COMPARISON OF WATER QUALITY IN THE TYWA RIVER, A RIGHT-BANK TRIBUTARY OF THE ODER RIVER, BASED ON BENTHIC FAUNA IN 1997 AND 2007

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Abstract

Macrobenthos fauna samples were collected at seven sites on the Tywa River, a right-bank tributary of the Oder River, in 1997 and 2007. After taxonomic identification was made to the rank of family, the waters of this stream were classified qualitatively with the BMWP-PL index method. Data analysis confirmed that a change in the structure of qualitative domination had occurred, namely that the dominant benthic macroinvertebrate families in 1997 had been replaced by environmentally more demanding families that score higher points with the BMWP-PL method. Improvement in water quality was noted at all of the sampling sites, which indicates that changes in the agricultural methods applied in the catchment area and the sewage management policies of local authorities had had more than a slight impact.

Keywords

River water quality, macrozoobenthos, BMWP-PL index, biodiversity

Introduction

European Union member states are required by Directive 2000/60/EC of October 26, 2000 to "...ensure the establishment of programmes for the monitoring of water status in order to establish a coherent and comprehensive overview of water status within each river basin district:..." (Directive 2000/60/EC Article 8, item 1). This suggests that surface waters should be evaluated using studies and methods

based on biological elements and supplemented with physicochemical and hydromorphological studies.

Biological elements that can define the ecological and chemical state of ecosystems are bioindicators. These are flora and fauna organisms, the lack or presence and abundance of speaks of the abiotic properties of a studied ecosystem [1]. In view of their biology, benthic macroinvertebrates are especially suitable as bioindicators. De Pauw and Hawkes [2] contend that biological water quality control is based on zoobenthos in two-thirds of systems. Currently, mainly biotic indexes based on analyses of benthic macroinvertebrates are applied. These are based on quantitative species diversity data combined with qualitative data regarding their ecological tolerance. The first biotic method used to evaluate water quality was developed for;] the Trent River in Belgium in 1964, and was known as the Trent Biotic Index (TBI) [3]. Modifications to this system led to the creation of many biotic water evaluation systems that were developed in various countries, including the the Extended Biotic Index (EBI) in Italy [4], the Belgian Biotic Index (BBI) in Belgium [2], the Danish Stream Fauna Index (DSFI) in Denmark [5], and the Biological Monitoring Working Party (BMWP) and Average Score Per Taxon (ASPT) systems in Great Britain [6]. Studies were initiated in 1993 at the Institute for Environmental Protection in Warsaw, Poland to adapt the evaluation systems and water classifications to the requirements of the Water Framework Directive. Over the course of a few years, various research institutions conducted studies on 49 rivers located throughout Poland. These studies resulted in a modified version of the British BMWP system that can be used in Poland and is known as BMWP-PL [7]. However, difficulties were encountered in comparing results because of the distribution of species, varied river biotypology, and geographical differences. This provided the impetus for initiating work aimed at unifying study procedures and the evaluation of results. One example is the STAR project, the aim of which was to develop a standard system for the ecological evaluation of water quality through the application of a variety of study methods to a varied group of aquatic organisms. Another aim of this project was to evaluate precision and identify possible errors in the study methods

investigated as well as to recommend procedures that should be applied. These procedures were developed by the AQEM/STAR consortium after consulting international publications and conducting studies at 742 sites in 13 countries and is referred to as Multi-Habitat Sampling [8]. Despite these measures, methods in Poland for determining the status of waters using biotic organisms linked with benthos, and precisely macroinvertebrates, remain to be fully developed and sanctioned by law; thus, the debate regarding their selection continues.

The aim of the current study was to evaluate the quality of the waters of the Tywa River using the BMWP-PL method based on classifications of macrobenthos fauna families. The classification was based on studies conducted in 1997 and 2007. The research thesis comprised comparing the results and identifying the causes of any changes in the quality of the Tywa River waters that occurred over the course of the decade. As mentioned previously, since there is presently no binding method for evaluating river water quality using macrobenthos fauna, it was decided to use BMWP-PL, which is one of the biotic indexes in the Decree of the Minister of the Environment of February 11, 2004 (Journal of Laws No. 32, item 284). The justification for this was that in 1997 regulations did not yet permit classifying river waters based on benthic organisms; by 2008 they still had not been taken into consideration because of the lack of a unified method.

The Tywa River is characterized by its distinct, deeply cut, meridionally aligned sub-glacial trough [9]. The surface area of its catchment basin is 256.4 km^2, and it is located in the western part of the Szczecin Lowland. The terrain in the vicinity of the Tywa River was shaped during the period of the Oder lobe retreat that filled the Cretaceous Szczecin aquifer as the ice sheet retreated during the Baltic glaciation period. The landscape here is quite varied in terms of altitude [9, 10]. The Tywa River is a small stream with a bed width ranging from 1 m at its source to 6 m in the mid-section of its course. The maximum mean depth is 0.79 m in its mid-course, while the minimum is 0.18 m in the section close to the source. Variations in flow rate are significant ranging from 0.14m/s to about 0.82 m/s. The mean flow is approximately 0.4 m/s [11]. The source of the river is located at approximately 70 m

above sea level in the vicinity of the town of Góralica, while its mouth flows into the East Oder-Regalicy near Gryfina through the post-cooling water canal of the Dolna Odra Power Plant. The total length of the Tywa river valley is 48.5 km. It is characterized by a relatively steep gradient and strong current, which in the past prompted its intense exploitation; a current inventory recorded 29 damming constructions (primarily small weirs and thresholds built for drainage or to power now-defunct mills). Currently, water is dammed for fish ponds and for seven small hydroelectric power plants. No intensive drainage or regulation work is performed in the river valley [9, 11].

Materials and methods

The Tywa River valley is primarily agricultural; 68.42% of its surface area is arable land, 20.94% are forests and forest lands,7.84% are grasslands, and 2.8% waters. The forests are located primarily in the mid and lower drainage basin, and most of the grasslands are located in the upper drainage basin while arable lands are distributed equally throughout the entire area of the basin [11]. The bed of the River Tywa is located in terrain covered by glacial till, and only in the lower course is it covered by glacial sands. The diversity of the terrain impacts the varied gradient that ranges from lazy stream to mountain stream with gorges. The terrain in the upper segment in the vicinity of the source is marshy, and the following flow-through lakes are located in this area – Trzcińskie Małe, Dołgie (Dłużyna), Leśne (Grzybno), Grodziskie, Długie, Dłużec, Mostowe, and Święte (Kępińska-Kasprzak and Wachowiak 1997). There are 19 villages and towns in the Tywa River basin, and the area includes the four municipalities of Banie, Gryfino, Trzcińsko Zdrój, and Chojna. The primary sources of discharge and treatment facilities are located in Banie, Grzybno, Rożnowo. Run-off from fields and fish farms in the vicinity of the river mouth also pose threats [11].

Samples of macrobenthos fauna were always collected with a bottom scraper measuring 0.25 x 10 cm from a segment 1 m in length; this permitted determining the density of organisms in 1 m^2. The samples were collected in late spring on April 26, 1997 and on May 29, 2007 at seven sites located along the length of the stream from

its source to its mouth.

The samples were processed to identify the collected materials to the rank of family, and the data obtained was used to evaluate the state of the waters based on the BMWP-PL modified biotic index and the Margalef diversity index [12, 13, 14, 15]. The standard BMWP – PL table, in which each macrobenthic fauna family is assigned a determined number of points (from 1 to 10) depending on their sensitivity to pollution, was used. The final BMWP-PL index score is obtained by adding up points (the maximum is 100), the result of which corresponds to the following water quality classes: class I > 100 points; class II – 70-99 points; class III – 40-69 points; class IV – 10-39 points; class V < 10 points. The values of the biodiversity index are calculated according to the modified Margalef diversity index expressed with the formula d=s/logN (s – number of taxa in the family rank, N – number of all individuals), and the value of d obtained corresponds to a five-class water quality scale (class I > 5.50; class II – 4.00-5.49; class III – 2.50-3.99; class IV – 1.00-2.49; class V - <1.00). The final classification is made after calculating the values of these two indexes (BMWP-PL and d) according to the following principles:

- if the result of water classification based on the values of the BMWP – PL and biodiversity indexes are identical, the final classification is that of the two indexes;
- if the results do not correspond (differ by one class), then the final classification is that which corresponds to the lower class;
- if BMWP-PL and d differ by two classes, the final classification is the mean value.

The final water classifications correspond to five quality classes: class I – very clean water; class II – clean water; class III – slightly polluted water; class IV – polluted water; class V – very polluted water.

Results

Site 1

At this site in 1997 six families and one class were considered in the BMWP-PL classification (with points from 2 to 7), and in 2007 there were eight families (with points from 3 to 7).

Table 1. Evaluation of Tywa River water quality according to the BMWP-PL index at site 1 in 1997 and 2007 (*families not scored on the BMWP-PL index)

Family	Number of BMWP-PL points	1997		2007	
		Density	Percentage share in samples	Density	Percentage share in samples
		[indiv./ m2]	%	[indiv. /m2]	%
Elmidae	7			8	1,74
Limnephilidae	7	15	1,41		
Empididae	6			8	1,74
Simulidae	6	504	47,24	232	50,43
Gammaridae	6	192	17,99	124	26,96
Haliplidae	5			4	0,87
Valvatidae	4			4	0,87
Sphaeriidae	4	30	2,81		
Glossiphoniidae	3	15	1,41		
Chironomidae	3	133	12,46	28	6,09
Asellidae	3			52	11,30
Oligochaeta	2	74	6,94		
Tabanidae	*	15	1,41		
Tipulidae	*	89	8,34		
Benthos density at site “N”		1067		460	
Number of all families at site		9		8	
Number of all families at site that are assigned points on the BMWP-PL “s”		7		8	
BMWP-PL index		31		40	
Quality class according to BMWP-PL		IV		III	
Diversity index „d”		2,31		3,00	
Quality class according to „d"		IV		III	
Final BMWP-PL quality class after verification		IV		III	

The most abundant families in both 1997 and 2007 were *Simuliidae* larvae and pupae (47.24% of the sample at a density of 504 indiv./m^2 and 50.43% of the sample at a density of 232 indiv./m^2 in 1997 and 2007, respectively) and *Gammaridae* (17.99% of the sample at a density of 192 indiv./m^2 and 26.96% of the sample at a density of 124 indiv./m^2), which are scored relatively highly with six points (Table 1). Only the family *Limnephilidae* received higher points in 1997, as did the family *Elimidae* in 2007. The occurrence of these representatives of families that are susceptible to pollution did not impact the final evaluation because of the occurrence of pollution-resistent families with low scores that mainly included *Glossiphoniidae*, *Chironomidae*, and *Oligochaeta* in 1997, and *Chironomidae* and *Assellidae* in 2007 (Table 1). This fauna at this site is moderately diverse (biodiversity index in 1997 was 2.31 and in 2007 – 3.00) with a predominance of fauna that are typical of polluted and slightly polluted waters (the BMWP-PL index was 31 in 1997 and 40 in 2007). The final evaluation of the Tywa River waters at this site was classified as class IV in 1997 and as class III in 2007, which indicated improvement from 1997 (Table 1).

Site 2

At this site in 1997 one family with low points and one class were considered in the BMWP-PL classification (with 2 and 3 points), while in 2007 there were 11 families with higher points (from 3 to 7) (Table 2); one of the families that was noted in both years was *Chironomidae.* In 1997 this was the most numerous family (92.33% of the entire sample at a density of 1421 indiv./m^2), while in 2007 *Chirinomidae* comprised 30% of the sample (at a density of 264 indiv./m^2). The fauna at the site in 1997 was weakly diversified (the biodiversity index was just 0.63), and fauna indicative of highly polluted waters were predominant (the BMWP-PL index was 5) (Table 2). The number of families occurring in 2007 increased (the biodiversity index was 3.74), and the predominant fauna were typical of slightly polluted waters (the BMWP-PL index was 63) (Table 2). The water quality in 2007 exhibited distinct improvement from that in 1997 when the Tywa River waters were classified as class V, with the 2007 classification indicating waters of class III

(Table 2).

Table 2. Evaluation of Tywa River water quality according to the BMWP-PL index at site 2 in 1997 and 2007 (*families not scored on the BMWP-PL index)

Family	Number of BMWP-PL points	1997		2007	
		Density	Percentage share in samples	Density	Percentage share in samples
		[indiv./ m2]	%	[indiv./ m2]	%
Caenidae	7			8	0,91
Ephemerellidae	7			8	0,91
Limnephilidae	7			8	0,91
Baetidae	6			20	2,27
Bythiniidae	6			4	0,45
Empididae (l.)	6			12	1,36
Gammaridae	6			8	0,91
Simulidae (l.+poczwarka)	6			68	7,73
Hydropsychidae	5			472	53,64
Sphaeriidae	4			8	0,91
Chironomidae	3	1421	92,33	264	30,00
Oligochaeta	2	59	3,83		
Dixidae	*	44	2,86		
Chaoboridae	*	15	0,97		

Benthos density at site “N”	1539	880
Number of all families at site	4	11
Number of all families at site that are assigned points on the BMWP-PL “s”	2	11
BMWP-PL index	5	63
Quality class according to BMWP-PL	V	III
Diversity index „d”	0,63	3,74
Quality class according to „d"	V	III
Final BMWP-PL quality class after verification	V	III

Site 3

In 1997 seven families and one class (Oligochaeta) were confirmed at this site and considered in the BMWP-PL classification (with points from 2 to 10), and in 2007 there were as many as 15 such families noted (with points from 2 to 10) (Table 3). In 1997, Oligochaeta were the most abundantly represented comprising

64.65% of the sample at a density of 1273 indiv./m^2, but which received only two index points.

Table 3. Evaluation of Tywa River water quality according to the BMWP-PL index at site 3 in 1997 and 2007

Family	Number of BMWP-PL points	1997		2007	
		Density	Percentage share in samples	Density	Percentage share in samples
		[indiv./ m^2]	%	[indiv ./m^2]	%
Leptoceridae	10	178	9,04	16	0,33
Caenidae	7			12	0,25
Dreissenidae	7	74	3,76		
Unionidae	7	44	2,23	40	0,82
Simulidae (l.+poczwarka)	6			4	0,08
Neritidae	6			136	2,79
Ecnomidae	6			32	0,66
Polycentopodidae	6			28	0,58
Bythiniidae	6			28	0,58
Hydrobiidae	5			4120	84,63
Hydropsychidae	5	15	0,76		
Sphaeriidae	4	148	7,52	44	0,90
Valvatidae	4			12	0,25
Glossiphoniidae	3	30	1,52		
Chironomidae	3	207	10,51	364	7,48
Asellidae	3			4	0,08
Lymnaeidae	3			4	0,08
Culicidae (p.)	2			24	0,49
Oligochaeta	2	1273	64,65		
Benthos density at site “N”		1969		4868	
Number of all families at site		8		15	
Number of all families at site that are assigned points on the BMWP-PL “s”		8		15	
BMWP-PL index		41		78	
Quality class according to BMWP-PL		III		II	
Diversity index „d”		2,43		4,07	
Quality class according to „d"		IV		II	
Final BMWP-PL quality class after verification		IV		II	

However, in 2007, the decisively strongest group of organisms at this site was

Hydrobiidae (5 points) – comprising 84.63% of the sample at a density of 4120 indiv./m^2 (Table 3). It is noteworthy that the highly-scored family *Leptoceridae* (10 points) was noted in both years, but in 1997 it could not increase the evaluation much because of the presence of families with lower point scores (*Glossiphoniidae*, *Chironomidae*, Oligochaeta) (Table 3). The comparison of the BMWP-PL indexes of 1997 and 2007 indicates there was a shift in the domination structure of the fauna; namely, in 1997 the fauna was typical of slightly polluted water (the BMWP-PL index was 41), while in 2007 it was characteristic of clean water (the BMWP-PL index was 78) (Table 3). Biodiversity increased as did benthos abundance nearly twofold (the biodiversity index increased from 2.43 to 4.07, while density increased from 1969 to 4868 indiv./m^2) (Table 3). The final evaluation of the Tywa River waters at this site in 2007 classified them as class II, which is a clear improvement of two quality categories in comparison to that in 1997 (class IV) (Table 3).

Site 4

At this site in 1997 just one family and one class were taken into consideration in the BMWP-PL classification (with points of 2 and 3); however, in 2007 13 families were noted (with points from 3 to 7) (Table 4). In 1997 the fauna comprised *Chironomidae* (79.57% of the sample with a density of 518 indiv./m^2) and Oligochaeta (20.43% at a density of 133 indiv./m^2), which are typical of waters that are heavily polluted (the BMWP-PL index was only 5) (Table 4). The predominance of fauna that is characteristic of slightly polluted waters was noted by 200 (the BMWP-PL index was 70). In comparison to that in 1997, biodiversity increased at this site (the biodiversity index was 4.08, in 2007, while in 1997 it had been just 0.71) (Table 4). The final evaluation of Tywa River waters at this site classified the waters as class II and this result, in comparison with that of 1997 (class V), is reason for optimism (Table 4).

Site 5

At this site in 1997 seven families and one class were confirmed and taken into consideration in the BMWP-PL classification (with points of 2 to 7), while in 2007 there were two additional families (with points of 2 to 7) (Table 5). These were the high-scoring families *Baetidae* and *Empididae* (with 6 points).

Table 4. Evaluation of Tywa River water quality according to the BMWP-PL index at site 4 in 1997 and 2007 (*families not scored on the BMWP-PL index)

Family	Number of BMWP-PL points	1997		2007	
		Density	Percentage share in samples	Density	Percentage share in samples
		[indiv./m^2]	%	[indiv./m^2]	%
Aphelocheiridae	7			36	2,33
Limnephilidae	7			28	1,81
Elmidae (l.)	7			24	1,55
Gammaridae	6			288	18,60
Bythiniidae	6			124	8,01
Neritidae	6			104	6,72
Empididae (l.)	6			8	0,52
Haliplidae (l.+poczwarka)	5			16	1,03
Hydropsychidae	5			40	2,58
Hydrobiidae	5			444	28,68
Sphaeriidae	4			332	21,45
Chironomidae	3	518	79,57	96	6,20
Asellidae	3			4	0,26
Oligochaeta	2	133	20,43		0,00
Pyralidae	*			4	0,26
Benthos density at site “N”		651		1548	
Number of all families at site		2		14	
Number of all families at site that are assigned points on the BMWP-PL “s”		2		13	
BMWP-PL index		5		70	
Quality class according to BMWP-PL		V		II	
Diversity index „d”		0,71		4,08	
Quality class according to „d"		V		II	
Final BMWP-PL quality class after verification		V		II	

Table 5. Evaluation of Tywa River water quality according to the BMWP-PL index at site 5 in 1997 and 2007 (*families not scored on the BMWP-PL index)

Family	Number of BMWP-PL points	1997		2007	
		Density	Percentage share in samples	Density	Percentage share in samples
		[indiv./ m^2]	%	[indiv ./m^2]	%
Aphelocheiridae	7			12	4,35
Limnephilidae	7	30	2,66		
Baetidae	6			12	4,35
Empididae (l.)	6			8	2,90
Limonidae (l.)	6	30	2,66		
Gammaridae	6	178	15,79		
Neritidae	6	30	2,66	44	15,94
Hydropsychidae	5	89	7,90		
Hydrobiidae	5			20	7,25
Sphaeriidae	4	429	38,07	12	4,35
Chironomidae	3	237	21,03	132	47,83
Erpobdellidae	3			4	1,45
Oligochaeta	2	44	3,90	16	5,80
Culicidae (p.)	2			4	1,45
Tipulidae	*	30	2,66		
Dytiscidae (l.)	*	30	2,66		
Benthos density at site “N”		1127		276	
Number of all families at site		10		11	
Number of all families at site that are assigned points on the BMWP-PL “s”		8		11	
BMWP-PL index		39		48	
Quality class according to BMWP-PL		IV		III	
Diversity index „d”		2,62		4,51	
Quality class according to „d"		III		II	
Final BMWP-PL quality class after verification		IV		III	

This is likely what contributed to increased water quality at the classification (the BMWP-PL index increased from 39 in 1997 to 48 in 2007) (Table 5). Increased biodiversity in 2007 (the biodiversity index was 4.51) in comparison to that in 1997 (the biodiversity index was 2.62) also meant that density decreased from

1127 indiv./m^2 in 1997 to 276 indiv./m^2 in 2007 (Table 5). The domination structure also shifted: in 1997 the most numerous were the families *Sphaeridae* (38.07% of the sample at a density of 429 indiv./m2), Chironomidae (21.03% of the sample at a density of 237 indiv./m2), and Gammaridae (15.79% of the sample at a density of 178 indiv./m2), while in 2007 Chironomidae comprised 47.83% at a density of 132 indiv./m2) and *Neritidae* comprised 15.94% of the sample at a density of 44 indiv./m^2 (Table 5). The final evaluation of the waters of the Tywa River at this site in 2007 was class III, which was one quality classification higher in comparison to that in 1997 (Table 5).

Site 6

At this site in 1997 seven families were noted that were taken into consideration in the BMWP-PL classification (with points of 2 to 7); however, in 2007 there were nine families and one class (Oligochaeta) (with points of 2 to 10) (Table 6). In 1997 the most numerously represented was the family *Chirononidae* at 61.48% with a density of 474 indiv./m^2, while in 2007 the families *Sphaeridae* and *Gammaridae* comprised a similar percentage share (35.96% at a density of 164 indiv./m^2 and 31.58% at a density of 144 indiv./m^2) (Table 6). The biodiversity index differed in the two years with the site exhibiting moderately diverse fauna in 1997 (the biodiversity index was 2.42) and a predominance of fauna typical of polluted waters (the BMWP-PL index was 34), and diverse fauna in 2007 (the biodiversity index was 3.76) with a predominance of fauna that is typical of slightly polluted water (the BMWP-PL index was 58) (Table 6).

In 1997 eight families occurred at this site, and of these seven were taken into consideration in the BMWP-PL classification (Table 6). The most abundantly represented was the family *Chirononidae* at 61.48% with a density of 474 indiv./m^2, while the least abundant were representative from the families *Limonidae*, *Baetidae*, *Sphaeridae* (1.95% of the sample at a density of 15 indiv./m^2). The four families at the site that scored the highest points (7 and 6) were *Limnephilidae*, *Gammaridae*, *Baetidae*, and *Limonidae*, while the other families scored no more than four points (Table 6). This site had moderately diversified fauna (the biodiversity index was 2.42)

and the predominant fauna was that which is indicative of polluted water (the BMWP-PL index was 34). The final classification of the Tywa River waters was class IV (Table 6).

Table 6. Evaluation of Tywa River water quality according to the BMWP-PL index at site 6 in 1997 and 2007 (*families not scored on the BMWP-PL index)

Family	Number of BMWP-PL points	1997		2007	
		Density	Percentage share in samples	Density	Percentage share in samples
		[indiv./ m^2]	%	[indiv./ m^2]	%
Leptoceridae	10			8	1,75
Molannidae	10			8	1,75
Limnephilidae	7	74	9,60	44	9,65
Viviparidae	7			16	3,51
Neritidae	6			8	1,75
Gammaridae	6	118	15,30	144	31,58
Limonidae (l.)	6	15	1,95		
Baetidae	6	15	1,95		
Sphaeriidae	4	15	1,95	164	35,96
Chironomidae	3	474	61,48	44	9,65
Lymnaeidae	3			4	0,88
Oligochaeta	2			16	3,51
Culicidae (p.)	2	30	3,89		
Tipulidae	*	30	3,89		
Benthos density at site “N”		771		456	
Number of all families at site		8		10	
Number of all families at site that are assigned points on the BMWP-PL “s”		7		10	
BMWP-PL index		34		58	
Quality class according to BMWP-PL		IV		III	
Diversity index „d”		2,42		3,76	
Quality class according to „d"		IV		III	
Final BMWP-PL quality class after verification		IV		III	

The final evaluation of the waters in the Tywa River at this site were classified

as class III, which was a class higher than that in 1997. The occurrence of the two families *Leptoceridae* and *Molannidae* with scores of 10, influenced this shift (Table 6).

Site 7

Table 7. Evaluation of Tywa River water quality according to the BMWP-PL index at site 7 in 1997 and 2007 (*families not scored on the BMWP-PL index)

Family	Number of BMWP-PL points	1997		2007	
		Density	Percentage share in samples	Density	Percentage share in samples
		[indiv. /m2]	%	[indiv. /m2]	%
Limnephilidae	7	15	1,11		
Rhyacophilidae	7	15	1,11		
Potamanhidae	7			44	11,22
Elmidae (l.)	7			16	4,08
Gammaridae	6			228	58,16
Baetidae	6			12	3,06
Neritidae	6			12	3,06
Bythiniidae	6			8	2,04
Empididae (l.)	6			4	1,02
Psychomyidae	5	459	34,05		
Hydropsychidae	5	326	24,18	28	7,14
Haliplidae (l.+poczwarka)	5			4	1,02
Veliidae	5	15	1,11		
Sphaeriidae	4			12	3,06
Chironomidae	3	444	32,94	24	6,12
Culicidae (p.)	2	15	1,11		
Dytiscidae (l.)	*	59	4,38		
Benthos density at site “N”		1348		392	
Number of all families at site		8		11	
Number of all families at site that are assigned points on the BMWP-PL “s”		7		11	
BMWP-PL index		34		61	
Quality class according to BMWP-PL		IV		III	
Diversity index „d”		2,24		4,24	
Quality class according to „d"		IV		II	
Final BMWP-PL quality class after verification		IV		III	

At this site in 1997 seven families were noted that were taken into consideration in the BMWP-PL classification (with points of 2 to 7), but in 2007 there were 11 such families (with points of 3 to 7) (Table 7).

In 1997 the predominance of the three families *Psychomyidae* (34.05% at a density of 459 indiv./m^2), *Chironomidae* (32.94% at a density of 444 indiv./m^2), and *Hydropsychidae* (24.18% of the sample at a density of 326 indiv./m^2) with point scores of five, three, and five (Table 7). In 2007 the high-scoring family *Gammaridae* (58.16% of the sample at a density of 228 indiv./m^2) was the dominant with six other high-scoring (6 and 7 points) families also occurring (Table 7). The comparison of 1997 and 2007 indicates that the fauna biodiversity increased from moderately diverse in 1997 (the biodiversity index was 2.24) to diverse in 2007 (the biodiversity index was 4.24) (Table 7). In 1997 the dominant fauna families were those that are typical of polluted waters (the BMWP-PL index was 34), while in 2007 the predominant fauna were those that are typical of slightly polluted waters (the BMWP-PL index was 61) (Table 7). The final evaluation indicated that the waters of the Tywa River at this site in 2007 were classified as class III, which was one class higher than the classification in 1997 (Table 7).

Discussion

The macroinvertebrates inhabiting the rivers of Western Pomerania are not well described, and the literature on the topic does not provide much data; this renders comparisons with rivers of similar parameters difficult.

The region of the Tywa River is one that is rich in benthic invertebrates. Overall, 12,774 indiv./m^2 were collected in 1997, while in 2007 this figure was lower at 8,880 indiv./m^2 (Table 8). The lower quantity of individuals collected after ten years can be explained by improved water quality since biodiversity increased during this same period (in 1997 index d was 4.38 and in 2007 it was 7.60) with a simultaneous decrease in abundance (Table 8). In 1997 the number of families taken into consideration using the BMWP-PL classification method was 18, and in 2007 this figure increased to 30 (and of which there was a greater number of high-scoring

families) (Table 8). The overall evaluation of all the sites combined (Table 8) indicated that the waters of the Tywa River in 1997 were classified as class II, despite the fact that sites 2 and 4 were classified as class V. However, in the combined analysis the presence of high-scoring families with more than five points increased the water quality classification. The number of families identified was also significant. Such drastic differences were not noted in 2007 as water quality oscillated between classes III and II, but in the overall evaluation for all sties combined (Table 8) the result was water quality class I, which was influenced by the presence of high-scoring families and their numbers. Classification should not be based on such analysis since it leads to inaccurate evaluations.

Table 8. Table 1. Evaluation of Tywa River water quality according to the BMWP-PL index in 1997 and 2007

	1997	**2007**
Benthos density at site "N"	12774	8880
Number of all families	23	31
Number of all families that are assigned points on the BMWP-PL "s"	18	30
BMWP-PL index	97	167
Quality class according to BMWP-PL	I	I
Diversity index „d"	4,38	7,60
Quality class according to „d"	II	I
Final BMWP-PL quality class after verification	II	I

The comparison of the two years (1997 and 2007) indicates there was change: families that are more susceptible to water pollution appeared, and biological diversity increased (Table 8). This is the result of improved water quality in the Tywa River. Improvement in water quality by one or two classes was noted at all the sites. This was significantly impacted by the appearance of additional families that are susceptible to pollution and that are scored more highly by the BMWP-PL system. At site 1 these are *Empididae* and *Elimidae*, while at site 2 they are *Caenidae*, *Ephemerellidae*, *Limnephilidae*, *Gammaridae*, *Simuliidae*, *Baetidae*, and *Empididae* (Tables 1-2). At site 3, *Caenidae*, *Ecnomidae*, *Polycenthopodidae*, and *Bythynidae* also occurred, but *Dreisenidae* did not occur in 2007, and *Leptoceridae* was noted

again; the increased number of families that occurred impacted the change in water quality class (Table 3). Great change in domination structure was noted at site 4: the number of families noted in 1997 was two which increased to 13 in 2007 (Table 4). The low-scoring *Chironomidae* and *Oligochaeta* were replaced by higher-scoring families such as *Hydrobidae*, *Spahaeridae*, and *Gammaridae* and the high-scoring families *Aphelocheiridae*, *Limnephilidae*, and *Elmidae* also appeared (Table 4). The high-scoring families *Aphelocheiridae*, *Neritidae*, and *Empididae* were confirmed at site 5, and the low-scoring families *Tipulidae* and *Dytiscidae* were not noted in 2007 (Table 5). Changes were also recorded at site 6: the low-scoring family *Culicidae* (with 2 points) was not noted in 2007, but the families *Leptoceridae* and *Molanidae* (with 10 points) were confirmed (Table 6). The low-scoring family *Culicidae* was also not noted at site 7 in 2007, while simultaneously the number of high-scoring families (with 6 and 7 points) increased, including *Baetidae*, *Neritidae*, and *Elmidae* (Table 7). All of these changes in domination structure impacted the final evaluation of the water quality of the Tywa River at the various sites, and they provide a good illustration of the changes that have occurred in the biocenosis of this river. All of the changes that have been implemented in water and sewage management over the span of ten years and the limitations in agriculture in the Tywa River basin have probably had an impact on these changes.

Changes in domination structure were noted at all the sites except site 1. These differences depend not only on the quality of flowing waters, but also on hydromorphological variable such as substrate type and current speed [15, 16]. One of the families that decreases water quality classification is *Chironomidae*, which is typical of medium-sized rivers with sandy substrates [17]. Representatives of this family occur on the entire length of the Tywa River, but in 2007 they comprised a smaller share of the sample as was particularly evident at sites 2, 4, 6, and 7 (Tables 2, 4, 6, 7). Their percentage share decreased in 2007 as compared to that in 1997 at these sites as follows: site 2 – from 92.3% to 30% (Table 2); site 4 – from 79.6 % to 6.2 % (Table 4); site 6 – from 61.5 % to 9.6 % (Table 6); site 7 – from 32.9 to 6,1 % (Table 7). It is possible that the the river bed structure changed in the 1997-

2007 period since these organisms prefer sandy substrates overgrown with macrophytes [15], and that water quality improved. These organisms are also linked to periphyton and are poor swimmers [18]. Another option is the possibility that environmental conditions in 2007 were advantageous so that larval *Chironomidae* transformed into adults more quickly. Their transformation period begins at the end of May or in early June, which could have resulted in their leaving the aquatic environment before samples were collected [6].

The data collected indicates that families typical of polluted waters are mutually intermittent with those that are typical of clean waters. Drift might be responsible for this[18]. The organisms that drift most frequently include the families *Gammaridae*, *Hydropsychidae*, *Simulidae*, and *Chironomidae* [19].

Conclusions

1. Macroinvertebrates occurring in the Tywa River are richly represented by families that vary in their tolerance of environmental change, particularly with regard to pollution.

2. In consideration of the two period compared (1997 and 2007), it is possible, based on the overall BMWP – PL indexes for the entire river, to conclude there has been an improvement of one water quality class in the Tywa River.

3. Improvement of one or two quality classes has also been noted at the individual study sites. The occurrence of additional families susceptible to pollution and higher-scoring on the BMWP-PL index has a substantial impact on this as did increased biodiversity.

4. Since evaluating water quality with the BMWP method takes into consideration the presence of given families without considering their density or the drift phenomenon, the classification of water quality at specific sites could be burdened with error, the main cause of which might be drift.

5. Applying the overall BMWP – PL index (for the entire river and not just individual sites) leads increased water quality evaluation.

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