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Siltation disturbance in a mountain stream: aspect of functional composition of the benthic community

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Abstract

Background and Purpose: *Siltation is a recognized stress for the benthic community. It may cause changes in the structure of habitat substrate and water physical and chemical properties. The aim of this study was to ascertain the effects of siltation on the function of a mountain stream benthic community, specifically in respect to availability of food resources.*

Materials and Methods: *The study was carried out at Bistra Stream on the Medvednica Mountain in NW Croatia. Siltation was caused by quarrying. Samples were taken at a control (unsilted) site and three impact sites on four dates during the spring of 2006. Turbidity, water temperature, pH, oxygen content, conductivity and COD were measured and triplicate benthos samples were taken using a 30×30 cm Surber sampler on each sampling date. Impact of siltation on functional feeding guilds was analyzed.*

Results and Conclusions: *Turbidity, pH and temperature increased significantly downstream of the siltation source. Total number of individuals decreased by 85%, number of taxa by 60% and Shannon's diversity index followed accordingly (by 56%). The grazers and the detritivores were proven to be most sensitive to the disturbance. The disturbance did not strongly affect shredders whereas predator abundance increased. We conclude that change in food availability is a crucial aspect of siltation disturbance and that allogenic siltation is more devastating because of the additional chemical changes not noted during natural siltation.*

INTRODUCTION

Siltation is a stress caused by excess input of fine sediments in streams. It can be caused by natural sediment erosion and settlement or anthropogenic (e.g. tampering with watercourses or mining) *(1, 2)*. The settling of fine particles on a natural substrate is the most obvious stress and it is an overwhelming one for the native fauna *(3, 4)*. Such stress may disrupt functional composition of the macroinvertebrate fauna on several levels. Stream metabolism can be disrupted by reducing the abundance of primary producers and hence availability and quality of food for some macroinvertebrates (grazers) is degraded *(5, 6, 7)*. Increased amount of suspended particles may hinder the feeding of filterers by clogging or even damaging and destroying their feeding appendages or nets.

Burrowing detritivores may be less affected by such disturbance. However, most of the detritivore fauna are represented by oligochaetes which permanently reside in the stream and cannot evade the stress, while other functional feeding guilds (FFG) are mostly represented by insects which leave the stream at adult stage and may partly avoid this stress *(4)*. In addition, general changes such as interstices filling, covering of the natural substrate, changes in water chemistry as well as temperature increase due to increased turbidity, are likely to be stressful for most taxa regardless of their life history and environmental preferences *(8, 9, 10)*.

It was our aim to investigate the anthropogenic long-term siltation effects on the functional feeding guild composition of the benthic macroinvertebrate community.

We expected: 1) a decrease in overall benthos abundance in respect to intensity of siltation and 2) dramatic change in functional composition of the benthic community, especially in respect to the filterer and grazer fauna. Most of the work to date was done either on natural siltation and work on anthropogenic siltation was carried out omitting the functional aspect of fauna *(3, 4, 5, 9, 10, 11, 12)*.

MATERIALS AND METHODS

Study area

The study was carried out at Bistra Stream on the Medvednica Mountain (NW Croatia). The spring is situated on green schist (Devonian) at 820 m a.s.l. The siltation is caused by a quarry located at a section with igneous rocks approximately 3 km downstream from the spring. Upstream of the quarry Bistra is a typical mountain stream of the temperate region with a cobble-pebble bed and thick riparian canopy. Downstream of the quarry it becomes turbid and silted with particles from the diabase excavation.

Four sampling sites were chosen: 0) upstream of the quarry (control), 1) immediately after the quarry, 2) approximately 1.5 km downstream and 3) approximately 3 km downstream.

Sampling and data analyses

The sampling was carried out at the peak of macroinvertebrate life cycles and of the siltation by the quarry, on four dates during the spring (May and June) of 2006. Physico-chemical parameters were measured *in situ* using respective probes (pH – WTW 330i, conductivity- Hach Sension 5, temperature and dissolved oxygen content- WTW Oxi 96). Further water analyses were carried out in a laboratory (COD using $KMnO_4$ equivalency titrimetric method and turbidity using SiO_2 equivalency spectrophotometric method; the turbidity was considered an indicator of the overall siltation).

Benthos samples were taken using a 30×30 cm Surber sampler (mesh size 300 μm). A mean of triplicate was used as a single data point for a given date. Specimens were identified to the lowermost taxonomic level based on respective keys for: Gastropoda *(13)*, Trichoptera *(14)*, Plecoptera *(15)*, Ephemeroptera *(16)*, Diptera *(17)* and Coleoptera (18). Subsequently they were classified to the FFG *(19)* (Table 1). Abundance of respective FFG was calculated per square meter. FFG that amounted to less than 1% of the community were omitted. Additionally, diversity measures were also analyzed (Shannon's diversity index, total number of individuals and taxa).

The Mann-Whitney U test was used to reveal the differences in studied variables between sites. A non parametric two-independent-group test was chosen because of the low number of data points for which normality cannot be established. Moreover, control values were several times higher and consequently the changes among the impact sites would not be revealed using a multiple-independent-groups test. Spearman's correlation coefficient was used to link the changes of biotic variables to the changes of abiotic parameters only for those parameters that were proven to change significantly among the four sites. Borderline significant ($0.05<p<0.09$) changes will be reported and subsequently interpreted to avoid type-two errors in result interpretation as suggested for smaller data sets *(20)*. Canonical correspondence analysis (CCA) was used to ordinate the changes of biotic variables with respect to abiotic variables. CCA was performed on 16 data points for 6 taxa and 4 environmental variables. Data were log transformed.

RESULTS

Turbidity, pH and temperature were higher downstream of the quarry and dissolved oxygen content, COD and conductivity values were lower (Table 2). Chemical and physical properties of water did not differ significantly among the sites 1, 2 and 3 located downstream of the quarry.

The effect of the siltation on functional composition was most evident in the sites near to the disturbance source and all the FFG increase in abundance site 3 (Figure 1). However, the proportion of the increase was not universal. Grazers and detritivores recovered the least,

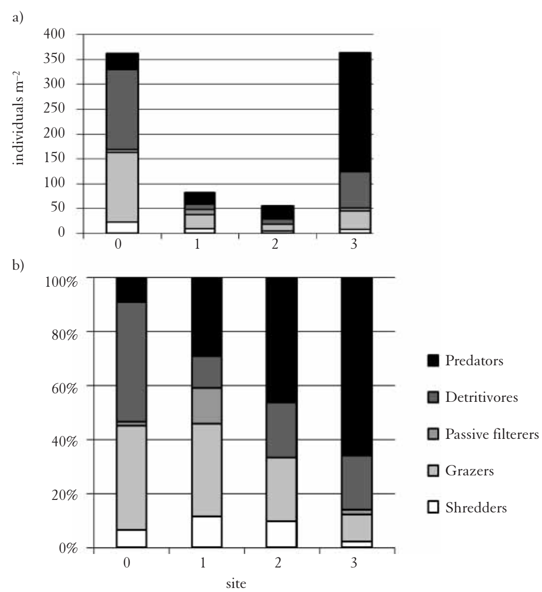

Figure 1. *Changes in benthic macroinvertebrate community along the study reach; a) total abundances; b) ratios.*

passive filterers attained the original abundance as at the control site, while the predator fauna exhibited a dramatic increase compared to the abundance at the control site. The ratios among the FFG therefore changed significantly along the studied stream reach (Figure 1 b). Predator ratio increased continuously along the stream reach, while shredders ratio increased at first but then decreased downstream. Conversely, detritivores ratio decreased and then started to recover. The decrease in grazer abundance was continuous along the affected stream reach.

Generally, the disruption was most severe at site 2. At the farthest studied site the abundance of macroinvertebrates recovered to the initial value. However, the number of taxa and Shannon diversity remained lower than the control even at the most distant site.

The correlation index revealed that the grazers were negatively affected by increase in pH and turbidity, the detritivores were negatively affected by increase in pH, turbidity and temperature and shredders were negatively affected by increase in temperature and turbidity (Table 3).

TABLE 1

Percentages of total catch that were assigned to given FFG for each taxon according to Moog (2002).

Taxon	Shredders	Grazers	Active filterers	Passive filterers	Detritivores	Predators
Gastropoda						
Bithyniidae		30	50		20	
Hydrobiidae		100				
Oligochaeta					100	
Amphipoda						
Gammarus fossarum	70	10			20	
Ephemeroptera						
Baetis		50			50	
Ecdyonurus		50			50	
Ephemerella		50			50	
Paraleptophlebia					100	
Rhithrogena		100				
Plecoptera						
Brachyptera		70			30	
Perla		10				90
Protonemura	50	30			20	
Trichoptera						
Agapetus		80			20	
Beraea	20				80	
Glossosoma		80			20	
Hydropsyche		20		50		30
Rhyacophila						100
Coleoptera						
Cyphon					100	
Hydraena		100				
Oulimnius		100				
Diptera						
Liponeura		100				
Tonnoiriella	40	40			20	
Athericidae						100
Empididae						100
Pediciidae						100
Simuliidae				100		
Tanypodiynae					20	80

TABLE 2

Changes in physical, chemical and biotical parameters along the study reach. Mean values ± SD are given. Variables that changed significantly compared to control values are marked *, borderline significant are marked +.

Site		0			1			2			3	
Turbidity	0.112	±	0.015	0.236	±	0.082 *	0.170	±	0.027 *	0.162	±	0.044 +
pH	7.94	±	0.09	8.13	±	0.07 *	8.12	±	0.10 *	8.04	±	0.15
Temperature	10.9	±	1.9	15.2	±	2.1 *	13.9	±	2.9 *	14.5	±	3.8 *
Oxygen	10.02	±	1.02	8.99	±	0.70	9.68	±	0.84	9.03	±	0.89
COD	1.90	±	0.78	1.62	±	1.05	1.62	±	0.96	1.72	±	1.07
Conductivity	229	±	11	226	±	16	226	±	18	224	±	19
Total abundance	363.9	±	241.1	83.3	±	55.6 *	55.6	±	32.7 *	363.9	±	240.4
Taxa	15	±	7	6	±	11 *	4	±	2 *	7	±	2.5 +
H'	3.17	±	0.32	2.35	±	0.34 +	1.39	±	1.03 *	1.80	±	0.57 *
Shredders	23.6	±	11.7	9.7	±	8.3	5.6	±	7.9	8.1	±	13.3
Grazer	140.3	±	80.4	28.6	±	20.9 *	13.1	±	14.7 *	37.5	±	20 *
Passive filterers	5.6	±	11.1	11.1	±	18.7	0.0	±	0.0	5.6	±	11.1
Detritivores	160.3	±	146.1	9.7	±	5.5 *	11.4	±	8.7 *	73.3	±	32.2
Predators	32.8	±	24.5	24.2	±	27.9	25.6	±	15.4	239.4	±	205.9 *

TABLE 3

Correlations (Spearman) between the chemical and physical and biotic community parameters. Bold are significant, bold italicized are borderline significant.

	pH	Temperature	Turbidity
Shredders	0.06	*–0.47*	–0.54
Grazers	*–0.48*	–0.30	–0.51
Passive filterers	0.39	0.14	–0.25
Detritivores	–0.55	*–0.45*	–0.59
Predators	0.09	–0.36	–0.31
Taxa	–0.33	–0.52	–0.62
H'	–0.37	–0.30	*–0.44*
Total abundance	–0.26	–0.37	–0.71

The CCA ordination reveals the combined negative effects of changed pH, turbidity and temperature on the studied FFG and on diversity measures (Figure 2). The first axis was highly correlated with the pH (R=–0.84) and axis 2 with both the turbidity and temperature (R=0.64 and 0.67 respectively). Comparing the lengths of the environmental vectors we conclude that changes in these three factors are the most important in community structuring.

Grazers and detritivores are both in the plane opposite the pH vector, revealing that pH change affected these FFG negatively. Detritivores were additionally negatively affected by the temperature increase. Shredders were affected by the combination of increased temperature and turbidity. The results for the passive filterers sug-

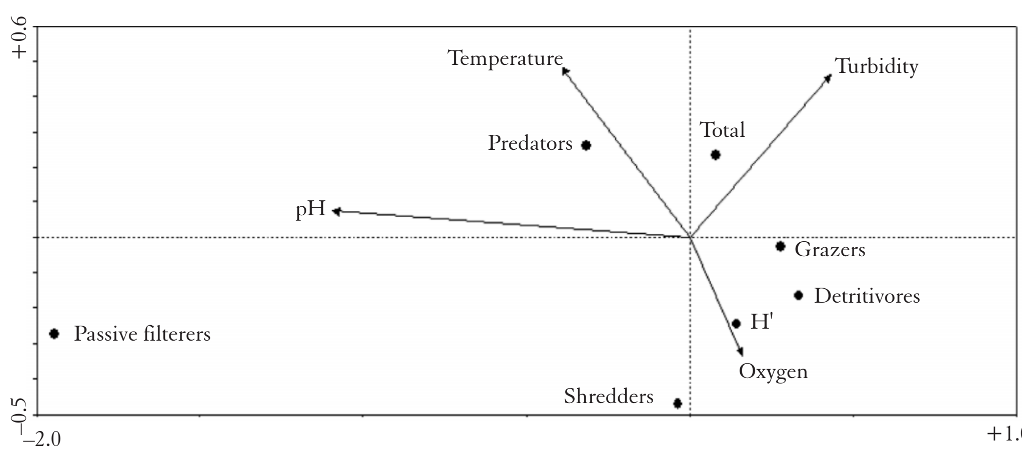

Figure 2. *Canonical correspondence analysis of selected biotic and abiotic variables at Bistra stream. Axis 1 Eigenvalue = 0.079; axis 2 Eigenvalue = 0.029; total inertia = 0.199; variance of species-environment relation explained: 92.8 %.*

gest that the increased amount of suspended particles affected them negatively. However, since their total abundance was low and the fact that none were found at site 2 this result should be taken cautiously. The predators seem to thrive under the increased pH and temperature.

DISCUSSION

All of the changes in water properties can be attributed to the siltation. The turbidity increase was a result of the rinsing of the material and of particles settling from air. Turbid water accumulates more solar energy especially at the non-shaded section of the stream within the quarry where the channel is broadened for purposes of rinsing the extracted diabase and the increase in pH was previously connected to quarry siltation *(9)*.

The intensity of disturbance is indicated by 85% loss of abundance immediately downstream of the quarry and 60% less taxa 1.5 km downstream of the disturbance source. Similar changes during siltation stress (64% less abundance and 40% less taxa) were previously recorded *(21)*. We attribute more severe disruption in our study to the prolonged and allogenic nature of disturbance in our study causing additional chemical changes *(9)*.

The grazers are the most affected overall. Their abundance decreased the most and their recovery is least downstream of the disturbance source. The suspended particles limit their food resources by eroding the substrate (at fast flow) on the one hand and by covering the substrate surface (at slow flow) on the other, thus changing the stream metabolism *(2, 6)*.

The decrease in abundance of the detritivores was most instantaneous as their abundance decreases the most immediately downstream of the disturbance. However, the scope of the decrease of detritivore abundance was unexpected as they inhabit the interstices and their food source is also located within the substrate so one might expect that the siltation would not impact these animals so severely. Nevertheless, the siltation hinders the food availability when particles clog the interstices *(4, 7, 22)*.

In some studies increase in the abundances of Ephemeroptera and Oligochaeta was reported in response to higher (autochthonous) fine sediment loads *(1, 2)*. However, since Ephemeroptera and Oligochaeta (as well as other taxa) were proven sensitive to changes in pH and temperature (*22*) we again propose that the allogenic nature of disturbance is the crucial reason for difference in our findings.

Shredders do not appear to be as affected by the chemical and physical changes. Their abundance decreases the least. We suggest that abundance of food surmounts the negative chemical and physical impacts caused by the quarry effluent. Leaf litter is abundant because the stream is surrounded by dense deciduous canopy and the *Gammarus fossarum* and *Protonemura* sp. prevail.

Passive filterer taxa are known to be sensitive to siltation disturbances *(3, 4)*. Even though the results of our study generally confirm such findings, these results should be taken cautiously because their abundance was very low along our study reach.

Continuous increase in the abundance of predators to such an extent that they amount to more than 60% of the community at the final site, confirms that the community is severely disrupted. We propose that the disrupted community may be easier to prey on and this is the reason why the predators thrive during the disturbance. Additionally, the predators here are represented by an eurivalent taxon (*Tanypodinae*) which can tolerate wide physical and chemical changes.

We conclude that limiting food resources is an important aspect in considering siltation effects and that allogenic siltation is more devastating for all stream macroinvertebrates, due to the chemical changes that are not evident in natural siltation.

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