DIVERSITY OF BENTHIC MACROINVERTEBRATES IN MARGARAÇA FOREST STREAMS (PORTUGAL).

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Keywords: biodiversity, stream macroinvertebrate communities, functional feeding groups.

ABSTRACT

Structure and diversity of the benthic macroinvertebrate fauna were studied in two deciduous forest streams in Central Portugal. In the three sampling occasions. 120 *taxa* were collected from the two streams. Number of *taxa* per sampling occasion ranged from 53 to 60. Macroinvertebrate densities ranged from 1465 to 2365. Insects were the most abundant taxonomic group (≥80 %) in all samples. Detritivorous invertebrates were numerically dominant in both streams, representing 62 to 85 % of the total macroinvertebrate community.

INTRODUCTION

Margaraqa Forest is a Natural Reserve (Protected Area of Serra do Açor, D.L. 67/82. 3rd March). It is a very old forest dominated by chestnuts (*Castanea sativa* Miller) and oaks (*Quercus robur* L.). Less abundant elements are Portuguese laurel cherries (*Prunus lusitanica* L. ssp *lusitanica*), laurels (*Laurus nobilis* L.). hollies (*Hex aquifolium* L.). arbutus (*Arbutus unedo* L.), hazels (*Corylus avellana* L.), cherries (*Prunus avium* L.) and morellos (*Prunus cerasus* L.). The understorey is predominantly composed of butcher's brooms (*Ruscus aculeatus* L.), blackberry bushes (*Rubus coutinhoi* Samp.), woodbines (*Lonicera periclymenum* L. ssp. *periclymenum*), etc. Several species of ferns can also be observed, as well as other rare plants of the Portuguese flora (PAIVA. 1981).

Biodiversity patterns are directly and indirectly influenced by the geomorphology of riverine landscapes (WARD, 1998). Margaraça Forest represents one of the last examples of the original vegetation of the schistous slopes in Central Portugal. According to CRISP *et al.* (1998), areas with a large proportion of native vegetation preserve the maximum number of other native species, such as invertebrates. A site containing high plant species diversity is likely to provide a greater range of invertebrate habitats (CRISP *et al.*, 1998). Because many terrestrial insects have aquatic larval instars, their development depends on the surrounding vegetation in two ways; while they live underwater and after their emergence as terrestrial adults. Thus. it is possible that the aquatic communities are also positively influenced by the high plant species diversity of the forest.

Several low order streams abundantly irrigate Margaraça Forest; nevertheless, no effort has been so far done to provide information about the aquatic invertebrates of these streams.

The aim of this work was to generate baseline data on the benthic macroinvertebrate communities of two streams flowing through Margaraça Forest, in order to assess the faunistic importance of these woods and to provide basis for the necessity of conservation of our natural patrimony.

MATERIAL AND METHODS

Margaraça Forest occupies an area of approximately 50 ha, it is exposed to N-NW and has a slope of 25°, between 600 and 850 m of altitude. It is located in Serra do Açor, near Coimbra (Fig.1). The two streams in study are orders 1 (Stream 1) and 3 (Stream 2). Basin drainage areas are 29 ha for Stream 1 and 182 ha for Stream 2.

Invertebrate sampling was performed in three times: autumn (December 1991), winter (March 1992) and

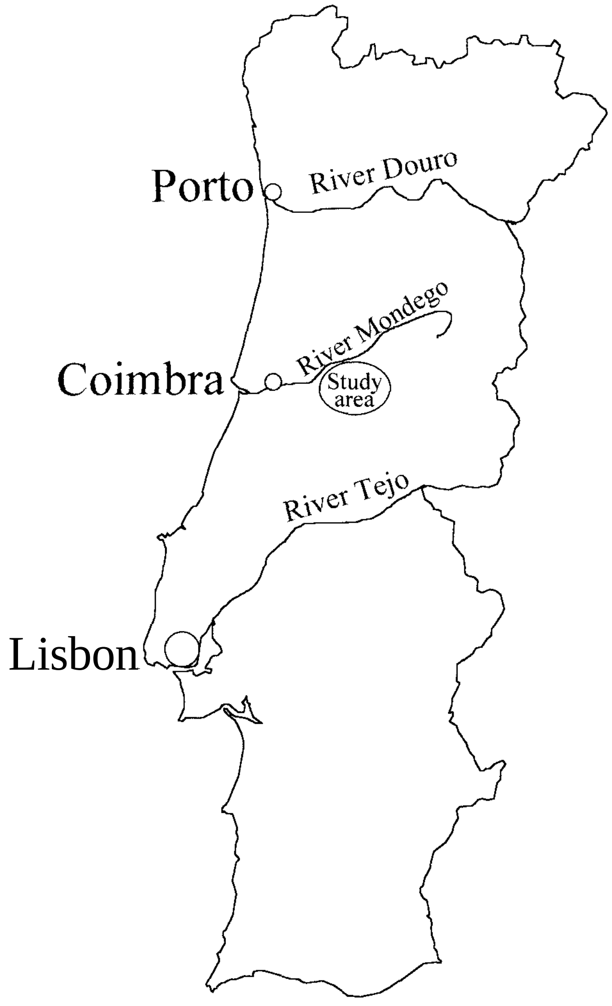

Figure 1. Location of the study area in Central Portugal.

summer (September 1992). In each stream, 6 samples were taken with a surber-net (0.3m x 0.3m; 0.5 mm mesh). The samples were brought to the laboratory, washed thoroughly and screened with a mesh of 0.5 mm. The 6 samples collected from each stream in each sampling occasion were treated as replicates. The arithmetic means were calculated from these replicates and the results were converted to number of individuals per unit area ($1 m^2$). Identification of the animals was carried out to the lowest possible taxonomic level, according to the available taxonomic keys.

Animals were classified into functional feeding groups according to MERRITT & CUMMINS (1996) and to TACHET *et al.* (1981). Differences between streams were tested by the Mann-Whitney non-parametric test (U; ZAR. 1996).

RESULTS

During the study period, 120 *taxa* of macroinvertebrates were identified in the samples collected from the 2 streams (Appendix). These included the following taxonomic groups: *Tricladida, Nematoda, Gastropoda, Lamellibranchiata, Oligochaeta, Hirudinea, Hydracarina, Isopoda, Collembola* and *Insecta*. Insects were the most abundant group (≥ 80% of total animals in all samples; Fig. 2), representing 6 orders: *Ephemeroptera, Plecoptera, Odonata, Coleoptera, Trichoptera* and *Diptera* (Fig. 3).

Identification of some groups was incomplete; *Nematoda, Hydracarina, Isopoda* and *Collembola* were not further identified. In many other cases, identification was carried out only to family level. The incomplete identification of many animals probably resulted in an under-estimation of the total number of *taxa*..

From the functional point of view, the two streams were dominated by detritivores (such as the *Leuctridae*), which constituted 62-85% of the total macroinvertebrate community. Scrapers represented 7-22% of the invertebrates, and predators 3-15% (Fig. 4).

Seasonal variation

The mean population density of benthic macroinvertebrates ranged from 1465 m^{-2} in summer to 2365 m^{-2} in winter in Stream 1 and from 1477 m^{-2} in summer to 1957 m^{-2} in winter in Stream 2. The number of *taxa* ranged from 60 in winter to 53 in summer in Stream 1 and from 60 in winter to 37 in summer in Stream 2 (Appendix). Insects (Fig. 2) were more abundant in winter (90% in Stream 1; 88% in Stream 2) and less abundant in summer (85% in Stream 1; 80% in Stream 2). The taxonomic composition of the insects (Fig. 3) varied between seasons. In autumn, *Diptera* was the most abundant order (67% of total insects in Stream 1; 49% in Stream 2). followed by *Plecoptera* (21% in Stream 1, 37% in Stream 2). In winter, *Diptera* again was the dominant order (81% in Stream 1; 37% in Stream 2), followed by *Plecoptera* (9%) in Stream 1 and by *Ephemeroptera* (32%) in Stream 2. Finally, in summer, *Plecoptera* was the dominant order (64%) in Stream 1, followed by *Diptera* (29%). In Stream 2, *Diptera* was more abundant (48%) followed by *Plecoptera* (38%).

The *taxa* found in the streams of Margaraça Forest during the study period can be divided into 3 arbitrary groups: (1) abundant *taxa* occurring regularly, (2) *taxa* occurring occasionally and (3) *taxa* occurring more or less regularly but not in great numbers at any time (Appendix). In group (1) 6 *taxa* were abundant in both streams (A, Appendix), 3 *taxa* were

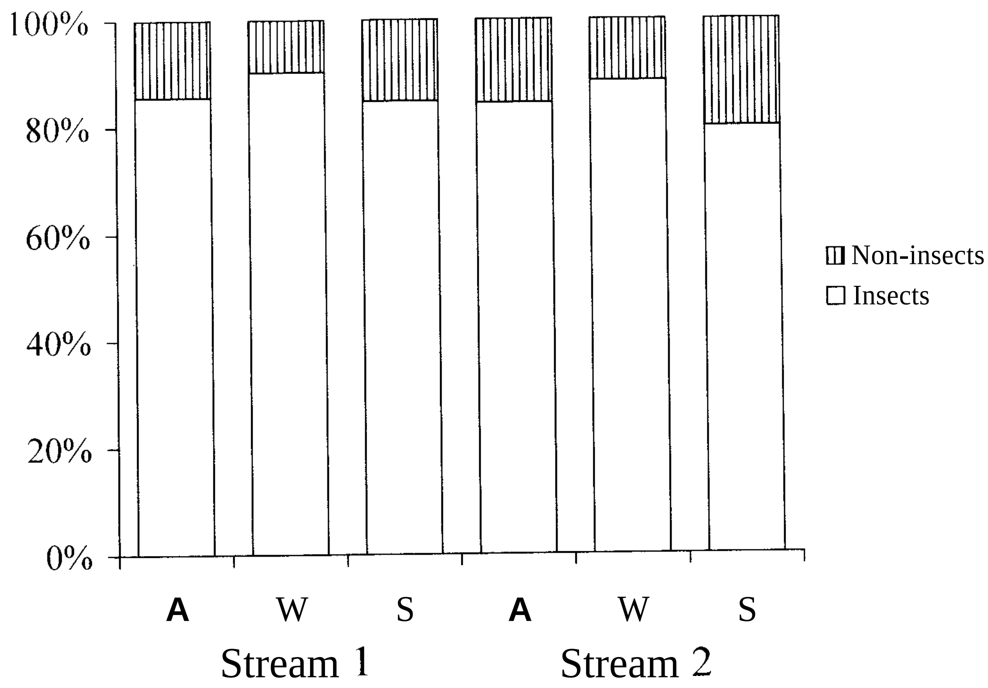

Figure 2. Seasonal variations in the percentage of insects and non-insects in the two streams A = autumn, W = winter, S = summer.

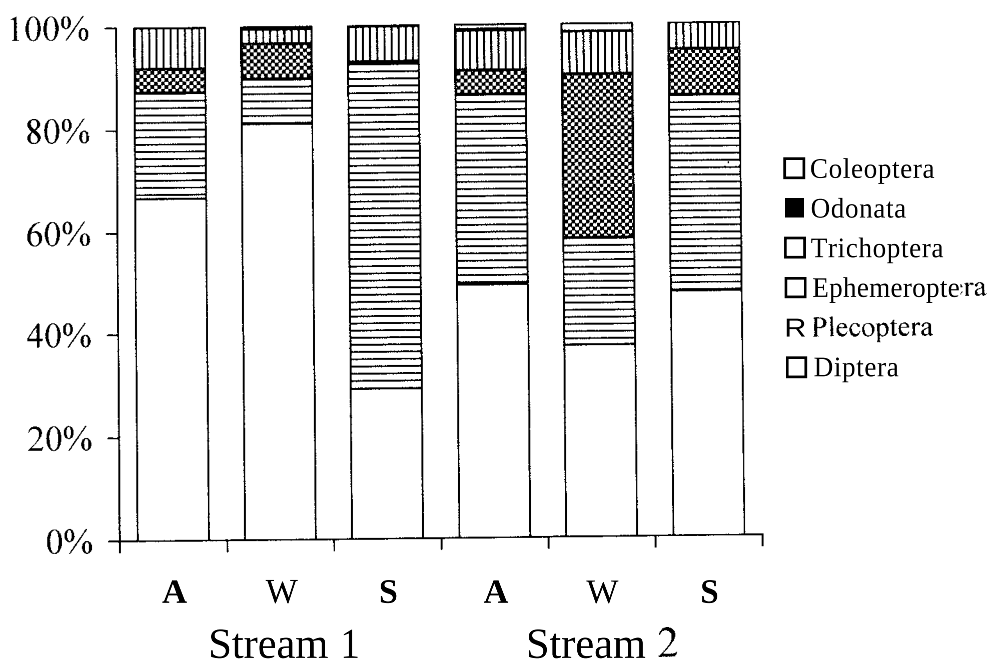

Figure 3. Seasonal variations in the relative contribution of insect orders in the two streams. A = autumn, W =winter, S = summer.

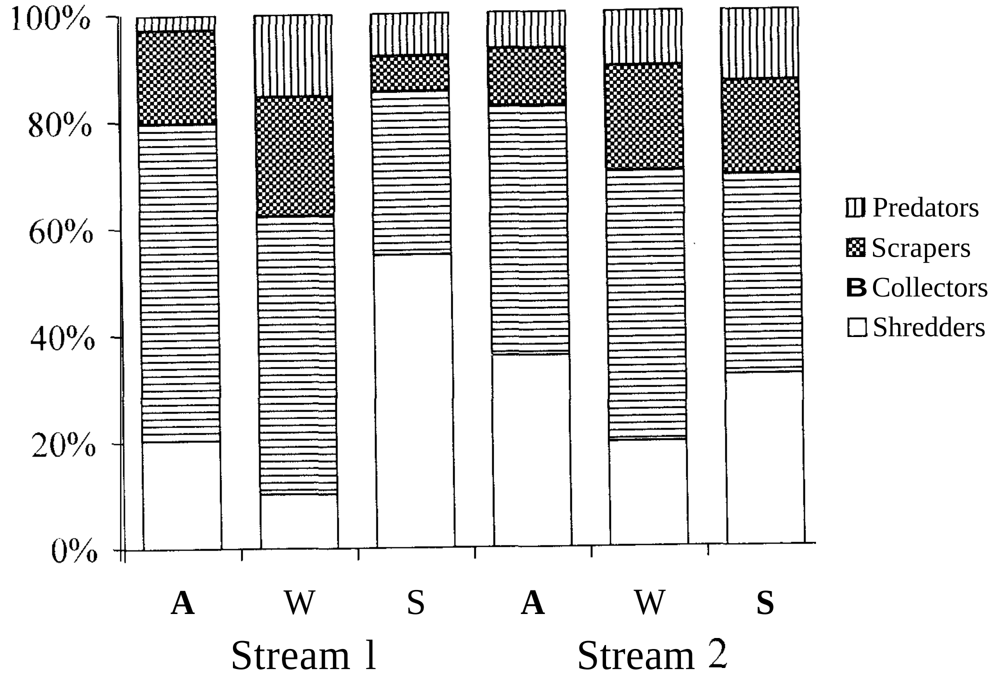

Figure 4. Seasonal variations in the percentage of functional feeding groups in the two streams. A =autumn, W = wtnter. S = summer

abundant in Strcam 1 (A_1, Appcndix), and 4 taxa were abundant in Stream 2 (A_2, Appendix). In group (2) 24 *taxa* were regular in both strcams (R, Appendix), 18 *taxa* were regular in Stream 1 (R_1, Appcndix), and 13 *taxa* were abundant in Stream 2 (R_2, Appendix). In group (3) 7 *taxa* were occasional in both streams (O, Appendix), 32 taxa wcre occasional in Stream1 (O_1, Appendix), and 28 taxa wcre occasional in Stream 2 (O_2, Appendix).

Spatial distribution

The rnean population density and thc number of *taxa* wcre not significantly different between streams ($U<6$, $DF=1$, $P<0.05$). On the basis of spatial distribution, the *taxa* can be divided into 2 major groups: (1) thosc occurring in both streams and (2) thosc occurring exclusively in one of the streams. Of the 120 taxonomic groups, 37 occurred exclusively in Stream 1 and 30 occurrcd exclusively in Stream 2 (Appendix). However, most of thcsc *taxa* were occasional; only 9 regular or abundant *taxa* (*Nematoda*, *Gastropoda* unidentificd 1, *Rhyacophila adjuncta/denticulata*, *Plectrocnemia geniculata*, *Micropterna* sp, *Crunoecia irrorata*, *Helius* sp, *Dicranota* sp and Psychodidae unidentified 2) occurred exclusively in Stream 1 and 8 regular or abundant *taxa* (*Ephemera glaucops*, *Ephemera lineata*, *Calopteryx virgo*, *Elmis* sp (larvae), *Hydropsyche bulbifera*, *Lithax niger*, *Lepidostoma hirtum* and *Dixa maculata*) occurrcd exclusively in Stream 2 (Appendix).

DISCUSSION

Although the two streams arc geographically very close, differences in taxonomic composition as well as in seasonal patterns could be observed. Stream 1 is much smaller than Stream 2, and completely shaded by the riparian vegetation, which is mainly composed of chestnut trees. Stream 2 is less shaded than Stream 1 and the riparian vegetation is rnore diverse. Thc differences in riparian vegetation could be one factor explaining the differences in the taxonomic cornposition of the streams. In fact, Stream 1 has a higher input of particulate organic matter (personal observation) than Stream 2. However, shredders (the group potentially more affected by the differences in the supply of allochthonous organic matter) are more abundant in Stream 2, except in summer, when they are more abundant in Strcam 1. Stream 1 is extremely retentive and benthic particulate organic maltcr can be observed in the stream throughout the year (ABELHO & GRACA, 1996). This pool of POM may be the reason for the greater abundance of shredders in Stream 1 during summer. On the other hand, JACOBSEN & FRIBERG (1997) found that, for Danish streams, size is more important than the dcgrec of forcst cover in determining the species richness and community structure of the invertebrate fauna. Moreover, *Psychodidae* and *Limoniidae* were rnorc diverse in Stream 1. which is in agreement with JACOBSEN & FRIBEKC (1997) that found that these two families were morc diverse in the small streams than in the larger ones.

The density of invertcbratcs collected during the study period (1465-2365 m^{-2}) is within the ranges reported by other studies in Europe (JACOBSEN & FRIBERG, 1997), South America (JACOBSEN *et al.*, 1997), and New Zealand (FRIRERG *et al.*, 1997), but arc much lower than the numbers reported by FRIBERG (1997) for Danish forest strcams.

The number of species obtained depends largely on the method and effort of sampling and identification. Considering that many groups (some usually considered very diverse in terms of spccies, such as chironomids and simulids), were incompletely identified, we can suppose that the taxonomic diversity of the streams is higher than showed here. Nevertheless, the number of *taxa* identificd from the study strcams (90 in Stream 1 and 83 in Stream 2) is high comparing to other stutlies. In a study where most insects were identified to specics, JACOBSEN & FRIBERG (1997) reported a maximum of 77 *taxa* in small forest streams, and FRIBERG *er al.* (1997) rcported a maximum of 40 *taxa*. Counting insect families and non-insect classes, JACOBSEN *et al.*, (1997) rcportcd a maximum of 33 *tax-a*. Using the same criteria, at least 49 man were idcntificd in Stream 1 and 47 in Strcam 2.

From the functional point of view, Margaraqa Forest streams are similar to other forest streams (FRIBERG, 1997), bcinp dominated by collectors and shredders. The plecopteran *Leuctra* spp was the dominant detritivore, reaching 48% of the total invertebrate community in summer at Stream 1. According to FRIBERG (1997), the ratio between invertebrates with a life-cycle $\geq$ 2 yr (such as the *Leuctridae*) and invertebrates with a life-cycle $\leq$ 1 yr is determined by both the quantity and the quality of the detritus. Thus. the higher the ratio, the lower the quantity and/or quality of the detritus. If this is also true for South Europe, than the invertebrates of the streams in study were food-limited, specially in summer at Stream 1.

The streams of Margaraça Forest have a high taxonomic richness. More important than divcrsity arc the taxonomic associations found in the streams of Margaraqa Forest (ABELHO & GRACA, 1992; ABELHO, 1994; ABELHO & GRACA, 1996). These suggest that the replacement of the original vegetation may cause irremediable loss of species.

Remnant patches of native forcst are important reserves for native insects (CRISP *et al.*, 1998). Animal species with complex life-cycles contribute two doses of biological diversity to a community: as larvae in aquatic and as adults in terrestrial patches (HARPER & HAWKSWORTH. 1995). The prescrvation of these patches should be a priority, specially in a country where afforestation with exotic species is taking place at a high rate.

In this paper we have shown that aquatic invertebrate diversity in an unperturbed area was high. However, bccausc only nearly one third of total *taxa* was fully identified, total diversity is surely much higher. It is therefore urgent to invest more in the formation of specialists in order to create conditions to evaluate local hiodiversity of arthropods and other important aquatic invertcbrates.

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APPENDIX

List of the *taxa* collected in Stream 1 and Stream 2, in the 3 sampling seasons (ind m^{-2}). Status: **(A)** abundant and regularly distributed *taxa;* (R) *taxa* occurring more or less regularly but not in great numbers; **(O)** *taxa* occurring occasionally; $_1$ in Stream 1 or $_2$ in Stream 2. **A** = Autumn, **W** = Winter, S = Summer.

		Stream 1			Stream 2		
Taxa	Status	A	W	S	A	W	S
Polycelis nigra/tenuis	**(R)**	5	11	63	1	13	0
Tricladida unidentified 1	**(O)**	0	0	4	0	4	0
Nematoda	**(R_1)**	0	2	4	0	0	0
Valvata cf *piscinalis*	**(O)**	1	0	0	2	0	0
Ancylus fluviatilis	**(R)**	8	1	0	6	5	10
Gastropoda unidentified 1	**(R_1)**	0	1	2	0	0	0
Sphaerium corneum	**(R)**	61	3	35	10	2	3
Lumbriculus varzegatus	**(A)**	244	39	81	200	165	166
Tubificidae	**(R_1O_2)**	0	37	6	0	3	0
Naididae	**(A)**	0	131	8	24	24	119
Eiseniella tetraedra	**(R_1O_2)**	3	0	5	0	1	0
Glossiphonia complanata	**(O_1)**	0	1	0	0	0	0
Glossiphonza heteroclita	**(O_2)**	0	0	0	0	1	0
Erpobdella monostriata	**(O)**	0	0	15	0	3	0
Erpobdella testacea	**(O)**	2	0	0	1	0	0
Hydracarina	**(R_1O_2)**	1	2	1	0	4	0
Isopoda unidentified 1	**(O)**	1	0	0	1	0	0
Isopoda unidentified 2	**(O_1)**	2	0	0	0	0	0
Isopoda unidentified 3	**(O_1)**	2	0	0	0	0	0
Collembola	**(O_1R_2)**	0	3	0	3	2	0
Baetis sp	**(R_1A_2)**	15	67	4	12	213	4
Epeorus torrentium/sylvicola	**(R)**	46	1	0	5	4	0
Ecdyonurus aurantiacus	**(R)**	5	1	1	5	31	14
Ephemerella ignita/mesoleuca	**(O_2)**	0	0	0	0	287	0
Paraleptophlebia submarginata	**(R)**	23	80	0	1	3	0
Ephemera glaucops	**(R_2)**	0	0	0	33	13	0
Ephemera lineata	**(A_2)**	0	0	0	7	1	88
Nemoura cinerea	**(O)**	0	1	0	1	0	0
Nemaura linguata	**(O_1)**	1	0	0	0	0	0
Nemoura uncinata	**(R)**	8	10	9	1	1	0
Protonemura sp	**(A)**	34	36	82	11	128	0
Leuctra gr. *aurita*	**(R_1A_2)**	20	3	28	20	0	117
Leuctra despaxi	**(R)**	33	0	7	32	0	32
Leuctra gr. *fusca*	**(R_1A_2)**	6	24	55	28	117	36
Leuctra sp5	**(A)**	301	97	607	402	119	267
Perla burmeisteriana	**(O_1)**	0	1	0	0	0	0
Perla marginata	**(O_1)**	0	4	0	0	0	0
Siphonoperla torrentium/baetica	**(O_1)**	0	11	0	0	0	0

Calopteryx splendens	**(O_2)**	0	0	0	1	0	0
Calopteryx virgo	**(R_2)**	0	0	0	2	1	0
Cordulegaster boltonii	**(R)**	1	1	1	1	1	0
cf. *Hydroporus* sp (adults)	**(O_2)**	0	0	0	1	0	0
Deronectes sp (adults)	**(O_1)**	0	1	0	0	0	0
Copelatus sp (larvae)	**(O_1)**	0	2	0	0	0	0
Agabus sp (larvae)	**(O_1)**	0	2	0	0	0	0
Agabus sp (adults)	**(O_1)**	0	1	0	0	0	0
Hydraena sp (adults)	**(O_2)**	0	0	0	0	6	0
Anacaena sp (adults)	**(O_1)**	0	1	0	0	0	0
Enochrus sp (adults)	**(O_1)**	0	0	1	0	0	0
Limnichus pygmaeus (adults)	**(O_1)**	0	1	0	0	0	0
Eubria sp (larvae)	**(O_2)**	0	0	0	3	0	0
Dryops sp (larvae)	**(O_2)**	0	0	0	5	0	0
Dryops sp (adults)	**(O_1)**	0	1	0	0	0	0
Elmis sp (larvae)	**(R_2)**	0	0	0	1	9	0
Elmis sp (adults)	**(O_2)**	0	0	0	0	4	0
Esolus sp (larvae)	**(O_2)**	0	0	0	0	4	0
Esolus sp (adults)	**(O)**	0	0	1	2	0	0
Coleoptera unidentified 1 (adults)	**(O_2)**	0	0	0	0	1	0
Coleoptera unidentified 3 (larvae)	**(O_2)**	0	0	0	0	1	0
Rhyacophila adjuncta/denticulata	**(R_1)**	1	0	1	0	0	0
Rhyacophila eatoni/tristis	**(R_1O_2)**	24	5	8	0	2	0
Rhyacophila pulchra	**(R_1O_2)**	4	0	1	0	2	0
Agapefus sp	**(R)**	10	4	1	4	23	0
Hydroptila sp	**(O_2)**	0	0	0	0	0	1
Philopotamus montanus	**(R_1O_2)**	7	0	5	0	0	1
Diplectrona felix/moralesi	**(R)**	59	8	23	22	73	2
Hydropsyche bulbifera	**(R_2)**	0	0	0	4	10	0
Hydropsyche instabilis	**(O_2)**	0	0	0	0	1	0
Hydropsyche siltalai	**(O_1R_2)**	0	0	3	4	7	0
Hydropsyche tibialis	**(R)**	2	0	6	1	1	0
Plectrocnemia geniculafa	**(R_1)**	0	3	6	0	0	0
Polycentropus flavomaculatus	**(O_2)**	0	0	0	0	0	10
Lype phaecopa	**(O_1)**	0	0	2	0	0	0
Lype reducta	**(O_2)**	0	0	0	0	0	1
Metalype fragilis	**(O_1)**	2	0	0	0	0	0
Ecnomus sp	**(O_2)**	0	0	0	0	0	1
Limnephilus sp	**(O_2)**	0	0	0	7	0	0
cf. *Micropterna* sp	**(R_1)**	8	1	0	0	0	0
Allogamus sp	**(R)**	0	10	2	0	2	1
cf. *Lithax niger*	**(R_2)**	0	0	0	1	1	2
Thremma gallicum	**(O_1R_2)**	0	0	2	1	4	16
Lepidostoma hirtum	**(R_2)**	0	0	0	6	0	2
Crunoecia irrorata	**(R_1)**	9	16	0	0	0	0
Adicella filicornis	**(O_1)**	0	3	0	0	0	0
Adicella meridionalis/reducta	**(O_1R_2)**	3	0	0	0	5	7
cf. *Sericostoma* sp	**(R)**	21	0	10	52	10	13
Beraea pullata	**(R)**	7	8	14	1	2	3
Calamoceras marsupus	**(O_1)**	0	1	0	0	0	0

Apistomyia sp	**(O_2)**	0	0	0	0	2	0
Liponeura sp	**(O_2)**	0	0	0	4	0	0
Tipula sp	**(R)**	2	1	3	6	1	1
Helius sp	**(R_1)**	4	1	0	0	0	0
Pedicia sp	**(O_1)**	0	2	0	0	0	0
Dicranota sp	**(R_1)**	4	1	1	0	0	0
Hexatoma sp	**(R)**	1	9	1	3	0	1
Erioptera sp	**(O_2)**	0	0	0	0	2	0
Molophilus sp	**(O_2)**	0	0	0	1	0	0
Gonomyia sp	**(O_1)**	2	0	0	0	0	0
Limoniidae unidentified 4	**(O_2)**	0	0	0	1	0	0
Psychodidae unidentified 1	**(O_1)**	1	0	0	0	0	0
Psychodidae unidentified 2	**(R_1)**	2	0	1	0	0	0
Psychodidae unidentified 3	**(O_1)**	2	0	0	0	0	0
Psychodidae unidentified 7	**(O_1)**	0	0	3	0	0	0
Dixa maculata	**(R_2)**	0	0	0	3	0	1
Dixa puberula	**(R)**	1	5	1	1	1	0
Simuliidae	**(A)**	294	28	119	239	126	27
Tanypodinae	**(A_1R_2)**	4	251	2	15	56	28
Corynoneura sp	**(R)**	17	17	0	2	2	0
Orthocladiinae	**(A)**	687	883	162	267	154	350
Chironomini	**(A_1R_2)**	39	122	12	35	82	41
Tanytarsini	**(A_1R_2)**	204	397	42	21	117	21
Bezzia sp	**(R)**	5	2	3	3	9	7
Thaumaleidae	**(O_1)**	0	1	0	0	0	0
Stratiomysa sp	**(O_1)**	0	2	0	0	0	0
Hemerodromiinae	**(R)**	0	2	2	0	8	6
Atalantinae	**(R)**	2	4	4	1	2	2
Dolichopodidae	**(R)**	25	1	2	7	11	10
Atherix sp	**(R)**	1	0	1	48	71	66
Anthomyidae	**(O_1)**	1	0	0	0	0	0
Diptera unidentified	**(O_1)**	0	0	2	0	0	0
Total ind m^{-2}		2278	2365	1465	1582	1958	1477
Number of **taxa**		56	60	53	90	58	60