified in comparison with the ones found in the spring samples (Fig. 3A). *Odonata*, *Coleoptera*, *Heteroptera* and *Mollusca* (Table 2 and 3) were more varied in the autumn samples than in the spring ones. In the spring samples the greater (statistically significant) variety of *Ephemeroptera* and *Trichoptera* was noted in comparison with the autumn samples (Table 2).

The BMWP-PL index used in the assessment of rivers in Poland is a qualitative index; it does not require information concerning the number of macrofauna individuals. Qualitative indices are more sensitive in the evaluation of slightly and moderately polluted lowland rivers than diversity indices [10]. The EPT larvae found in the studied rivers were scored 5 to 7 in the 10 grade scale. Other families which were more diversified in the autumn than in the spring samples were scored as follows: *Odonata* 6 – 7, *Coleoptera* and *Heteroptera* – 5, *Bivalvia* 4 and 7, *Gastropoda* 3 – 7. The EPT families found in the studied rivers do not seem to be good indices of waters of high purity. It is confirmed by Koperski and Golub [28] who noted that EPT families of lowland rivers have certain bottom substrata and oxygen concentration requirements but they are not sensitive to biogenic concentration, which often indicates polluted environments. The phosphate ion concentration was the chemical factor that decided about the classification of the Liwiec River water [25] and of

Table 2. Mean numbers of individuals and the mean number of families of insects and their larvae in three seasons (F – empirical value of F statistic, p – statistical probability, ns – non significant).

Taxonomic group (number of families)	A – Mean numbers of individuals B – Mean number of families	Season of the year			Macroinvertebrates families dominant in number	F p
		spring	summer	autumn		
Ephemeroptera (9)	A	8.26±37.26	4.22±6.97	3.89±14.50	*Ephemeridae* 45.3% *Baetidae* 27.6%, *Caenidae* 15.1% *Heptageniidae* 7.0% *Ephemerellidae* 2.3%	ns
	B	0.93±1.01 ^{a}	1.27±1.19 ^{a}	0.69±0.91 ^{b}		F=4.76 p=0.009
Plecoptera (2)	A	1.58±4.77 ^{a}	0.12±0.79 ^{b}	0.03b±0.25 ^{b}	*Nemouridae* 95.1% *Perlodidae* 4.9%	F=5.68 p=0.004
	B	0.25±0.46 ^{a}	0.05±0.29 ^{b}	0.017±0.130 ^{b}		F=8.22 p=0.0003
Trichoptera (14)	A	8.84±17.48	7.87±13.86	14.68±14.17	*Limnephilidae* 61.5% *Hydropsychidae* 21.4% *Molannidae* 7.3%	ns
	B	2.03±.1.01^{a}	1.65±1.05 ^{b}	1.47±1.02 ^{b}		F=4.60 p=0.011
Odonata (8)	A	15.4±22.8	11.2±19.6	8.9±11.5	*Calopterygidae* 32.3% *Gomphidae* 19.7% *Platycnemididae* 11.4%	ns
	B	1.37±1.09 ^{a}	1.20±1.03 ^{a}	1.85±1.03 ^{b}		F=5.63 p=0.004
Diptera (10)	A	12.35±27.2	19.58±26.3	21.58±30.0	*Chironomidae* 82.8% *Simuliidae* 8.7%	ns
	B	1.49±02.22	2.03±2.49	2.12±4.18		ns
Coleoptera (8)	A	0.95±1.30 ^{a}	1.34±2.43 ^{a}	3.88±7.45 ^{b}	*Dytiscidae* 58.4% *Gyrinidae* 20.5% *Haliplidae* 5.8%	F=7.85 p=0.0007
	B	0.53±0.62	0.67±0.84	0.79±0.88		ns
Heteroptera (7)	A	4.59±22.7	2.65±7.52	9.16±22.9	*Corixidae* 64.0% *Notonectidae* 7.3% *Gerridae* 12.5%	ns
	B	0.47±0.68 ^{a}	0.82±0.94 ^{b}	1.13±0.92 ^{b}		F=9.37 p=0.0001
Megaloptera (1)	A	3.47±9.18 ^{a}	8.46±13.37 ^{b}	6.74±11.17 ^{b}	*Sialidae* 100%	F=4.69 p=0.010

Table 3. Mean numbers of individuals and the mean number of families of *Bivalvia*, *Gastropoda*, *Hirudinea* and *Crustacea*, and mean numbers of *Oligochaeta* in three seasons (F – empirical value of F statistic, p – statistical probability, ns – non significant).

Taxonomic group (number of families)	A – Mean numbers of individuals B – Mean number of families	Season of the year			Macroinvertebrates families dominant in number	F p
		spring	summer	autumn		
Bivalvia (2)	A	5,.79±9.96^{a}	11.08±25.90^{b}	12.07±29.36^{b}	*Sphaeriidae 91.7%* *Unionidae 8.3%*	F=3.34 p=0.037
	B	0.84±0.67	1.00±0.59	1.08±0.67		ns
Gastropoda (7)	A	5.14±11.13	4.39±5.83	8.12±13.32	*Lymnaeidae 55.3%* *Bithyniidae 27.0%* *Planorbidae 11.4%* *Physidae 3.4%*	ns
	B	1.19±1.15	1.67±1.39	1.57±1.13		ns
Crustacea (2)	A	10.34±15.81	16.66±28.93	21.68±36.34	*Asellidae 82.2%* *Gammaridae 17.8%*	ns
	B	0.89±0.67	1.14±0.78	1.10±0.73		ns
Hirudinea (3)	A	4.89±7.81	6.00±8.62	7.11±15.08	*Erpobdellidae 92.6%* *Glossiphoniidae 6.7%* *Piscicolidae 0.7%*	ns
	B	0.86±0.89	0.98±0.86	1.07±0.88		ns
Oligochaeta	A	7.96±17.98	4.50±17.54	1.68±3.70		ns

Table 4. The values of Spearman correlation coefficients (R) between some physical and chemical parameters of water and chosen biological parameters (p – significance level).

	O_2	BOD_5	NO_3^-	PO_4^{3-}	Conductivity	Ca^{2+}
Number of families		-0.2163 p=0.004	-0.1717 p=0.024		-0.1769 p=0.020	
BMWP-PL index value		-0.2028 p=0.007	-0.1665 p=0.029		-0.1686 p=0.027	
Number of macrofauna individuals			-0.2631 p<0.001			
Number of *Insecta* individuals			-0.2494 p=0.001	-0.1655 p=0.030		
Number of *Insecta* families					-0.2223 P=0.003	
Number of *Plecoptera* individuals	0.1906 p=0.012				-0.1693 p=0.026	
Number of *Plecoptera* families	0.1633 p=0.032					
Number of *Ephemeroptera* individuals						0.1894 p=0.013
Number of *Trichoptera* individuals	0.1704 p=0.025		-0.2362 p=0.002		-0.2376 p=0.001	
Number of *Megaloptera* individuals	-0.1906 p=0.012	-0.2215 p=0.003	-0.2494 p<0.001			
Number of *Hirudinea* individuals	-0.1704 p=0.025				-0.2714 p=<0.001	0.1783 p=0.019
Number of *Hirudinea* families	-0.1912 p=0.012				-0.2201 p=0.004	

other studied rivers. Statistical analysis showed that the increased concentration of phosphate ions limits the occurrence of insect larvae (Table 4).

The lowest values of the BMWP-PL index were calculated for the spring samples, the highest for the autumn samples. Differences in the BMWP-PL index values calculated for three sampling seasons were not statistically significant. The mean value of the BMWP-PL index allows for the classification of the studied rivers to the 3rd quality class [21].

Our research showed that autumn seems to be the best season to collect samples from lowland rivers such as the Liwiec and its tributaries; samples are more diversified and numerous in autumn than in, for example, spring. However, the most accurate results are obtained in studies done on the basis of samples collected three times a year, which is also indicated by literature sources [14].

Macroinvertebrate taxa found in the studied rivers are typical of many lowland rivers of Poland. A similar taxonomic composition was noted by Czerniawska-Kusza [29] in the Nysa Klodzka River, Kornijow and Lachowska [30] in the Bystrzyca Lubelska River, and Bis et al. [23] in the Grabia River. In order to verify seasonal changes in macrofauna occurrence similar studies of other rivers from different geographical regions of Poland should be carried out. Cowell et al. [13] indicates that in such an analyses rivers of similar hydrology should be compared.

Summary

1. In each study period differences in the values of measured physical and chemical parameters were noted.
2. Macroinvertebrates were more diversified in the samples collected in summer and autumn than in the spring ones; the summer and autumn samples were richer in *Odonata*, *Coleoptera*, *Heteroptera* and *Mollusca*. EPT larvae were more diversified in spring samples than in the autumn ones.
3. Statistically significant correlations between chosen physical and chemical parameters of water and the taxonomic composition of chosen macroinvertebrate communities were identified.
4. The results of the studies show that samples used for the biotic assessment of the quality of waters of moderately polluted lowland rivers typical of central and eastern Poland should be collected in autumn, not spring.

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