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ORGANIC MATTER IN A LOWLAND RIVER OF STRONGLY MODIFIED DISCHARGE
2. DISCHARGE VOLUME AND "RESISTANCE" OF HABITATS

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Summary. To estimate the threshold value triggering off destabilization of dominant habitats of the Drzewiczka, a river affected by a highly fluctuating discharge regime, an "experiment" was carried out in the river in three seasons: autumn, spring, and winter. It consisted in two-three week periods of maintaining the discharge on its natural level over a 24 h. period and then releasing from a dam reservoir a large water volume, which exceeded the natural discharge by several to over 16 times, reaching, respectively, 8.4 m^3s^{-1} in September 2000, 12.0 m^3s^{-1} in March 2001 and 41.8 m^3s^{-1} in February 2002, the last discharge occurring during the complete emptying of the reservoir, before its dredging. In each habitat morphometric, hydraulic and biotic parameters were measured before and during water releases. A threefold increase in discharge (in September) caused a destabilization of inorganic substrate, organic sediment and periphyton, only in a habitat located closest to the dam and the white/wild water canoe slalom track, while a fivefold increase in the discharge (in March) determined similar changes of parameters in this habitat and in another, of coarse substrate and very fast current. The highest discharge (February) was a cause of substrate destabilization, the least changes being recorded in a stagnant off-shore habitat, overgrown by submerged macrophytes; thus, this habitat may be considered a refuge for benthofauna.

Keywords: river, discharge fluctuations, substrate, BPOM, TPOM

INTRODUCTION

Disturbances of the natural hydrologic regime disrupt riverine ecosystems; high frequency increases in discharge volumes result in destabilization of nutrition availability, substrate composition and other physical environments and, consequently, in much decrease in zoobenthos abundance and diversity [10]. The perturbations may be caused by floods [4, 15, 17], dams and impoundments, other hydroconstructions related to river regulation, such as building drainage ditches, simplifying the structure of river channel through deepening and straightening it, and by droughts [3, 20].

However, long-term and diverse intensity changes in the hydrological regime may also result in increase in the heterogeneity of environmental conditions (mosaic site). Such diversification of substrate enables a greater number of co-occurring species of zoobenthos to exist and contributes to lotic invertebrate patchiness [11, 13]. Respective habitats may display various resistance to this kind of stress.

The aim of this study in the Drzewiczka, a river of permanently modified hydrological regime, was to determine the discharge level that causes the sorting, removing and re-depositing of inorganic and organic substrate in each of the dominant habitats. These events change the variability in environmental conditions influencing invertebrate communities.

STUDY AREA

The studied section of the Drzewiczka is located downstream of a dam and of a wild–water slalom canoeing track (W-WSCT) (20°28' E and 51°27' N). Both these hydroconstructions have long determined water discharge: the dam for 70 and the track for 20 recent years. However, the regime of the discharge frequently changes. For the recent two decades, several times a week for two hours a day the discharge was increased 3-5 fold in relation to the median one.

The established study site was just downstream of the track; it was a 160 m long and, on average, 0.5 m deep reach, with several islands and with various size of mineral substrate particles (Fig. 1). The ecotone trees were dominated by the common alder (*Alnus glutinosa* (L.) Gaertn.).

A total of 5 dominant habitat types were distinguished (Fig. 1):

H_1 – pool at the left river bank, at the height of one of the islands;

H_2 – stagnant river meander overgrown by emerged macrophytes;

H_3 – mid-current zone in its middle current; sandy bottom overgrown by submerged vegetation *Potamogeton pectinatus* L.. Other pond-weeds: *Potamogeton lucens* L., *Potamogeton crispus* L. and *Potamogeton filifornis* L. also occur there. In summer the filamentous green alga (*Cladophora glomerata* (L.) Kutz) develop there. This type of habitat is dominated in the studied river reach;

H_4 – close to the river bank at a straight river section;
H_5 – typical reophilous habitat (Fig. 1).

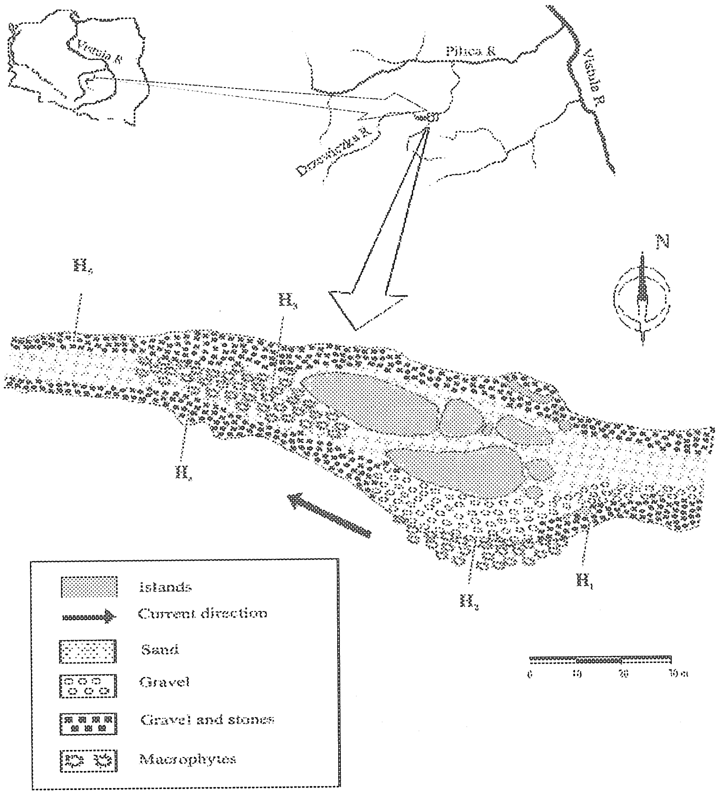

Fig. 1. Study area with marked habitats (H_n)

MATERIAL AND METHODS

Samples were collected in the Drzewiczka, downstream of Lake Drzewieckie, in three seasons: autumn (September 2000), spring (March 2001) and winter (February 2002).

In each habitat 5 samples (10×10 cm^2 of river bottom) were taken before (I) and after (II) water release, using a tubular sampler 10 cm^2 in cross section area. In each habitat, its depth, current velocity and area were measured.

On the basis of obtained samples the following characteristics were estimated:

– the population parameters of zoobenthos;

– scale of inorganic particle size classification. On the basis of these data the single inorganic substrate index (SI), was calculated;

– and amounts of benthic particulate organic matter (BPOM) were estimated. Using sieves and filters this organic matter was divided into two fractions: coarse (BCPOM > 1 mm) and fine particulate organic matter (BFPOM < 1 mm); see details in [5].

In order to estimate amounts of both fine (TFPOM) and coarse transported organic matter (TCPOM) three nets were mounted on 0.5×0.7 m frames and were 1.5 m in length; they were put into each habitat for ten minutes. To measure total amounts of transported organic matter (TPOM) triplicate water samples were collected in 10 l plastic bags. These samples were filtered through Whatman filters; see details in [2].

Periphyton was measured as chlorophyll *a* concentration using the Golterman et al. method; see details in [5].

All statistical analyses were carried out using CCS Statistica; see details in [5].

RESULTS

Discharge threefold increased in the river in autumn (from 4.74 $m^3\ s^{-1}$ to 8.27 m^3s^{-1}), fivefold in early spring (from 4.30 m^3s^{-1} to 11.52 m^3s^{-1}) and sixteenfold in winter (to over 41 m^3s^{-1}) (Fig. 2). This caused changes of numerous parameters, mainly depth and current velocity, which in turn affected the amount of transported and benthic organic matter. However, the changes varied from habitat to habitat.

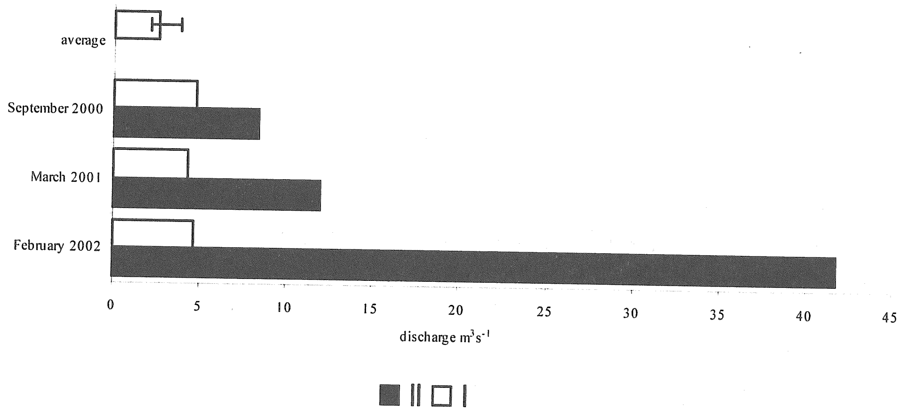

Fig. 2. Discharge of the Drzewiczka in September 2000, March 2001 and February 2002 before (I) and after (II) the water release

Of numerous river parameters current velocity and scale of inorganic particle size mostly affected the amount of organic matter. They determined both fractions of the particulate organic matter and periphyton (chlorophyll a) related to them.

Values of Pearson "r" correlation coefficient between the river's parameters are presented in Table 1.

Table 1. Pearson "r" correlation coefficient between abiotic and biotic parameters at the investigated habitats

Parameters			
Depth	FPOM***,	CPOM***,	chlorophyll *a****
Current velocity	FPOM***,	CPOM***,	chlorophyll *a****
SI	FPOM***,	CPOM***,	chlorophyll *a****

Significance level of correlation coefficient: *P < 0.05, **P < 0.01,***P < 0.001. SI – granularity of inorganic substrate index, FPOM – fine particulate organic matter, CPOM – coarse particulate organic matter, chlorophyll *a* – chlorophyll *a* concentration in periphyton

Results of ANOVA proved that changes in discharge caused translocation of inorganic substrate in each of the habitats except H_3. At habitat H_1 considerable differences in SI during each change of discharge (post-hoc Tuckey test) were observed, while at stagnant H_2 such a change occurred only after discharge increased sixteen times (depositing of sand). In turn, at a habitat close to the river bank (H_4) high flood washed out fine substrate (Tab. 2).

Table 2. A one-way ANOVA was used to determine significant differences of given environmental parameters between three terms of sampling in the Drzewiczka River (df = 5;24); df – number of degrees of freedom

Parameters	SI		FPOM		CPOM	
Statistics	F	P	F	P	F	P
Habitats						
H_1	6.486	0.001	9.771	0.000	4.848	0.003
H_2	5.600	0.001	3.596	0.014	13.775	0.000
H_3	2.203	0.087	1.635	0.189	2.290	0.078
H_4	11.915	0.000	6.858	0.001	14.911	0.000
H_5	13.802	0.000	10.724	0.000	11.407	0.000

Benthic fine particulate organic matter (BFPOM) was the dominant fraction analysed in the Drzewiczka habitats (Fig. 3). The amount of this fraction changed in all habitats except that overgrown by submerged macrophytes (Tab. 2, Fig. 3). The post-hoc Tukey test proved that results obtained at H_1 and at H_5 reflect differences between severalfold (autumn and spring) and ten and severalfold increase in discharge (winter). At H_4 no statistically significant differences between the first autumn, first and second spring, and first and second winter sampling occasions were detected (Fig. 3). In turn, no decisive tendency was recorded at H_1 – either washing out (in March) or depositing (in September) of BFPOM were noted; no changes during the highest discharge were detected (Fig. 3).

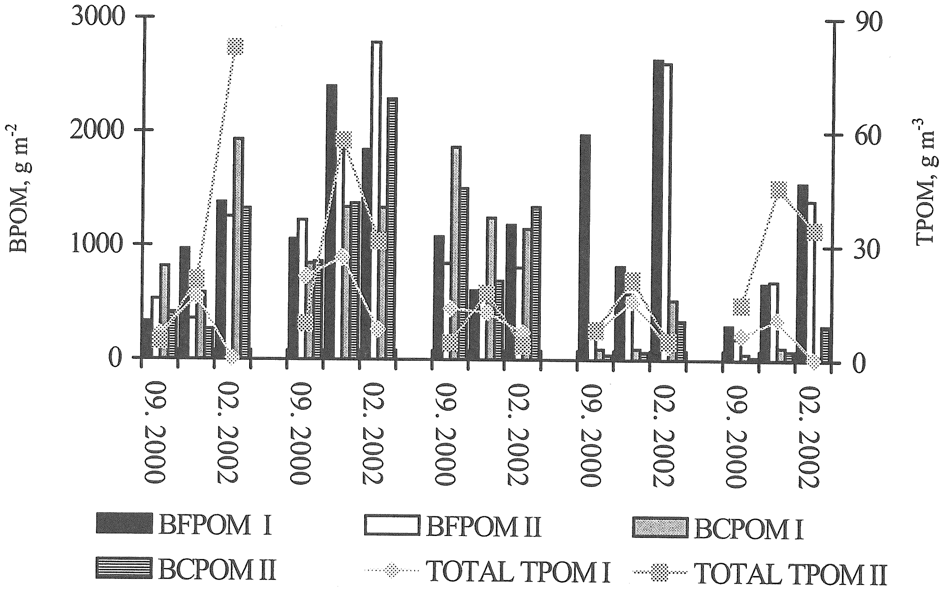

Fig. 3. Amount of fine (BFPOM) and coarse (BCPOM) organic matter at given habitats on given sampling occasions (I, II) in three seasons (bars) and of transported organic matter (TPOM – lines)

The ANOVA results proved that changes in discharge did not cause any translocation of benthic coarse particulate organic matter only at H_3 (Table 2). In the close to the margin and typically reophilous habitats no considerable cumulating of coarse organic matter (CPOM) occurred, both before and during discharge increase on each sampling occasion (Fig. 3). At H_2 threefold and fivefold discharge increase did not cause essential changes in amount of CPOM; it was as late as the February release of large water volume that resulted in coarse particulate organic matter depositing in the stagnant river meander. Another tendency was observed at H_1 – each change in discharge caused removal of benthic CPOM from this habitat (Fig. 3).

Each increased discharge caused increase in transported particulate organic matter (TPOM); the fine particulates (TFPOM) constituted over 99% of the whole TPOM (Fig. 3).

DISCUSSION

Because this river may be described as a mosaic of habitat patch-types the resistance of the major macrobenthic groups to the disturbance at five dominant habitats was estimated, including the levels of interannual variability in invertebrate communities and community changes in response to variability in environmental conditions of the Drzewiczka River. Besides, it is important that the results of some studies suggest that disturbance can contribute to lotic invertebrate patchiness [12]. In rivers, physical disturbances of the streambed occur during spates and floods; some lotic invertebrates may avoid the destructive effects of this kind of perturbation by sheltering in refugia [8, 14].

Heterogeneity in environmental conditions that appears due to changes in discharge, creates suitable conditions for the colonization and development of numerous organisms, thus increases diversity and abundance of the benthofauna. This patchiness of habitat distribution enables invertebrates to avoid the destructive effects of these disturbances by sheltering in refugia (these bottom fragments which are least hydraulically harassed) [7, 8, 14]. Refugia also play an essential role in the reconstruction (recolonization) of zoobenthos communities [11, 12].

In the Drzewiczka river section below the dam and below W-WSCT such a considerable mosaic of habitat patch-types due to multiannual discharge changes was determined. In each of them a slightly different reaction to the disturbance was recorded. The bottom surface overgrown by submerged macrophytes proved the most stable habitat. The paradigm in limnological hydrobiology [9] states that although aquatic plants do not constitute direct food resources for invertebrates, yet they impede water flow and circulation (in contrast to often unstable and unprotected bottom substrates), form one of the most important habitats for many invertebrates, chiefly because they offer relatively stable and deposit-free surfaces on which it is easy to forage and/or construct larval cases. Note that macrophytes have a mechanical role and offer additional surface areas allowing epiphytic forms to develop on them; these algae are major food resources for scrapers. In addition, submerged macrophytes are considered important refuges from predators and provide a heterogeneous substrate that allows co-existence. Finally, macrophytes may create favourable conditions for pelophilous zoobenthos by trapping fine particulate organic matter on the bottom [1, 6, 21]. Abundance and diversity of the epiphytic fauna is much dependent on the spatial structure of plants, among others, the shape of leaves [18]. A high stability (resistence to stress) of this Drzewiczka habitat, even in conditions of very high discharge (exceeding the median 16 times) testifies to essential function of plants in preventing inorganic substrate as well as particulate organic matter removal over the bottom at this habitat.

Also, the presence of emerged macrophytes belongs to factors that stabilize environment, at small (three- to fivefold) increase in discharge [2, 19]. However, a sixteenfold increase is enough to re-deposit in this stagnant habitat not only coarse and fine POM but also sand, thus essentially changing the composition of inorganic and organic substrate, and thus also conditions for invertebrate community (materials in preparation).

The majority of stream-dwelling macroinvertebrates live in close association with inorganic substrate thus the size of mineral particles fulfills an essential role for zoobentos [8, 16, 17]. Each change of inorganic substrate particle size results in serious consequences for organisms inhabiting them, as it was the case during the highest of Drzewiczka discharges. Sand was then re-deposited to each of the reophilous habitats. The altering of these habitats, which turned out to be a a catastrophic event for the benthofauna, was necessitated by the then planned dredging of the reservoir. For several years the Drzewiczka will have its natural discharge. Whether this mosaic section of the river that developed due to several decades of changing hydrologic regime will be preserved or not? Which of the distinguished habitats will display the greatest stability? The answers for these questions will be given by further investigations.

CONCLUSIONS

Patchiness of environmental conditions in the lowland Drzewiczka, the result of multiannual changes in discharge caused by two hydrotechnical constructions (dam reservoir and white-water slalom canoeing track), has led to a high diversity of lotic biota. Each habitat displays a slightly different resistance to changing stress; the highest stability (refugium?) was observed in the habitat overgrown by submerged macrophytes.

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MATERIA ORGANICZNA W NIZINNEJ RZECE O SILNIE MODYFIKOWANYM PRZEPŁYWIE
2. WYSOKOŚĆ PRZEPŁYWU A „OPORNOŚĆ" SIEDLISK

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S t r e s z c z e n i e. Celem odpowiedzi na pytanie, jaka wartość progowa przepływu wywołuje destabilizację dominujących siedlisk Drzewiczki, rzeki podlegającej silnym zmianom reżimu hydrologicznego, przeprowadzono „eksperyment" w trzech sezonach: jesienią, wiosną i zimą. Polegał on na dwu- trzytygodniowym okresie utrzymywania przepływu na naturalnym poziomie w ciągu całej doby, a następnie uwolnienia ze zbiornika dużej masy wody, która spowodowała od kilkukrotnego do ponadszesnastokrotnego przekroczenia tego poziomu, osiągając odpowiednio: 8,4 $m^3 \cdot s^{-1}$ we wrześniu 2000 roku, 12,0 $m^3 \cdot s^{-1}$ w marcu 2001 roku oraz 41,8 $m^3 \cdot s^{-1}$ w lutym 2002 roku; ten ostatni przepływ miał miejsce podczas całkowitego opróżnienia zbiornika, przed jego bagrowaniem. W każdym z siedlisk mierzono parametry morfometryczne, hydrauliczne oraz biotyczne przed i w czasie upustu wody. Trzykrotny wzrost przepływu (we wrześniu) spowodował destabilizację nieorganicznego podłoża, osadów organicznych i peryfitonu, tylko w siedlisku położonym najbliżej tamy i górskiego toru kajakowego, podczas gdy pięciokrotne zwiększenie przepływu (w marcu) zdeterminowało podobne zmiany parametrów w tym siedlisku oraz następnym, o gruboziarnistym podłożu i bardzo szybkim prądzie. Najwyższy przepływ (luty) był przyczyną destabilizacji podłoża, przy czym najmniejsze zmiany odnotowano w stagnującym przybrzeżnym siedlisku, porośniętym zanurzonymi makrofitami; siedlisko to można zatem uznać za refugium dla bentofauny.

Słowa kluczowe: rzeka, zmiany przepływu, podłoże, BPOM, TPOM