Biharean Biologist (2009) Vol. 3, No.1, Pp.: 59-70
P-ISSN: 1843-5637, E-ISSN: 2065-1155 Article No.: 031110

Studies upon the structure and dynamics of the benthic macroinvertebrate communities from two habitats of The Ier River's Channel (Bihor county, Romania)

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Abstract. The aim of the present study was to describe the structure and dynamics of the macrozoobenthic communities on a sandy and muddy substrate from Ier Channel, in order to show the importance of the composition of the substratum in the macrozoobenthic community settlement. During the study period (May-October 2006) we identified 43 species and 884 individuals of benthic organisms, especially Gastropoda and insect larvae. The number of species and individuals exhibited high variability on the sandy substrate. Groups with high density were Gastropoda, Trichoptera and Chironomidae larvae. The most frequent groups were Hirudinea, Gastropoda, Bivalvia and Chironomidae larvae. The most abundant species were found to be tolerant to water pollution and the sensitive groups were missing. The diversity indices showed a more diverse community on the muddy substrate and the value of the IBGN index revealed a poor water quality.

Key words: benthos, macroinvertebrates, community structure, habitats, sandy substrate, muddy substrate.

Introduction

The Ier Valley is situated in the north-western part of Romania, crossing Bihor and Satu-Mare Counties. It is a tributary of Barcău River and a component of the Crişuri rivers system. In the past the whole region was a marshy area, but in the ’60s it had been drained and since the land has been using for agriculture. Now the Ier Valley is only a channel with dyked banks with a linear flow. The dyke was made to avoid floods in rainy periods of the year.

The studies concerning Ier Valley are numerous and includes geomorphologic (Benedek 1960), geographic (Borbély et al. 2004) botanical (Ardelean & Karácsony 2002, 2005, Benedek 1996, Bezdek 1910) and faunistical ones (Covaciu-Marcov 2001-2002, Covaciu–Marcov et al. 2003a,b, Sas et al. 2006, Wilhelm 1984, 1987, 1998).

The benthic macroinvertebrate community has an important role as water quality indicator because the invertebrate species from benthos have different environmental requirements and many species are sensitive to pollution or water quality modification. Also the macrozoobenthic invertebrates are an important trophic base for different fish and amphibian species, especially newts.

Investigation of the macrozoobenthic fauna can show us the diversity of this community, the quality of the water and help us to make recommendations about the conservation measures for this particular, anthropically affected ecosystem.

Despite these numerous studies the benthic macro-invertebrates of this river were never investigated. The main aim of our study was thus to describe the structure of the benthic macroinvertebrate community from two different substrates, sandy and muddy, which are characteristic for the Ier Channel.

Materials and methods

Study area

The Ier River is a right side tributary of Barcău River, and both are part of the Crişuri rivers system. It flows through Careiului Depression to south-east. It has a very small slope and along its course there are many stagnant waters localized in a sandy area (Fig. 1). The Ier flows into Barcău River on the territory of Hungary at 9 kilometres from the Romanian-Hungarian border. Its hydrographical basin is relatively big, about 1437 km^2 and the river is 107 km long. The springs enter the Şimleului Depression and reach Sărmăşagu Nou Village. Not far from its spring it receives water from Crasna River through a channel. This sector of the Ier River is embanked to avoid flowing into the Crasna River during the flooding periods. The Ier River was diked from Diosig to the border (Ujvari 1972).

In the study area the river is 4-5 m wide and has a depth between 1.5-2 m. The thickness of the substratum is between 0.75-1 m in the muddy region and about 0.5 m in the sandy area. The water flows slowly, except the rainy periods when its speed is higher and floods the nearby agricultural fields (Fig. 2).

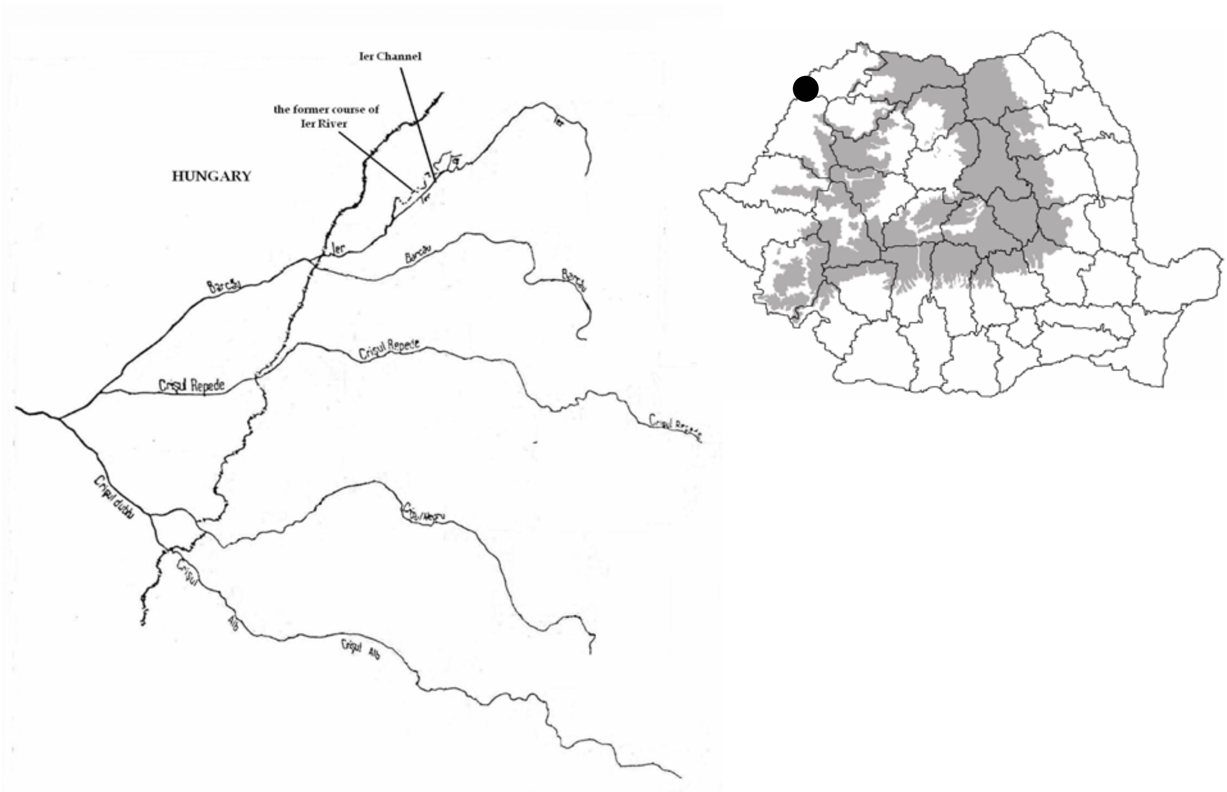

Figure 1. The position of Ier Channel in Crişuri rivers system and the study area.

Figure 2. The Ier River's Channel in the studied region.

The vegetation of the river banks consists of trees as *Salix alba* and herbaceous plants as *Phragmites communis*, *Typha latifolia*, *Carex riparia*, *Iris pseudacorus*. The most important aquatic plants are: *Sagittaria sagittifolia, Butomus umbellatus, Cicuta virosa*, *Potamogeton natans*, *Myriophyllum verticillatum, Ceratophyllum demersum*, *Elodea canadensis*. The aquatic vegetation is better represented in the muddy than in the sandy bottom portions of the channel.

Field methods and data analysis

The sampling sites were located in the middle course of the Ier Channel, one on a sandy and the other on a muddy bottom portion. Samples were collected monthly from each site from May to October 2006 with a Surber bottom sampler, preserved in field with 4% formalin, labelled and transported to the laboratory.

Some gastropod species as *Planorbis corneus, Viviparus viviparous, Limnea stagnalis*, bivalve species *Anodonta cinerea* and *Unio pictorum* and crustaceans (*Astacus leptodactylus*) were determined at the sample sites without preservation and then released back in their environment.

In the laboratory the samples were sorted under a 40X magnifying stereomicroscope and transferred in 70% ethylic alcohol. Specimens were determined to the species level using guides for different invertebrate groups (Stoica-Godeanu 2002, Chiriac & Udrescu 1965). The following statistical parameters were determined: relative abundance, frequency, Margaleff diversity index (D), Simpson diversity index (I), inverted Simpson index (I^{-1}), Shannon-Wiener diversity index (H) and evenness (E) (Sîrbu & Benedek 2004).

To assess the water quality of this river bend we determined the value of the IBGN index (L'Indice Biologique Global Normalisé (IBGN) 2007) for both substrates.

Results

In the study period (May – October 2006) there were identified a number of 43 species, 29 on muddy substrate and 34 on sandy bottom, totalising 884 specimens, 409 from muddy and 475 from sandy bottom (Appendix 1).

The number of species on the sandy substrate varies between larger ranges (9-18 species) comparatively to the muddy substrate (12-16 species). The same variability can also be observed for the number of individuals: on sandy substrates between 16-262 individuals and on muddy 51-84.

The density of species is not very high, for most of them is under 1 specimen/m^2. Only a few species as *Erpobdella octoculata, Viviparus viviparus, Asellus aquaticus, Ephemera danica, Hydropsyche angustipennis* and the Chironomidae larvae have higher densities in some period of the study.

The most abundant species were the same as the most dense ones (*Erpobdella octoculata, Viviparus viviparus, Asellus aquaticus, Ephemera danica, Hydropsyche angustipennis* and the Chironomidae larvae). The Oligochaeta have low abundances and in some months they are missing especially from the sandy substrate. The Hirudinea species are abundant especially in the summer period (June, July) and were found mainly on muddy substrate also. Among the gastropod species the most abundant are *Planorbis corneum* and *Viviparus viviparus,* which were found in every period on both substrates. The rest of the gastropod species have lower abundances and they are not present during the whole study period. The bivalve species have lower densities; one of the found species *Unio pictorum* is protected. The Acarina, Decapoda and Collembola appeared with only one species and just once along the studied period. The Amphipoda are rare, with low abundances and were present only in spring and early summer period, but the Isopoda have high densities and were present almost during the whole study period on both substrates.

From the Ephemeroptera species *Ephemera danica* has the highest densities and was found almost in every month. The rest of the ephemeropterans were found accidentally with low densities. The Odonata species have low densities and excepting *Ischnura elegans* they were found accidentally.

From the Trichoptera species *Hydropsyche angustipennis* is the densest and also frequently found. The Heteroptera and Coleoptera species have small densities and also low frequencies. The Chironomidae have high densities especially in the summer period and were found during the whole study.

The frequency of species is relatively low, a small number of groups are euconstant (11 on muddy and 6 on sandy substrate) and there are no constant species just a great number of accessory and accidental species. As euconstant species on both substrates it can be mentioned the Chironomidae larvae, Isopoda, *Unio pictorum* and several gastropod species. On the muddy substrate are euconstant the Oligochaeta, *Erpobdella ocotculatta, Ephemera danica* and *Ischnura elegans*. On sandy substrate *Hydropsyche angustipennis* is euconstant together with the species mentioned above as constant on both substrates (Appendix 2, Fig. 3).

The Margaleff diversity index has higher values in four periods of the study (May, June, July, September) for sandy substrate than in muddy and in the rest of the months is greater for muddy substrate. The inverted Simpson index takes greater values for sandy substrate than for muddy in May, July and September (Appendix 2). But the Shannon-Wiener index has the highest values for muddy substrate except September (Appendix 2, Fig. 4). The evenness is relatively high especially in May, July and September for sandy substrate and for muddy substrates in rest of the studied periods (Appendix 2, Fig. 5).

The IBGN index value ranges between 5 and 8 which means the water quality is poor.

Discussions

The study area is situated in a strongly anthropically affected sector of the river Ier, which was dyked to avoid floods and to allow agricultural activities in the fields nearby. The anthropic activity has great effects on the aquatic ecosystems because it modifies the physical habitat together with the biological community and the ecological functionality (Principe et al. 2007). Anthropization determines a simplification of the benthic community and a substitution of the species with ones tolerant to habitat degradation (Tullos 2006). The macrozoobenthic community structure found in the Ier Channel is very similar with those from lower sectors of other rivers from Romania, for example Mureş in the territory of Lunca Mureşului National Park (Battes & Pavelescu 2006). This resemblance is due to the fact that most of the Romanian rivers, particularly from the western part of the country (Barcău, Crişul Repede, Crişul Negru, Crişul Alb, Mureş, Bega) are dyked in the lower sectors to avoid flooding. Embankment leads to a great uniformity of the habitats in the river substrates because this channel like form modifies the hydrology especially by increasing the flowing speed of the water. This greater speed causes a strongly washout of river bed in the rainy periods particularly in small rivers like Ier. The habitat of the benthic community is a dynamic entity in space and time determined by structural and hydrological elements (Maddock 1999). The washing out of the substratum during rainy periods leads to a permanent modification of the habitats and to a relatively instability of the macrozoobenthic communities, because the benthic organisms are directly influenced by the architecture and the type of the substratum (Robson & Barmuta 1998). The benthic invertebrates are good indicators of habitat loss and pollution because they have limited migration possibilities and they cannot escape from pollution (Horne 2003).

The greater number of species and individuals on the sandy substrate is due to the fact that on the muddy substrate in the summer period the decomposition of organic substances in the substratum creates oxygen deficit which is doubled by the decrease of dissolved oxygen together with the increasing of water temperature (Tura et al. 2006) and the respiration of the submerged aquatic plants which are abundant here. Very similar macrozoobenthic structure were found in other rivers too, particularly in lower sectors (Andriev et al. 2008, Galdean et al. 2001) or in lakes (Yildiz et al. 2005) due to the sedimentary substrate of these regions.

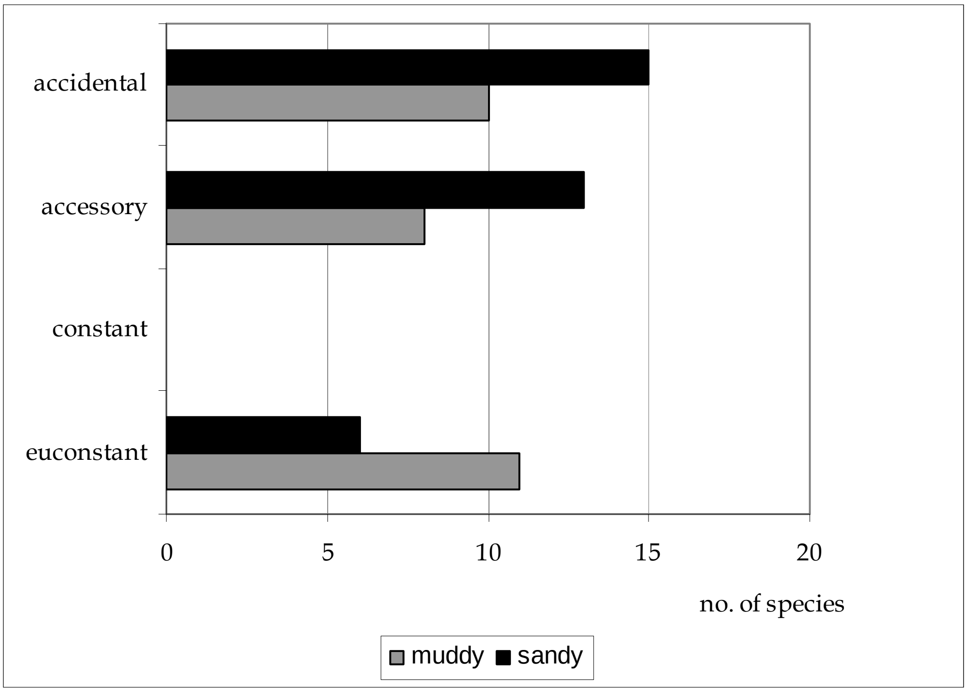

Figure 3. The constancy of species on the investigated substrate.

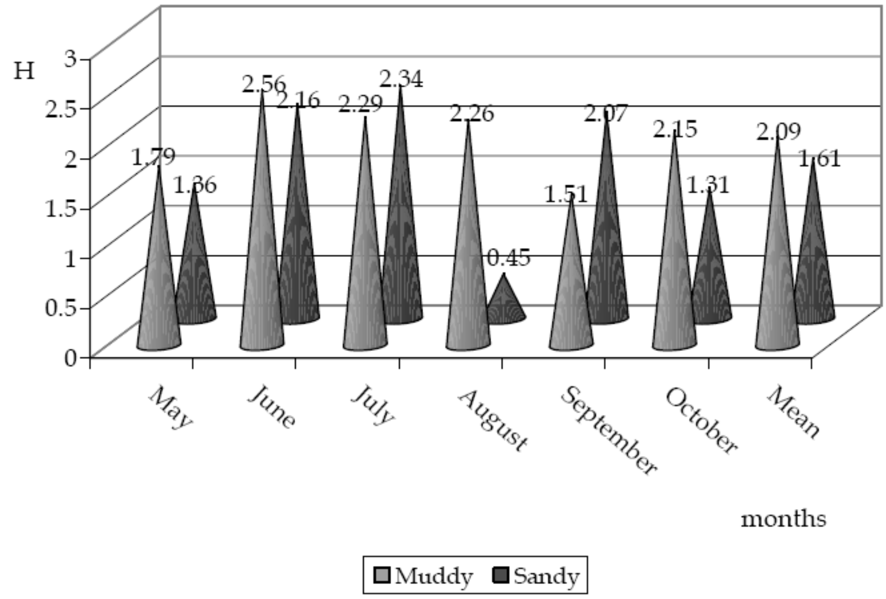

Figure 4. The Shannon-Wiener diversity index (H) values.

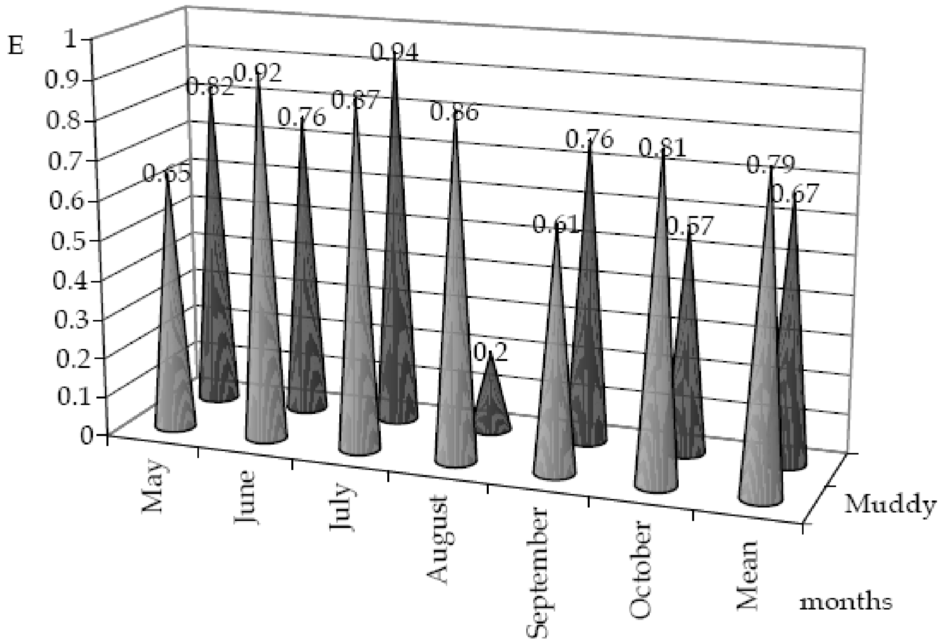

Figure 5. The evenness index values.

The relatively low density of individuals can also be explained by the great uniformity of the substrates, the variation of the flow during rainy and dry periods of the year, usually the density of benthic invertebrates decreasing together with the decrease of the flow rate (Wills et al. 2006). In the rainy periods the increasing of the density is due to the greater quantity of organic matter in the substrate brought here by the water from upper sectors or from the banks and also by the tendency of the invertebrates to conglomerate in those substrate portions where they are protected from the current (Callisto et al. 2001). This is not a general rule, there are situations in rivers when benthic organisms cannot protect themselves against the current and are washed out from the substratum in the rainy periods. In these situations, characteristic especially to small rivers, the density of individuals and the number of species are greater in the dry periods of the year (Callisto et al. 2004).

The number of individuals on the muddy substrate has a smaller variation during the year because this kind of substrate provides a greater quantity of organic substances than the sandy substrate, which ensures the trophic base for most invertebrates. Also, the existent submerged vegetation is a refuge for species and decrease the flowing speed of the water preventing thus the wash out of benthic organisms. In the muddy substrate the invertebrates are distributed more uniformly than on the sandy substrate which offers scarce food resource and determine the crowded distribution. The trophic base offered by the sandy substrate cannot support very dense populations.

The density of the individuals on muddy substrate is higher in the early summer period, (May, June) and also in early autumn (September) when the temperature of the water is not too high and the decomposition of the organic substances and the water temperature do not induce oxygen deficit in the substratum. In August which is the warmest month, the density on muddy substrate decreases because of the oxygen deficiency in the substratum. The decrease of the density in October is a normal process owed to the seasonal activity of the invertebrates and it was also observed in other rivers (Celik 2002).

The presence of Oligochaeta and Hirudinea in the lower sector of the rivers, in polluted areas or on substrates rich in organic substances is very common in other rivers too (Andriev et al. 2008; Tura et al. 2006). These species indicate the organic pollution.

The great abundance of Gastropod species which are scrappers shows a well developed periphytic community especially on muddy substrate where they are present mostly on the submerged vegetation.

The Bivalve species can survive on muddy substrate as well as on sandy ones because this is a lotic environment and the water flow ensures the necessary oxygen for their living. In water bodies where the Oligochaeta species are well represented the Bivalve species are supplied with oxygen by the body movement of the Oligochaeta. The feeding activity of Bivalve enriches the sediments with organic substances which are easily broken down by the Oligochaeta (Galdean et al. 2001).

Concerning the insect larvae groups, it can be seen that the Plecoptera are missing and this is a clear sign of water pollution, they being the most sensitive insect group and the first that disappears in a polluted river sector (Mare-Rosca et al. 2008).

Ephemeropterans are more resistant than plecopterans and have representatives which are resistant to pollution like Baetidae, Caenidae (Mare Rosca et al. 2008), also generalist species, found on erosional and sedimentary substrates (Callisto et al. 2004) and they can feed on organic particles in suspension (Galdean et al. 2001). They can predominate on the lower course of the rivers in rifle areas (Baptista et al. 2001). Ephemeropterans are also common on sandy substrates (Galdean et al. 2001) observed by us too, during the study.

Odonate larvae have small density because they are predators and the food resources offered by this river sector cannot sustain a dense population. They prefer slow current (Baptista et al. 2001), so they are looking for shelter in rainy periods (like October).

From trichopterans, abundant are the pollution resistant species as the Hydropsychidae (Kazanci & Dugel 2000). This order is one of the most affected by anthropic activities (Ailenei 2005), the water flow rate (Wills et al., 2006) and by pollution (Mare Rosca et al. 2008). We found *Hydropsyche angustipennis* both on muddy and sandy substratum. They are common on both substrata because they are filterers and thus favoured by the presence of suspensions in the water (Galdean et al. 2001).

There are few Heteroptera species, with small densities although they prefer sedimentary substrata (Baptista et al. 2001) but a greater number of species can be found characteristically at higher altitudes (Ilie 2004).

Coleopterans were found only on sandy substrate, preferred by them (Galdean et al. 2001), with a small number of species because they need submerged vegetation and a constant flow rate of the water to establish well represented communities (Cojocaru 2005). The habitat conditions in this river sector and also the scarce trophic base limit the development of coleopteran species.

Chironomidae are the most constant species and also very abundant. Their presence is very common in lower sectors of the rivers (Battes & Pavelescu 2006) and also in polluted river stretches (Andriev et al. 2008, Tura et al. 2006). The Chironomidae have greater abundance on the sandy substrate which they prefer (Baptista et al. 2001, Galdean et al. 2001). In August they reached the highest abundance probably due to the emergence of a new larval generation from eggs laid down by adults during the summer months.

The diversity indices that assess the number of species and individuals (Margaleff and Simpson) showed a greater diversity for sandy substrate for most of the studied periods because here there was found a larger variation in the number of species and individuals than on muddy substrate. The Shannon-Wiener index which evaluates the heterogeneity had greater values for muddy substrate except September. The muddy substrate offers a more diverse habitat because of the present submerged aquatic plants and also a richer trophic base for organisms due to the higher organic content compared to the sandy substrate.

The value of the IBGN index is low because of the absence of the sensitive species especially from groups like Ephemeroptera, Plecoptera and Trichoptera larvae which are the first affected by pollution (Mare Rosca et al. 2008, de Barruel 2003). We found in the Ier channel mainly pollution tolerant species.

The investigated area of the Ier Channel showed a great uniformity of substrates in the sandy portion which determines the existence of a not very diverse macrozoobenthic community compared to that established on the muddy substrate which is more variable. The quality of the water is poor, the sensitive species are missing and this is partially due to the embankment of the river which causes a laminar flow, with a high speed especially in rainy periods, a great quantity of suspensions in the water and oxygen deficiency in the substrate during the warm period of the year. The hydrological conditions and the human impact on the Ier Channel determine a great vulnerability of the very uniform benthic community that can be washed out from substratum by heavy rains and the river zone will be slowly recolonized from upstream sectors.

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Submitted: 16 November 2008
/ Accepted: 07 April 2009

Published Online: 04 May 2009

Appendix 1. Density (N/m²), number of species and specimens of macrozoobenthic invertebrates in the two habitats during the study period

No. of species	Species	Sampling months																	
		May		June		July		August		September		October		Total		Mean density		Group density	
		Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand
1	**Oligochaeta -** Lumbricidae	-	0.2	0.4	-	0.2	0.2	0.4	-	0.2	0.4	0.2	-	1.4	0.8	0.23	0.13	0.23	0.13
	Hirudinea																		
2	*Erpobdella octoculata*	0.2	0.4	1.2	2	2.2	0.6	0.4	-	0.6	-	0.6	-	5.2	3	0.86	0.5	0.96	0.66
3	*Glossiphonia complanata*	0.2	0.2	0.2	0.4	-	0.4	-	-	-	-	-	-	0.6	1	0.1	0.16		
	Gastropoda																		
4	*Bithynia tentaculata*	-	-	-	0.2	-	-	0.4	-	-	0.4	0.2	0.2	0.6	0.8	0.1	0,13		
5	*Anisus spirorbis*	-	-	-	-	-	-	-	-	-	-	0.2	-	0.2	-	0.03	-		
6	*Gyraulus albus*	-	-	-	0.2	-	-	-	-	-	-	-	-	-	0.2	-	0.03		
7	*Physa fontinalis*	-	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.03		
8	*Physa acuta*	-	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.03	3.19	1.17
9	*Planorbis corneum*	0.4	0.2	0.6	0.4	1	0.2	1.4	0.6	0.8	0.2	1.2	0.4	5.4	2	0.9	0.33		
10	*Valvata piscinalis*	-	-	0.4	0.2	-	-	0.4	-	-	0.6	0.2	0.4	1	1.2	0.16	0.2		
11	*Viviparus viviparus*	1.2	0.2	1	0.4	1.4	0.2	1.2	0.4	1.6	0.6	1.4	0.4	7.8	2.2	1.3	0.36		
12	*Limnea stagnalis*	0.4	-	0.6	0.2	1.2	-	0.4	-	0.6	0.2	1	-	4.2	0.4	0.7	0.06		
	Bivalvia																		
13	*Anodonta cinerea*	0.8	-	1.2	0.2	1	-	0.8	-	1.4	0.2	0.8	-	6	0.4	1	0.06	1.66	0.42
14	*Sphaerium corneum*	-	-	-	0.2	-	-	[illegible]	-	-	0.4	-	0.8	-	1.4	-	0.23		
15	*Unio pictorum*	0.6	0.2	1.4	0.4	0.4	0.2	1	0.4	0.6	0.2	-	-	4	1.4	0.66	0.23		
	Arachnida - Acarina																		
16	*Limnochares aquatica*	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.03	-	0.03	-
	Crustacea - Decapoda																		
17	*Astacus leptodactylus*	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.2	-	0.03	-	0.03
	Crustacea - Amphipoda																		
18	*Gamarus kischineffensis*	-	0.4	0.2	0.8	0.2	-	-	-	-	-	-	-	0.4	1.2	0.06	0.2	0.06	0.2
	Crustacea - Isopoda																		
19	*Assellus aquaticus*	4.2	1.6	2.4	2.6	1.2	-	2.4	1.2	-	0.2	0.2	1.4	10.4	7	1.73	1.16	1.73	1.16
	Insecta - Collembola																		
20	*Podura aquatica*	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.03	-	0.03	-
	Insecta - Ephemeroptera																		
21	*Caenis epfemera*	-	-	-	-	-	-	0.2	-	-	-	-	-	0.2	-	0.03	-		

Appendix 1. (Continued)

No. of species	Species	Sampling months														Mean density		Group density	
		May		June		July		August		September		October		Total					
		Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand
22	*Caenis robusta*	-	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.03	1.06	0.46
23	*Ephemera danica*	-	1.2	1.2	-	1	-	1.4	0.6	1.6	0.2	1	-	6.2	2	1.03	0.33		
24	*Potamanthus luteus*	-	-	-	-	-	-	-	0.6	-	-	-	-	-	0.6	-	0.1		
	Insecta - Odonata																		
25	*Coenagrion pulchellum*	-	0.2	-	-	-	-	-	-	-	0.2	-	-	-	0.4	-	0.06		
26	*Ischnura elegans*	0.4	-	0.2	-	0.2	0.2	-	-	0.2	-	0.2	-	1.2	0.2	0.2	0.03		
27	*Lestes sponsa*	-	0.6	-	-	-	-	-	-	-	-	-	-	-	0.6	-	0.1	0.26	0.22
28	*Libellula quadrimaculata*	-	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.03		
29	*Libellula depressa*	-	-	-	-	-	0.2	-	-	0.2	-	-	-	0.2	0.2	0.03	0.03		
30	*Sympetrum sanguineum*	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.03	-		
	Insecta - Trichoptera																		
31	*Hydropsyche angustipennis*	-	-	2.4	1.2	1	0.2	-	25.6	-	2.2	-	6.2	3.4	15.4	0.56	2.56		
32	*Psychomia pusilla*	-	-	2.2	-	0.4	0.4	0.2	-	-	-	-	-	2.8	0.4	0.46	0.06	1.05	2.62
33	*Rhyacophila fasciata*	-	-	-	-	-	-	-	-	-	-	0.2	-	0.2	-	0.03	-		
	Insecta - Heteroptera																		
34	Larvae	4.6												4.6	-	0.76	-		
35	*Nepa cinerea-adult*	-	0.2	-	0.2	-	-	-	-	-	-	-	-	-	0.4	-	0.06	0.82	0.09
36	*Sigara (subsigara) falleni*	-	-	-	-	-	0.2	-	-	02.	-	-	-	0.2	0.2	0.03	0.03		
37	*Sigara nigrolineata*	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.03	-		
	Insecta - Coleoptera																		
38	*Lacophilus variegatus*	-	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	0.03	-	0.06
39	*Limnebius truncatellus*	-	-	-	-	-	-	-	0.2	-	-	-	-	-	0.2	-	0.03		
	Insecta - Diptera																		
40	*Eulalia cincta*	0.4	-	-	-	-	-	-	-	-	0.2	-	-	0.4	0.2	0.06	0.03		
41	*Psilopa petrolei*	-	-	-	-	0.2	-	-	-	-	-	-	-	0.2	-	0.03	-	2.49	5.03
42	*Simulium columbaczense*	-	-	-	0.2	-	-	-	-	-	0.2	-	0.2	-	0.6	-	0.1		
43	Chironomidae	0.6	0.8	1.2	1.6	0.6	0.2	2.8	22.8	6.4	0.8	2.8	3.2	14.4	29.4	2.4	4.9		
	No. of species	16	18	16	17	14	12	14	9	12	15	14	10	29	34				
	No. of specimens	74	37	84	57	61	16	67	262	72	36	51	67	409	475				

Appendix 2. Relative abundance (%), frequency (%), diversity indexes and evenness of macrozoobenthic invertebrate species in the two habitats during the study period

No. of species	Species	Frequency			Sampling months												Mean abundance	
					May		June		July		August		September		October			
		Mud	Sand	Mean	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand
1	**Oligochaeta -** Lumbricida	83.33	50	66,66	-	2.77	2.40	-	1.66	6.66	3.07	-	1.40	5.88	2	-	1.75	2.55
	Hirudinea																	
2	*Erpobdella octoculata*	100	50	75	1.36	5.71	7.59	21.27	22	23.07	3.07	-	4.34	-	6.25	-	7.43	8.34
3	*Glossiphonia complanata*	33.33	50	41,66	1.36	2.77	2.40	3.63	-	14.28	-	-	-	-	-	-	0.62	3.44
	Gastropoda																	
4	*Bithynia tentaculata*	33.33	50	25	-	-	-	1.78	-	-	3.07	-	-	5.88	2	1.51	0.84	1.52
5	*Anisus spirorbis*	16.66	-	8.33	-	-	-	-	-	-	-	-	-	-	2	-	0.33	-
6	*Gyraulus albus*	-	16.66	8.33	-	-	-	1.78	-	-	-	-	-	-	-	-	-	0.29
7	*Physa fontinalis*	-	16.66	8.33	-	2.77	-	-	-	-	-	-	-	-	-	-	-	0.46
8	*Physa acuta*	-	16.66	8.33	-	2.77	-	-	-	-	-	-	-	-	-	-	-	0.46
9	*Planorbis corneum*	100	100	100	2.77	2.77	3.65	3.63	8.92	6.66	11.66	1.89	5.88	2.85	13.33	3.07	7.70	3.47
10	*Valvata piscinalis*	50	50	50	-	-	2.40	1.78	-	-	3.07	-	-	9.09	2	3.07	1.24	2.32
11	*Viviparus viviparus*	100	100	100	8.82	2.77	6.25	3.63	12.96	6.66	9.83	1.25	12.5	9.09	15.9	3.07	11.04	4.41
12	*Limnea stagnalis*	100	33.33	66.66	2.77	-	3.65	1.78	10.90	-	3.07	-	4.34	2.85	10.86	-	5.93	0.77
	Bivalvia																	
13	*Anodonta cinerea*	100	33.33	66.66	5.71	-	7.59	1.78	-	-	6.34	-	10.76	2.85	8.51	-	6.48	0.77
14	*Sphaerium corneum*	-	50	25	-	-	-	1.78	-	-	-	-	-	5.88	-	6.34	-	2.33
15	*Unio pictorum*	83.33	83.33	83.33	4.22	2.77	8.97	3.63	3.38	6.66	8.06	1.25	4.34	2.85	-	-	4.82	2.86
	Arachnida - Acarina																	
16	*Limnochares aquatica*	16.66	-	8.33	1.36	-	-	-	-	-	-	-	-	-	-	-	0.22	-
	Crustacea - Decapoda																	
17	*Astacus leptodactylus*	-	16.66	8.33	-	-	-	-	-	-	-	-	-	-	-	1.51	-	0.25
	Crustacea - Amphipoda																	
18	*Gamarus kischineffensis*	33.33	33.33	33.33	-	5.71	4.76	7.84	1.66	-	-	-	-	-	-	-	1.07	2.25
	Crustacea - Isopoda																	
19	*Asselus aquaticus*	83.33	83.33	83.33	39.62	27.58	16.43	29.54	10.9	-	21.81	3.87	-	-	2	11.66	15.12	12.10
	Insecta - Collembola																	
20	*Podura aquatica*	16.66	-	8.33	1.36	-	-	-	-	-	-	-	-	-	-	-	0.22	-
	Insecta - Ephemeroptera																	
21	*Caenis ephemera*	16.66	-	8.33	-	-	-	-	-	-	1.51	-	-	-	-	-	0.25	-
22	*Caenis robusta*	-	16.66	8.33	-	2.77	-	-	-	-	-	-	-	-	-	-	-	0.46
23	*Ephemera danica*	83.33	50	66.66	-	19.35	7.59	-	8.92	-	11.66	1.89	12.5	2.85	10.86	-	8.58	4.01
24	*Potamanthus luteus*	-	16.66	8.33	-	-	-	-	-	-	-	1.89	-	-	-	-	-	0.31

Appendix 2. (Continued)

No. of species	Species	Frequency			Sampling months												Mean abundance	
					May		June		July		August		September		October			
		Mud	Sand	Mean	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand	Mud	Sand
	Insecta - Odonata																	
25	*Coenagrion pulchellum*	-	33.33	16.66	-	2.77	-	-	-	-	-	-	-	2.85	-	-	-	0.93
26	*Ischnura elegans*	83.33	16.66	50	2.77	-	4.76	-	1.66	6.66	-	-	1.40	-	2	-	2.09	1.11
27	*Lestes sponsa*	-	16.66	8.33	-	8.82	-	-	-	-	-	-	-	-	-	-	-	1.47
28	*Libellula quadrimaculata*	-	16.66	8.33	-	2.77	-	-	-	-	-	-	-	-	-	-	-	0.46
29	*Libellula depressa*	16.66	16.66	16.66	-	-	-	-	-	6.66	-	-	1.40	-	-	-	0.23	1.11
30	*Sympetrum sanguineum*	16.66	-	8.33	1.36	-	-	-	-	-	-	-	-	-	-	-	0.23	-
	Insecta - Trichoptera																	
31	*Hydropsyche angustipennis*	33.33	83.33	58.33	-	-	16.43	11.76	8.92	6.66	-	21.05	-	44	-	86.11	4.22	28.6
32	*Psychomia pusilla*	50	16.66	33.33	-	-	14.86	-	3.38	6.66	1.51	-	-	-	-	-	3.29	1.11
33	*Rhyacophila fasciata*	16.66	-	8.33	-	-	-	-	-	-	-	-	-	-	2	-	0.33	-
	Insecta -Heteroptera																	
34	Larvae	33.33	-	16.66	45.09	-	-	-	-	-	-	-	-	-	-	-	7.51	-
35	*Nepa cinerea-adult*	-	33.33	16.66	-	2.77	-	1.78	-	-	-	-	-	-	-	-	-	0.75
36	*Sigara (subsigara) falleni*	16.66	16.66	16.66	-	-	-	-	-	6.66	-	-	1.40	-	-	-	0.23	1.11
37	*Sigara nigrolineata*	16.66	-	8.33	1.36	-	-	-	-	-	-	-	-	-	-	-	0.23	-
	Insecta -Coleoptera																	
38	*Lacophilus variegatus*	-	16.66	8.33	-	2.77	-	-	-	-	-	-	-	-	-	-	-	0.46
39	*Limnebius truncatellus*	-	16.66	8.33	-	-	-	-	-	-	-	0.62	-	-	-	-	-	0.10
	Insecta - Diptera				-													
40	*Eulalia cincta*	16.66	16.66	16.66	2.77	-	-	-	-	-	-	-	-	2.85	-	-	0.41	0.47
41	*Psilopa petrolei*	16.66	-	8.33	-	-	-	-	1.66	-	-	-	-	-	-	-	0.27	-
42	*Simulium columbaczense*	-	50	25	-	-	-	1.78	-	-	-	-	-	2.85	-	1.51	-	1.02
43	Chironomidae	100	100	100	4.22	12.12	7.59	11.59	5.17	6.66	26.41	242.55	80	12.5	37.83	31.37	26.87	52.7
	D				8	10.83	7.81	9.1	7.26	9.17	7.1	3.31	5.91	8.97	7.6	4.92	7.28	7.72
	I				0.21	0.11	0.15	0.15	0.15	0.13	0.18	0.43	0.27	0.19	0.25	0.29	0.20	0.22
	I^{-1}				0.79	0.89	0.85	0.85	0.85	0.87	0.82	0.57	0.73	0.81	0.75	0.71	0.80	0.78
	H				1.79	1.36	2.56	2.16	2.29	2.34	2.26	0.45	1.51	2.07	2.15	1.31	2.09	1.61
	E				0.65	0.82	0.92	0.76	0.87	0.94	0.86	0.2	0.61	0.76	0.81	0.57	0.79	0.67

D - Margaleff diversity index, **I** - Simpson diversity index, **I^{-1}** - inverted Simpson index, **H** - Shannon-Wiener diversity index, **E** - evenness