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RESEARCH ARTICLE

Gastropods and periphytic algae relationships in the vicinity of a small hydroelectric plant on the Pasłęka River in northeast Poland

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Abstract. This study of periphytic algae and gastropods differentiation on macrophytes, stones, and dam substrates and the relationships between these communities in the vegetative season of 2001-2003 was conducted in the vicinity of a hydroelectric plant on the Pasłęka River. Damming the river caused decreased water discharge upstream from the plant, and increased it downstream. Thus, oxygen conditions downstream from the plant improved, but high nutrient concentrations were also recorded. Generally, increased orthophosphate concentrations do not allow river waters to be classified as having good or maximum ecological potential. Damming contributed to changes in the growth conditions of the periphytic algae and gastropods and their differentiation. The highest biomass of periphytic algae was noted on the dam, while the highest gastropods biomass was noted on macrophytes. The periphytic algae was dominated by the diatoms *Diatoma vulgaris* and *Melosira varians* (epiphyton, dam) and the chlorophytes *Ulothrix tenuissima* and *Spirogyra* sp. (epilithon), while the gastropods were dominated by *Lymnea stagnalis* (macrophytes), *Theodoxus fluviatilis* (stones), and *Radix balthica* (dam). The relationship between the gastropods and the periphytic algae on macrophytes and the dam in spring and summer revealed an increase in gastropods biomass and a decrease in periphytic algae biomass. This was indicated by the negative correlation between the biomass of these communities.

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Introduction

In rivers periphytic algae inhabit various natural (epiphyton, epilithon) and artificial substrates, e.g. those of human constructions in waters. The most important factors influencing the development of plant periphyton in rivers include water discharge, substrate type, nutrient concentrations, and grazing (Cattaneo 1983, Pringle 1990, Biggs 1996, Szlauer 1996, Perrin and Richardson 1997, Komulaynen 2006, Stevenson et al. 2006, Szabo et al. 2007). Substrate structure and chemical composition are essential factors in determining periphytic algal biomass (Lowe and Gale 1980, Biggs 1996, Allan 1998, Komulaynen 2002, Szabo et al. 2007, Komulaynen 2009, Belyaeva 2010, Morin et al. 2010).

Periphytic algae are a food source for several invertebrate and fish species (Cattaneo et al. 1993). Herbivorous invertebrates can influence periphytic algae directly by grazing, and indirectly by nutrient regeneration. General studies of relationships between plant periphyton and invertebrates have been analyzed previously in rivers (Lewis 1986, Perrin and Richardson 1997, Winter and Duthiel 1998, Komulaynen 2006, Morley et al. 2008, Coe et al. 2009). Gastropods also play an important role in shaping periphyton biomass, species composition, and productivity (Brönmark 1989, Tuchman and Stevenson 1991). Even on homogeneous substrates, the grazing effect contributes to a mosaic of periphyton communities (Kawata et al. 2001).

The Pasłęka River is a typical example of a montane river transformed by the construction of a small hydro-electric power plant. The invertebrate biomass in this river was dominated by gastropods prior to its construction (Szymańska 2012). It is hypothesized that damming the river has influenced the growth conditions of gastropods grazing on periphytic algae inhabiting both natural and artificial substrates. The objective of this paper is to determine the differentiation of periphytic algae and gastropods communities on macrophytes, stones, and dam substrates, and to identify the relationships between these communities in the vegetative season in the 2001-2003 period and under the conditions created by damming the Pasłęka River.

Materials and methods

Study area

The study on periphytic algae and gastropods was conducted in the Pasłęka River, which is designated as a nature reserve on some segments, and is the only montane river in the Warmia and Mazury region of northeastern Poland (Fig. 1). The origin of the river is in Lake Pasłęk, and it flows into the Vistula Lagoon. The total length of the river is 172 km. In the southern part of its catchment area near the mouth, approximately 80% of the area is forested, while in the remaining areas forests constitute approximately 10% to 35% of the catchment area. The Pasłęka River catchment includes four protected landscape areas and four nature reserves. The Pasłęka River has varied water discharge because of surface drop fluctuations, which range from 5 to 0.4% (Czachorowski 1988), and the river bed width in the area studied was about 20 m. In the upper part of its course, it is a typical lowland river, whereas in the lower segments it assumes the features of a montane river (Szymańska and Bonar 2004). The study site was located in the vicinity of a part of the Ostoja Bobrów Nature Reserve. The Kasztanowo hydroelectric power plant is located on the Pasłęka River, and has been producing a average of 50 kW since 1989. The facility comprises a dam that directs some of the water to the power station through the upper penstock, a discharge pipe that directs water from the power station to the natural river bed, and a building that houses the turbine.

Periphytic algae and gastropods sampling and analysis

Samples of periphytic algae were collected monthly during each April-November period in 2001-2003 at the following sites with different substrates located at distances ranging from 800 m upstream to 600 m downstream from the hydroelectric plant and the dam:

1) epiphyton from macrophyte leaves (*Acorus calamus* L., *Glyceria maxima* (Hartm.) Holmb., *Typha angustifolia* L.) at low water discharge (natural substrate);
2) epilithon from stones at high water discharge (natural substrate);
3) periphyton from the dam slopes (artificial substrate).

The periphytic algae were scraped from the dam (2 sub-samples), from 1 cm^2 of stone surfaces (3 sub-samples), and from macrophyte leaves that had previously been cut into 5 cm lengths (2 sub-samples). The samples were rinsed and preserved in an ethanol and formaldehyde solution. In the vegetative season, the dam and stones were overgrown systematically with *Cladophora glomerata* (L.) Kützing thallophytic green algae. This chlorophyte occurred as large thalluses, and was an

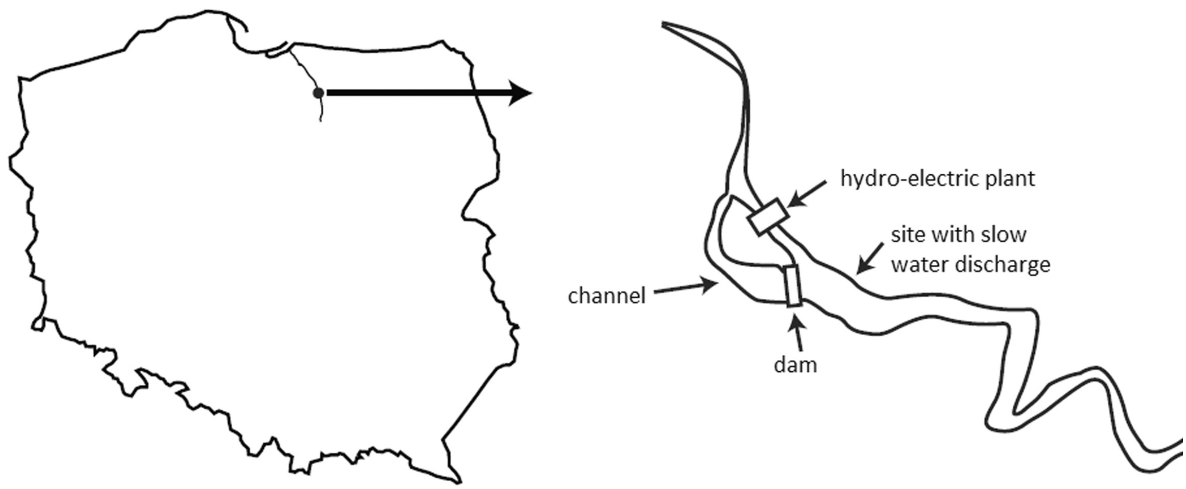

Figure 1. Location of study site on the Pasłęka River – the Kasztanowo hydroelectric power station.

element of the natural substrate for small periphytic algae. *C. glomerata* was eliminated from this analysis because it concentrated on algae of smaller sizes and similar structures to the epiphytic algae occurring on the leaves of other macrophytes. The periphyton was shaken carefully in distilled water to separate the algae, including diatoms, from the chlorophyte thalluses. Any remaining periphyton was scraped off macrophyte leaves with a knife. The samples were rinsed and preserved using an ethanol and formaldehyde solution. A total of 108 samples were collected. Qualitative and quantitative determinations of periphytic algae were performed with an Alphaphot YS2 optical microscope at magnifications of 10x, 20x, 40x, and 100x. Identifications were performed based on works by Krammer and Lange-Bertalot (1986, 1988, 1991a and 1991b), Huber-Pestalozzi et al. (1983), and Hindák (1996). Diatom preparations followed the standard procedures described by Battarbee (1979). Algae biomass was calculated using biovolume by comparing algae to their geometrical shapes (Rott 1981). Mean biomass was calculated for 10 individuals of each periphytic algae species and expressed in mg cm^{-2}.

Samples of gastropods were collected monthly in the April-November period in 2001-2003 with different substrates: (1) macrophytes (mainly *Acorus calamus* accompanied by *Glyceria maxima* and *Typha angustifolia*), (2) stones (macro-mesolithal), and (3) the dam slope (technolithal). Gastropods samples were collected from 40 cm^2 areas of these substrates with sieves and dredges (Davies 2001, Bis 2006), so that all live gastropods were selected and preserved in 96% ethanol. The collected material was determined to the highest taxa using the keys by Piechocki (1979 and 2008) under a MOTIC stereoscopic microscope and a NIKON optical microscope. Individual gastropod mass was determined with a WPA 40/160/C/1 analytic weighing device to the nearest 0.00001 g and expressed in mg cm^{-2}. A total of 93 samples were collected, as follows: 24 from macrophytes; 62 from macro- and mesolithal sites; 7 from technolithal areas.

Basic physical and chemical water parameters were measured directly at the sampling sites from April to November 2001-2003. Water temperature values were measured to the nearest 0.1°C, oxygen content to the nearest 0.01 mg O_2 l^{-1}, and pH and conductivity in the range of 1-1743 μS cm^{-1} were measured *in situ*. Concentrations of orthophosphates, silicon, calcium, and total nitrogen were measured in the laboratory using Spectroquant Merck tests (NOVA 400 spectrophotometer). The physicochemical water parameters were analyzed based on water quality indexes to determine the ecological potential of strongly altered rivers according to Appendixes 5 and 8 of the Regulation of the Minister of the Environment (2011).

In this study periphytic algae and gastropods differentiation was analyzed on substrates (macrophytes, stones, and the dam) in the spring (April and May), summer (June, July, August) and autumn (September, October, November) in the 2001-2003 period. The species diversity of the periphytic algae and gastropods biomass was analyzed to calculate the Shannon-Weaver index (Shannon and Weaver 1949). Means of the sum biomass of individuals on particular substrates and divided by the number of measurements were used in the analysis. Standard deviations were also calculated for periphytic algae and gastropods biomass and for physicochemical water parameters. Eudominants and dominants were determined based on percentages of total periphytic algae and gastropods biomass in the following ranges: (1) above 10% for eudominants and (2) from 5.1 to 10% for dominants (Tischler 1949). All of the data were analyzed statistically using Statistica 8.0. The biomass of the gastropods was correlated with the biomass of the periphytic algae using non-parametric methods because these data were not normally distributed. The relationships were confirmed by calculating Spearman's rank correlation coefficient.

Results

Physical and chemical water parameters

The differences within the physicochemical parameters of Pasłęka River waters in 2001-2003 were examined at sites with different macrophyte, stone, and dam substrates (Table 1). Water temperature ranged from 6 to 21°C, while orthophosphates ranged from 0.05 to 1.28 mg PO_4 l^{-1} at all the sites. The highest ranges in the variability of conductivity and silicon, at 74-1667 μS $cm^{-1}$and 0.12-3.04 mg Si l^{-1}, respectively, were recorded on the dam. Moreover, the highest variability in the ranges of oxygen content at 3.76-14.76 mg O_2 l^{-1}, total nitrogen at 0.5-5.7 mg N l^{-1}, and calcium concentration at 10-304 mg Ca l^{-1} was noted at sites with macrophytes. The mean water temperature ranged from 13.8°C at stone sites to 14.3°C at macrophytes sites when water discharge was low. The highest mean oxygen content of 9.75 mg O_2 l^{-1} was noted on the dam when water discharge was high, and the lowest oxygen content was noted at macrophyte sites (8.39 mg O_2 l^{-1}). The mean conductivity ranged from 466 μS cm^{-1} at stone sites to 538 μS cm^{-1} at macrophyte sites. Mean orthophosphate content ranged from 0.42 mg PO_4 l^{-1} at macrophyte sites to 0.44 mg PO_4 l^{-1} at stone sites. The macrophyte sites had higher nutrient concentrations than did the remaining sites (2.0 mg N l^{-1}, 1.14 mg Si l^{-1},119 mg Ca l^{-1}); however, the lowest total nitrogen of 1.5 mg N l^{-1} and calcium of 105 mg Ca l^{-1} were recorded on the dam. The measurement values show that the Pasłęka River has first class water quality in terms of dissolved oxygen concentration, temperature and conductivity, and total nitrogen according to the Polish Regulation of the Minister of Environment (Table 1). The calcium concentration was second class water quality, and orthophosphates was below the second class water quality standard.

General characteristics of periphytic algae

Differences in the biomass of periphytic algae were observed in the Pasłęka River (Fig. 2). The highest mean periphytic algae biomass was recorded on the dam (5.92 mg cm^{-2}), and the lowest on epiphyton (1.02 mg cm^{-2}). The highest mean periphytic algae biomass of 5.26 mg cm^{-2} was noted in spring and the lowest of 1.58 mg cm^{-2} in summer (Fig. 3). The greatest species diversity was recorded for epiphyton at 3.96 and the least for periphyton on the dam at 1.78, which is where the lowest number of taxa of 80 was recorded, while the most taxa noted was 115 in the epilithon (Table 2).

For epiphyton biomass, the following eudominants were identified; (1) *Diatoma vulgaris* Bory (30.5%), *Cymbella compacta* Estrup. (23.2%) and *Lyngbya hieronymussii* Agardh. (14.5%) in

Table 1
Physicochemical water parameters (N=72; mean ± SD, and range) measured in the Pasłęka River in 2001-2003 and water quality indexes for determining the ecological potential of strongly altered rivers according to Appendix 5 of the Regulation of the Minister of Environment (2011)

Substrate	Macrophytes	Stones	Dam	Water quality class
Water temperature (°C)	13.9±4.64 (6.1-21.3)	13.8±4.78 (6.0-21.1)	14.3±4.06 (6.0-21.0)	I
Oxygen content (mg O_2 l^{-1})	8.39±2.91 (3.76-14.76)	9.35±2.30 (3.93-13.70)	9.75±2.05 (6.46-16.24)	I
Electrolytic conductivity (µS cm^{-1})	538±334 (160-1735)	466±344 (378-1674)	495±302 (74-1667)	I
Total nitrogen (mg N l^{-1})	2.0±1.5 (0.5-5.7)	1.8±1.2 (0.5-4.2)	1.5±0.9 (0.5-4.1)	I
Orthophosphates (mg PO_4 l^{-1})	0.42±0.34 (0.05-1.26)	0.44±0.34 (0.05-1.25)	0.42±0.35 (0.05-1.28)	exceed class II
Silicon (mg Si l^{-1})	1.14±0.76 (0.16-2.75)	0.89±0.62 (0.07-2.26)	1.02±0.71 (0.12-3.04)	
Calcium (mg Ca l^{-1})	119±69 (10-304)	117±63 (58-314)	105±57 (10-245)	II

Table 2
Periphytic algae and gastropods species diversity and number of taxa in the vicinity of the Pasłęka River hydroelectric plant in 2001-2003

Substrates	Macrophytes (epiphyton)	Stones (epilithon)	Dam (periphytic algae)
Periphyton			
Species richness	97	115	80
Shannon-Weaver diversity index	3.96	3.46	1.78
Gastropods			
Species richness	22	16	11
Shannon-Weaver diversity index	2.98	2.04	0.10

spring; (2) *Melosira varians* Agardh. at 67.9% in summer; (3) *Cymbella tumida* (Bréb.) Van Heurck (20.0%) and *Gomphonema olivaceum* (Hornemann) Bréb. (11.8%) in autumn. The dominant diatoms were: *Ulnaria ulna* (Nitzsch) P.Compére and *M. varians*. The epilithon was dominated by *Ulothrix tenuissima* Kütz. at 50.2% and *D. vulgaris* at 27.2% in spring, and the genus *Spirogyra* sp. in the summer and autumn seasons at 51.6% and 26.2%, respectively, accompanied by the genus *Mougeotia* sp. (29.4%) and *M. varians* (15.6%). The following eudominants occurred in the periphytic algae biomass on the dam: (1) *Diatoma vulgaris* var. *linearis* (Grun.) Van Heurck at 28.9%, *D. vulgaris* at 19.7%, and *G. olivaceum* at 12.6% in spring; (2) *M. varians* in the summer and autumn seasons at 59.5% and 47.7%, respectively, together with the genus *Spirogyra* sp. (19.7%) and *Diatoma hyemalis* (Roth) Heib. (11.6%). Accompanying species were *U. ulna* and *D. vulgaris* (Table 3).

General characteristics of gastropods

Differences in gastropods biomass were also observed in this study (Fig. 2). The highest gastropods biomass was on macrophytes (5.68 mg cm^{-2}) and the lowest was at macro- and mesolithal sites (2.06 mg cm^{-2}). The highest gastropods biomass was in summer (3.70 mg cm^{-2}) and the lowest was in spring (2.01 mg cm^{-2}; Fig. 3). Among the gastropods, the greatest species diversity and taxa number was on the macrophytes at 2.98 and 22 taxa, and lowest values were noted on the dam at 0.10 and 11 taxa (Table 2).

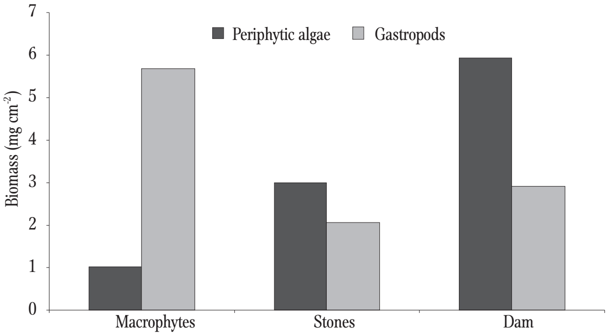

Figure 2. Mean biomass of periphytic algae and gastropods on macrophytes, stones, and dam substrates in the vicinity of the hydroelectric plant on the Pasłęka River in 2001-2003.

The eudominant of gastropods biomass was *Radix auricularia* (L.) at 70.5% on macrophytes. This species attached at a lower proportion (34.7%) in summer, when the other eudominants *Lymnea stagnalis* (L.) and *Bithynia tentaculata* (L.) occurred, which were also eudominants in the autumn. *Radix ampla* (Hartm.), *B. tentaculata* and *Radix balthica* (L.) were accompanying species. Two dominants, *Bithynia leachii* (Shep.) and *Planorbarius corneus* (L.), were noted in summer. The second species was recorded as a eudominant with the highest proportion at 32.2% in autumn. The gastropods composition on the macro- and mesolithal surfaces were fairly stable. The eudominant *Theodoxus fluviatilis* (L.) attached at the highest proportions from 39.2 in autumn to 68.8% in summer, and was accompanied by *R. ampla* in all seasons, *B. tentaculata* in spring, and *R. balthica* in autumn. Meanwhile, *R. balthica* was eudominant in all seasons at the dam technolithal site. This was the only species that occurred in spring, accompanied by the eudominant *Physa fontinalis* (L.), the dominant *Valvata piscinalis* (O.F.M.) in summer, and the eudominant *R. ampla* in autumn (Table 3).

Relationships between gastropods and periphytic algae in the vegetative season

The standard deviations for periphytic algae and gastropods did not exceed twice the value of arithmetic means, which indicated the data were statistically representative. Statistical analysis showed significant,

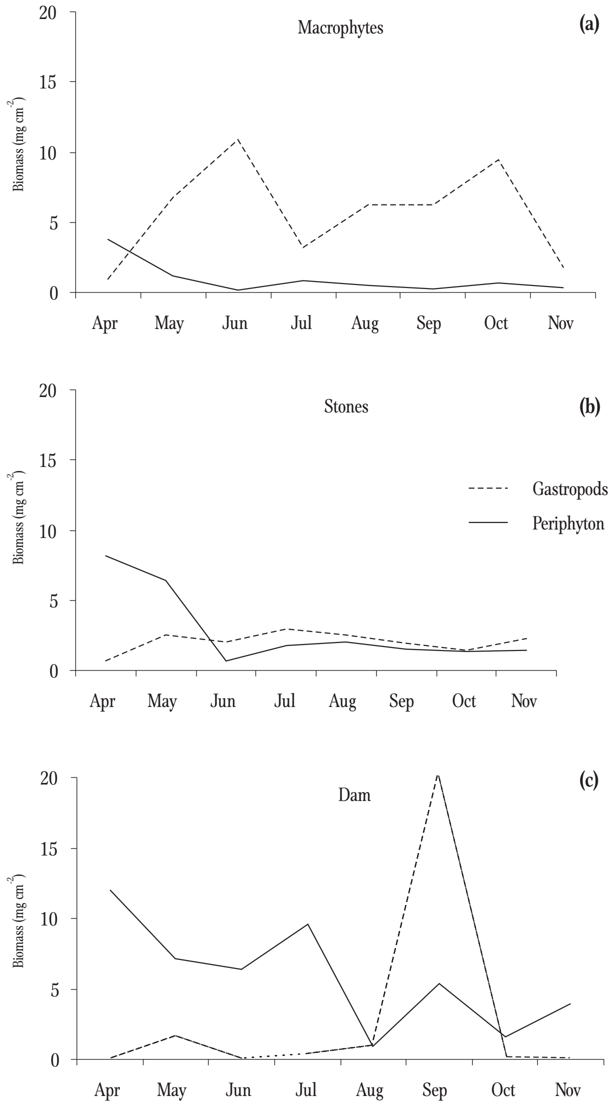

Figure 3. Relationships between gastropods and periphytic algae on macrophytes (a), stones (b), and the dam (c) in the vegetative season in the Pasłęka River (mean values in 2001-2003).

negative correlations between gastropods and periphytic algae biomass in all seasons ($r = -0.312$, $P < 0.05$) and in spring ($r = -0.464$, $P < 0.05$) (Table 4).

The following relationships between gastropods and periphytic algae biomass in the Pasłęka River were observed during the vegetative season on the different substrates; (1) macrophytes – (a) in spring and early summer, between April and June, there was increased gastropods biomass accompanied by a rapid decrease in epiphyton biomass, (b) in summer in July and August there was a decrease in

Table 3
The total biomass (mg cm^{-2}) and share (in parentheses, %) of eudominants (10 % ≤ Di ≤ 100 %) and dominants (5 % ≤ Di < 10 %) periphytic algae and gastropods on substrates (M – macrophytes, S – stones, D – dam) in the Pasłęka River in 2001-2003

	Spring			Summer			Autumn		
Taxa	M	S	D	M	S	D	M	S	D
Periphytic algae									
Cymbella compacta	0.790 (23.2)		0.638 (5.7)						
Cymbella tumida							0.156 (20.0)		
Diatoma hyemalis									0.489 (11.6)
Diatoma vulgaris	1.035 (30.5)	3.13 6 (27.2)	2.219 (19.7)				0.062 (7.9)	0.209 (7.3)	0.267 (6.3)
Diatoma vulgaris var. *linearis*			3.253 (28.9)						
Ulnaria ulna	0.183 (5.4)		0.783 (7.0)						
Gomphonema olivaceum			1.416 (12.6)				0.092 (11.8)		
Lyngbya hieronymussii	0.493 (14.5)								
Melosira varians				0.499 (67.9)	0.503 (6.0)	4.319 (59.5)	0.078 (10.0)	0.429 (15.6)	2.010 (47.7)
Mougeotia sp.					2.452 (29.4)				
Spirogyra sp.					4.302 (51.6)	1.434 (19.7)		0.717 (26.2)	
Ulothrix tenuissima		7.887 (50.2)							
Gastropods									
Bithynia leachii				0.335 (5.1)					
Bithynia tentaculata	0.443 (6.8)	0.131 (23.7)		0.776 (11.8)	0.051(5.5)		0.627 (22.7)	0.072 (7.8)	
Lymnea stagnalis				1.917 (29.2)			0.675 (24.5)		
Physa fontinalis						0.110 (15.2)	0.260 (9.4)		
Planorbarius corneus				0.551(8.4)			0.887 (32.2)		1.393 (20.4)
Radix ampla	0.521 (8.0)	0.072 (13.0)			0.139 (15.1)		0.225 (8.2)	0.121 (13.1)	
Radix auricularia	4.564 (70.5)			2.284 (34.7)					5.384 (78.9)
Radix balthica	0.396 (6.1)		1.599 (100)		0.064 (6.9)	0.547 (75.8)		0.295 (31.9)	
Theodoxus fluviatilis		0.294 (53.3)			0.634 (68.8)			0.361 (39.2)	
Valvata piscinalis						0.037 (5.1)			

Table 4
Biomass data (mg cm^{-2}, mean±standard deviation) and Spearman rank correlation (r) between gastropods and periphytic algae in the Pasłęka River in 2001-2003

	All seasons N = 93	Spring N = 30	Summer N = 32	Autumn N = 31
Gastropods	3.11±4.48	2.01±3.06	3.70±4.95	2.61±3.83
Periphytic algae	2.47±3.90	5.26±5.59	1.58±2.91	1.69±3.18
Spearman correlation coefficient	r = -0.312*	r = -0.464*	r = -0.308	r = 0.337

*statistically significant (P < 0.05)

epiphyton biomass (Fig. 3a); (2) on stones – (a) in spring in April and May there was also an increase in gastropods biomass accompanied by decreased periphytic algae biomass, and then (b) from July right through to November similar dynamics were observed for these communities (Fig. 3b); and (3) the dam – (a) in both spring (April, May) and summer (July, August) there was increased gastropods biomass with decreased periphytic algae, and (b) similar biomass dynamics were again recorded in late summer and autumn (Fig. 3c). Additionally, statistically significant correlations were not noted among the biomass of these communities in the summer and autumn seasons (Table 4).

Discussion

According to Xiaocheng et al. (2008), human constructions are use in montane-type rivers similar to the Pasłęka River with high water discharge, low water temperature, and high oxygen content, and additionally, when the physicochemical water parameters of rivers are highly variable. This can be linked to water discharge, nutrient inflow from catchment areas, sediment nutrient re-suspension, especially at macrophyte sites when water discharge is slow. Although some authors have reported considerably lower nutrient concentrations (Gosh and Gaur 1998, Potapova et al. 2004, Passy and Bode 2004, Zalocar de Domitrovic et al. 2007), in the present study Pasłęka waters in 2001-2003 contained quite high concentrations, especially of PO_4. Generally, increased orthophosphate concentrations do not permit classifying the ecological potential of river waters as good or maximum according to Appendix 8 of the Regulation of the Minister of the Environment (2011). High concentrations of N_{tot} and PO_4 could have supported the growth of epiphytic algae, as was indicated by positive correlations between algae biomass and these nutrients (Zębek 2013). The high gastropods biomass in the Pasłęka River is comparable to that from other studies that examined invertebrates dominated by gastropods in streams with diverse geological structures at 400 to 800 μS cm^{-1} conductivity (Egglishaw and Morgan 1965). Therefore, the Pasłęka River has potentially ideal conditions for the development of all invertebrates, especially gastropods, which attached at the highest biomass on macrophytes.

The periphytic algae in rivers that inhabit various natural and artificial substrates, e.g., those of human constructions, are layered and varied. As is comparable with other studies (Chudyba 1965, St-Cyr et al. 1997), the substrates of the periphytic algae in the Pasłęka River were macrophytes, stones, and elements of the dam. Similarly, the thallophytic chlorophyte *Cladophora glomerata* is a natural substrate for small periphytic algae, but Bohr (1962) recognized this chlorophyte algae as an element of the periphytic algae. In the present study, differentiation was noted among the periphytic algae occurring on these different substrates. The highest periphytic algae biomass was noted on the dam because filamentous diatoms and chlorophytes inhabit rough artificial substrates more often than they do natural ones (St-Cyr et al. 1997). Some authors have recorded the dominance of *Diatoma vulgaris* in periphytic assemblages in the Pasłęka River (Potapova et al. 2004, Szabo et al. 2007, Zębek

2009). However, in the current study, the periphytic algae were dominated by *Diatoma vulgaris* var. *linearis* and *Melosira varians,* which could have resulted from the phytoplankton being dominated by these species in summer. Simultaneously, the lowest gastropods biomass on the dam contributed to less grazing periphytic algae in comparison with other substrates. Moreover, the lowest species diversity of gastropods and periphytic algae on the substrate could have resulted from increased water discharge of dammed waters that caused algal thalluses to rupture and smaller-sized species to be washed away. According to Xiaocheng et al. (2008), obstructing the rivers with small hydroelectric plants induces negative changes in gastropods species composition and density and causes an overall depletion in biological diversity. Therefore, *R. balthica* was a eudominant in all seasons on the dam, which is of a flattened shell shape that has a comparatively large surface area and which provides excellent conditions for organism adhesion and means that organisms can tolerate increased water discharges. Additionally, its survival is ensured by access to an adequate periphytic algal food source and the absence of other gastropods competitors.

Gastropods are one of main grazers on periphytic algae (McClatchie et al. 1982). The lowest epiphyton biomass in the Pasłęka River is linked to the very high number of gastropods species, their diversity and biomass, and the fact that they exist on the macrophytes found there. These gastropods graze directly on periphytic algae and indirectly on macrophytes. Both the highest species diversity and the number of dominants, including *C. compacta*, *D. vulgaris*, *L. hieronymussii*, *C. tumida*, and *G. olivaceum* in the epiphyton, could have been related to the grazing effects of a mosaic of periphyton communities which are present even on homogeneous substrates (Kawata et al. 2001). Moreover, damming the river slowed water discharge and increased sediment accumulation, which provided ideal conditions for both floating and submerged macrophytes to develop. Szymańska and Bonar (2004) reported that a variety of new habitats had formed upstream from the dam, including a macrophyte substrate with the accompanying nutrients that favored different periphytic algae, and the macrophyte and periphytic algal food sources on this substrate that sustained gastropods species.

Stony substrates and rapid water discharge created conditions that were too difficult for periphytic algae and gastropods species to colonize, precisely because few of them are adapted to inhabit such lothic environments (Crowl and Schnell 1990). As was noted with regard to the Pasłęka River, some other authors also reported the lowest biomass, fewer species, and lower diversity of gastropods on macro and mesolithal substrates in areas with increased water velocity (Strzelec and Królczyk 2004). *T. fluviatilis* dominated these conditions (Piechocki 1979), and was a eudominant in all seasons. This species consumes filamentous periphytic algae such as *Cladophora* sp. (Jacoby 1985) that inhabits stone surfaces and is the main shaft for small periphytic algae. In the present study, the epilithon was dominated by the filamentous chlorophytes *Ulothrix tenuissima* in spring and the genus *Spirogyra* in the summer and autumn seasons, which is comparable with other studies (Ghosh and Gaur 1998, Asaeda and Son 2000). The largest number of taxa of the epilithon could be linked with the continuous rinsing of these algae from stones, which led to frequent changes in algal composition and the increased number of taxa.

Regardless of the substrate type, gastropods also play an important role in shaping periphyton biomass, species composition, and productivity (Brönmark 1989, Tuchman and Stevenson 1991). The lowest epiphytic algae biomass in the Pasłęka River, stemmed from intense gastropods grazing, which is evidenced by the significant, negative correlations between gastropods and periphytic algae biomass. The most intensive grazing occurred in spring when increased gastropods biomass was accompanied by decreased periphyton biomass on all substrates, as is indicated by the significant, negative correlation between these communities in spring. However, this phenomenon was less intense during summer on macrophytes and the dam. Brönmark (1989) and Komulaynen (2006) reported that filamentous algae and diatoms comprised a high percentage of the invertebrate diet. The gastropodss in the Pasłęka River fed on periphytic algae such as filamentous diatoms (*Melosira varians*) and chlorophytes, and did so with greater intensity on the substrates of macrophytes and the dam than they did on that of the stones. Differences in periphytic algae composition could, however, be related to gastropodss alimentary preferences.

In conclusion, the hydroelectric power facility on the Pasłęka River contributed to changes in periphytic algae and gastropodss habitat conditions. This stemmed from changes in water discharge. As a result of decreased water discharge, the river upstream from the facility is of a lowland character, while that downstream is of a montane character with decidedly higher water discharge. Damming the river contributed to water quality deterioration with regard to nutrient concentrations upstream from the plant. Consequently, this has created new habitats for periphytic algae on macrophytes in areas where water discharge is low and on the dam slopes. These habitats are characterized by both intense periphytic algae production and gastropodss grazing, especially upstream from the hydroelectric plant when water discharge is slow and nutrient concentrations are high. The results of the present study suggest that all of the environmental effects and phenomena focused upon in the current study should be considered carefully in future when planning of construction projects on small rivers and restoration projects.

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