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Scientific Editors

Aquatic Ecology of the Mondego River Basin Global Importance of Local Experience

Coimbra • Imprensa da Universidade

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FRESHWATER MACROINVERTEBRATES IN THE MONDEGO RIVER BASIN

Abstract

Invertebrates in streams and rivers are diverse, abundant and perform important ecological functions, recycling organic matter, feeding upon algae and transferring energy for larger animals, including fish, birds, amphibians and others. The macroinvertebrate communities of 34 stream sites in the Mondego River basin were analysed to assess changes in taxa richness and percentage of shredders along river order / size gradient and to assess water quality by means of biotic indices. Taxa richness was higher in low order streams when compared with larger rivers. In some rivers, shredder abundance was higher in autumn, but in other rivers we did not observe changes in shredder abundance along the year. Water quality, measured by the application of the biotic index BMWP', revealed that many small low order streams can be considered as unpolluted. However, water quality decreased in larger rivers.

Introduction

In stream ecology studies, the definition of macroinvertebrates is subjective: invertebrates visible to the naked eye. In more practical terms, they are invertebrates captured by a 0.2 to 0.5mm sampling net (Hellawell 1978). Unlike in salt-water systems and soil, freshwater macroinvertebrates are uniform in size, with most of specimens ranging from fractions of mm to 30mm.' In streams and rivers, macroinvertebrates comprise mostly insects, but also include other arthropods (Acarina, Crustacea), worms and leaches (Annelida), flatworms (Plathelminthes), nematodes (Nemathelminthes), snails and bivalves (Mollusca) (Tachet et al. 1987). Among the insects, 4 orders have juvenile stages exclusively aquatic and adults with aerial life: Ephemeroptera, Plecoptera, Odonata and Trichoptera. Some Diptera also have a juvenile aquatic phase. Two additional orders may be abundant in the water either as juveniles and / or adults: Heteroptera and Coleoptera.

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Vannote et al. proposed in 1980 a general model – the River Continuum Concept (RCC) – to explain the functional link along rivers, from the source to the mouth. This framework establishes the relationships between stream order / size and energy sources of rivers. According to the RCC, streams receive most of their energy in the form of leaves and other plant detritus produced in the riparian area. This material will be used as food by a large proportion of aquatic macroinvertebrates. Macroinvertebrates are, in turn, the energy source for many species of fish, amphibians and aquatic birds and mammals.

Freshwater macroinvertebrates have been used for nearly a century as indicators of water quality (e.g. Kolkwitz and Marsson 1908, 1909). The reason is simple: It has been documented for long time that as the quality of water deteriorates, an increasing number of species no longer are capable of survive and the diversity of the community generally decreases. The first taxa to disappear are known as "intolerant". With the elimination of competitors and predators, the remaining species tend generally to grow to large numbers, especially if the food is abundant. These organisms are known as "tolerant". Decrease in water quality may therefore result in a decrease in diversity and change community structure and function.

Changes in (a) diversity of macroinvertebrates, (b) the structure of the community and (c) the proportion of taxa with known environmental tolerances have been therefore used as indicators of environmental quality in biomonitoring programmes (Metcalfe-Smith 1996). Biotic indices have also been used to assess water quality. Those indices are numerical expressions based on the presence and number of indicator taxa. Biotic indices have been used in Europe and North America for several decades for routine rapid assessment of water quality in rivers (e.g. De Pauw and Vanhooren 1983, Washington 1984, Metcalfe 1989).

Although several groups of taxa can be used for biomonitoring proposes (e.g. algae, macrophytes, bacteria, fish, protozoans), macroinvertebrates are the most popular. Three main reasons contribute to such popularity: (a) They have low mobility or are fixed to the substratum and, therefore, their composition is related to water conditions at the place where they occur. (b) Most taxa are ubiquitous; this is very convenient when trying to make comparisons among different areas. (c) There is a high diversity of forms, colonizing almost any environmental condition (Hellawell 1978).

In Portugal several research groups have been studying the distribution or the ecology of freshwater invertebrates. E.g. Fontoura (1984), Fontoura and De Pauw (1989) in Northern Atlantic rivers; Cortes (1990, 1992) in the Northeast; Moreira et al. (1988) in the Vouga Basin; Graça et al. (1989), Abelho and Graça (1996) in the Central Portugal and Graça and Coimbra (1998), Coimbra and Graça (1998), Graça et al. (1995), Coimbra et al. (1996), Malo et al. (1998) in the South.

The objective of this paper was to summarise the research carried in the Mondego River basin in terms of (a) richness of taxonomic invertebrate groups along a longitudinal gradient (b) proportion of shredders along river order gradients, and (c) classification of water quality by means of macroinvertebrate indicators. For this propose, we used published and unpublished data.

Materials and methods

We used data originally from Graça et al. (1989, R. Alva and R. Soure), Abelho and Graça (1996; rivers from Açor and Margaraça Mountains), Graça et al. (2001; Lousã mountain and Ceira basin). We also used unpublished material collected by (a) Carvalho and Coimbra in several rivers at the Lousã and Caramulo Mountains, and (b) Oliveira and Coimbra at the upper Mondego River and several tributaries.

Samples of invertebrates were generally collected with a hand net 0.3 × 0.3 aperture and 0.5 mm mesh size. When rigorous quantitative sampling was necessary (and possible) Surber samples were collected (same dimensions as hand net). At each sampling site, in general, six sample replicates were collected at the major macrohabitats, covering each a distance of approximately 1 meter. Samples were transported to the laboratory and the specimens sorted alive. Alternatively, samples were preserved in the field with 4% formalin, and the invertebrates sorted after washing with tap running water. For preservation we used 70% ethanol. Identification was done to the level of species (e.g. some Plecoptera) or, more frequently to genus (e.g., Coleoptera), but in many cases specimens were only identified to family (e.g. Diptera) or to sub-family (e.g. Chironomidae) levels.

Invertebrate sampling was generally accompanied of water sampling for chemical analysis. Several physical parameters of streams and rivers were also measured. In order to understand the distribution of macroinvertebrate taxa, a table was produced relating the 3 more abundant taxa with the environmental stream characteristics. For each biological sample, the proportion of shredders (i.e. invertebrates feeding on decaying leaves) was computed, related with the stream order and compared with the previsions of the river continuum model. Finally, for each invertebrate collection, a biotic index was computed: the BMWP' adapted for the Iberian Peninsula (Alba-Tercedor 1996, Alba-Tercedor and Sanchéz-Ortega 1988) in order document water quality.

Results

We analysed more than 30 stream sites sampled once to four times. Most of the sites corresponded to low order (≤ 4), narrow rivers (width < 5m; Table 1). In terms of discharge and width, the larger rivers were Alva, Soure and Ceira. In general, those were also the rivers with higher water velocities. The Mondego River was not sampled in a correspondent larger section. All rivers had high content of dissolved oxygen, probably as a result of the continuous flow and/or lack of strong organic load. However, in terms of water chemistry, there was a high variation with pH values ranging from acidic (pH < 5) to basic (pH > 8) and conductivity ranging from < 30 µS to > 300 µS (Table 2). Nutrient content was generally low, except in some sites were the higher values denote organic pollution (Table 2).

In general, the number of invertebrate families was low in larger rivers, when compared with streams of low to intermediate order (≤ 5; Table 3). As an example, along a longitudinal transept, the maximum number of invertebrate families sampled in

Table 1. Selected physical characteristics of the studied stream / river sites. Subst.= mean size of the dominant substrate particles

Stream / River	Subst. (cm)	Width (m)	Depth (m)	Current ($m\ s^{-1}$)	Flow ($m^3\ s^{-1} \times 10^{-3}$)	Temp. (°C)	O_2 mg L^{-1}	Source
Rib. da Fonte de Espinho	19	0.4-1.7	0.1-0.2	0.13-0.22	9-49	8-13	9.3-9.5	Graça et al. 2001
Rib. do Cabeço	16	0.5-1.1	0.1	0.10-0.17	9-11	8-13	9.5-9.6	Graça et al. 2001
Rib. do Candal	17	1.3-1.6	0.1	0.27-0.29	48-52	8-14	9.5-9.6	Graça et al. 2001
Rib. de Cerdeira	21	0.6-0.6	0.2	0.44-0.46	38-58	8-15	9.4-9.5	Graça et al. 2001
Rib. Pé da Lomba	>30	0.3-0.7	0.1-0.2	0.10-0.11	3-16	9-15	9.5-9.7	Graça et al. 2001
Rib. de Espinho (Cadaixo)	12	2.1-2.2	0.1	0.39-0.41	94-114	11-18	10.1	Graça et al. 2001
Rib. da Sra da Piedade (Pereira)	16	0.9-2.3	0.1-0.3	0.13-0.45	59-75	10-18	10.2-10.5	Graça et al. 2001
Rib. da Avessada	8	1.2-1.2	0.1	0.31-0.55	39-40	11-18	9.5-9.8	Graça et al. 2001
Rib. de S. João (Lousã)	10	1.5-6.8	0.2-0.4	0.07-0.22	58-200	9-17	9.9-10.2	Graça et al. 2001
Rio Sotão (Ponte do Seladinho)	>30	0.7-11.1	0.3-0.4	0.07-0.46	94-295	9-18	9.8-10.2	Graça et al. 2001
Rio Ceira (Serpins)	18	17	0.2	0.38	1058	10	10.5	Graça et al. 2001
Rio Ceira (Azenha)	14	12.5-11.7	0.2-0.3	0.70-0.79	1888-2773	10-23	9.4-10.8	Graça et al. 2001
Rio Soure 1 (Alberg. dos Doze)	5	2	0.3	0.48	290	14-16	9.4-11.3	Graça et al. 1989
Rio Soure 2 (Vermoil)	15	7	0.3	0.25	380	16-22	9.3-11.9	Graça et al. 1989
Rio Soure 3 (Almagreira)	10	9	0.3	0.80	1780	6-25	9.8-10.1	Graça et al. 1989
Rio Soure 4 (V.N. de Anços)	<1	15	0.7	0.49	4730	17-27	9.6-10.0	Graça et al. 1989
Rio Alva 1 (Sabugueiro)	>30	5	0.2-0.5	0.30-1.60	100-5200	9-12	8.5-11.4	Graça et al. 1989
Rio Alva 2 (Sandomil)	10	13	0.3-0.9	0.20-1.05	500-12300	1-14	8.6-12.4	Graça et al. 1989
Rio Alva 3 (Coja)	9	15	0.6-1.1	0.40-1.40	3600-20600	3-21	8.8-12.4	Graça et al. 1989
Rio Alva 4 (Pombeiro da Beira)	2	14	0.8-1.0	0.10-0.50	1000-7500	4-26	9.0-12.2	Graça et al. 1989
Rio Alva 5 (Foz do Alva)	<1	28	0.5-1.6	0.90-1.20	16200-27400	4-27	9.1-12.3	Graça et al. 1989
Rio Ceira (Foz de Arouce)	7	-	0.3	1.00	-	16.5	7.9	Oliveira & Coimbra unp.
Rio Ceira (Vendas de Ceira)	8	-	0.4	0.60	-	15.9	7.4	Oliveira & Coimbra unp.
Rio Dueça (Sobral)	5	-	0.3	0.43	-	16.0	8.6	Oliveira & Coimbra unp.
Rio Dueça (Tremôa)	5	-	0.4	0.80	-	15.8	7.7	Oliveira & Coimbra unp.
Rio Alva (Coja)	8	-	0.5	0.22	-	5.2	9.9	Oliveira & Coimbra unp.
Rio Alva (Sabugueiro)	19	-	0.5	0.14	-	6.8	10.5	Oliveira & Coimbra unp.
Rio Mondego (Trinta)	13	-	0.4	0.34	-	4.6	11.5	Oliveira & Coimbra unp.
Rio Mondego (P. da Rainha)	-	-	-	-	-	7.6	9.4	Oliveira & Coimbra unp.
R. da Mata da Margaraça 1	7	-	-	0.24-0.62	5-15	10.0-13.6	10.4-14.1	Abelho & Graça 1996
R. da Mata da Margaraça 2	6	-	-	0.15-0.32	4-28	9.0-14.2	10.3-17.1	Abelho & Graça 1996
R. da Fraga da Pena	6	-	-	0.10-0.67	21-71	10.0-16.0	10.2-16.3	Abelho & Graça 1996
R. da Mata da Margaraça 1	7	-	-	0.24-0.62	5-15	10.0-13.6	10.4-14.1	Abelho & Graça 1996
R. da Mata da Margaraça 2	6	-	-	0.15-0.32	4-28	9.0-14.2	10.3-17.1	Abelho & Graça 1996
R. da Fraga da Pena	6	-	-	0.10-0.67	21-71	10.0-16.0	10.2-16.3	Abelho & Graça 1996
R. Sótão (Ponte do Seladinho)	7-8	6-9	0.2-0.4	0.11-0.34	346-392	13.6-14.1	10.8-11.0	Carvalho & Coimbra unp.
R. S. João (Lousã)	9-10	5-8	0.2-0.4	0.01-0.10	24-91	14.2-15.7	9.6-9.8	Carvalho & Coimbra unp.

Table 2. Water chemistry of the studied stream / river sites.

Stream / River	pH	Cond. µS cm^{-1}	Alk mg L^{-1}	NO_3 mg L^{-1}	NO_2 µg L^{-1}	PO_4 mg L^{-1}	Source
Rib. da Fonte de Espinho	5.9-6.4	34-35	2.8-3.3	1.35-2.66	<2	2	Graça et al. 2001
Rib. do Cabeço	5.8-6.4	27-28	2.3-3.4	0.44-0.53	<2	4-10	Graça et al. 2001
Rib. do Candal	6.2-6.5	31-33	4.2-4.6	0.09-1.32	<2	7-21	Graça et al. 2001
Rib de Cerdeira	6.2-6.7	36-40	5.2-7.3	0.50-0.52	<2	4-11	Graça et al. 2001
Rib. Pé da Lomba	6.4-7.0	51-53	9.1-9.5	1.52-1.66	<2-4	7-15	Graça et al. 2001
Rib de Espinho (Cadaixo)	6.5-7.1	67-83	9.7-13.3	3.41-7.51	3-4	10-34	Graça et al. 2001
Rib. da Sra da Piedade (Pereira)	6.3-6.7	44-46	5.3-6.3	1.34-2.09	<2-3	4-5	Graça et al. 2001
Rib. da Avessada	6.6-7.2	100-112	11.0-13.6	3.16-3.32	<2-5	3-19	Graça et al. 2001
Rib. de S João (Lousã)	6.3-6.9	45	5.1-7.6	1.67-1.86	2	6-16	Graça et al. 2001
Rio Sotão (Ponte do Seladinho)	6.0-6.6	33-34	3.7-5.9	1.94-2.13	<2-2	3-13	Graça et al. 2001
Rio Ceira (Serpins)	6.3	65	7.9-13.0	5.62	15	12	Graça et al. 2001
Rio Ceira (Azenha)	6.6-7.1	79-92	13.9	4.40-6.68	17-25	7-21	Graça et al. 2001
Rio Soure 1 (Alberg. dos Doze)	6.6-7.8	75-205	22-61	-	-	-	Graça et al. 1989
Rio Soure 2 (Vermoil)	7.6-7.9	117-335	69-145	-	-	-	Graça et al. 1989
Rio Soure 3 (Almagreira)	7.6-8.1	129-420	79-205	-	-	-	Graça et al. 1989
Rio Soure 4 (V.N. de Anços)	7.8-8.2	210-440	96-235	-	-	-	Graça et al. 1989
Rio Alva 1 (Sabugueiro)	5.0-5.8	9-15	1-2	-	-	-	Graça et al. 1989
Rio Alva 2 (Sandomil)	4.8-6.1	10-15	2-4	-	-	-	Graça et al. 1989
Rio Alva 3 (Coja)	5.2-6.3	12-23	2-7	-	-	-	Graça et al. 1989
Rio Alva 4 (Pombeiro da Beira)	5.4-6.5	15-39	2-9	-	-	-	Graça et al. 1989
Rio Alva 5 (Foz do Alva)	5.9-6.9	17-78	3-10	-	-	-	Graça et al. 1989
Rio Ceira (Foz de Arouce)	-	72	14	6.3	10	142	Oliveira & Coimbra unp
Rio Ceira (Vendas de Ceira)	-	-	6	5.6	15	157	Oliveira & Coimbra unp
Rio Dueça (Sobral)	-	355	-	-	-	-	Oliveira & Coimbra unp
Rio Dueça (Tremôa)	-	356	55	10.0	99	398	Oliveira & Coimbra unp.
Rio Alva (Coja)	-	37	9	1.4	5	10	Oliveira & Coimbra unp.
Rio Alva (Sabugueiro)	-	19	8	1.2	3	35	Oliveira & Coimbra unp.
Rio Mondego (Trinta)	-	22	7	2.2	3	64	Oliveira & Coimbra unp.
Rio Mondego (P. da Rainha)	-	76	16	3.7	15	18	Oliveira & Coimbra unp.
R. da Mata da Margaraça 1	6.3-6.8	40-50	20-24	-	-	-	Abelho & Graça 1996
R. da Mata da Margaraça 2	6.1-6.5	30-58	17-23	-	-	-	Abelho & Graça 1996
R. da Fraga da Pena	6.2-7.2	20-45	9-11	-	-	-	Abelho & Graça 1996
R. Sótão (Ponte do Seladinho)	7.1-7.3	23-38	-	0.09-0.14	3-7	9-10	Carvalho & Coimbra unp.
R. S. João (Lousã)	6.1-6.2	44-59	-	0.16-0.2[illegible]	<2-2	7-10	Carvalho & Coimbra unp

the Alva River decreased from 27 in the uppermost site to 21, 18, and 16 just before the confluence with the Mondego. Low number of families were also observed in the Ceira (8-11) and in the Mondego itself (18-19), when compared with low order streams (generally > 20 taxa; Table 3).

In low order streams, shredders were the dominant feeding group in terms of percentage of taxa or percentage of total invertebrate AFDM (Tables 4 and 5). The importance of shredders tended to decrease downstream. Patterns of seasonal (summer vs. winter) variation of shredders differed among rivers. In the Lousã streams, the variation was low. However, in the Alva River the shredder taxa varied from 0% to 37% (Graça et al. 1989). The longitudinal and seasonal variation in shredders was in agreement with the River Continuum (Vannote et al. 1980).

In terms of water quality, as judged by the application of the biotic index BMWP', the rivers and streams from the Lousã mountain can be considered unpolluted (Table 3). Scores above 200 were recorded at ribeira do Espinho (Cadaixo) and Ribeira da Sra. da Piedade (Pereira). According to data from 1989, the Soure River had an intermediate situation. In some cases it revealed clean conditions, whereas in other occasions it revealed pollution stress. At Soure 4 (V. N. Anços) the low score of the index revealed a clear pollution stress. The situation was similar for the Alva River. However, the lower Alva River had a predominance of a sandy substrate and it has frequently demonstrated that this substrate is unfavourable for invertebrate colonisation and therefore, the low score could reflect, in this case, not only a decrease in water quality, but also the substrate characteristics.

Water quality in the Ceira rivers varied from good – acceptable (BMWP' = 122-152) to bad (BMWP' = 48 and 75). The same occurred in the Mondego River (BMWP' = 89-114). In general, in the Mondego River there are streams with a clear high quality of waters and severely polluted sites.

Discussion

Higher taxa richness was observed in low order streams (≤ 4) when compared with intermediate / larger rivers (≥ 5). This pattern was postulated by the river continuum concept (Vannote et al. 1980), based on the spatial and temporal environmental heterogeneity of intermediate rivers. Although we measured richness in terms of number of families, some studies have shown a strong correlation between the number of species and the number of higher taxonomic groups (e.g. Graça et al. 1995, Chessman 1995).

As predicted by the river continuum concept, shredders were the dominant group in the low order streams but decreased downstream. This can be explained by the expected differences in the amount of coarse particulate organic matter. However, the differences in seasonal changes are more challenging. Although litter inputs are higher in autumn than in other seasons (Abelho and Graça 1998), organic matter accumulation in the stream bed may not be correlated with litterfall due the hydrologic regime and the occurrence of spates causing an increased transport of benthic organic

Table 3. Biological parameters and water quality according with the BMWP' index for several stream / river sites in the Mondego river basin.

Stream / River	Order	Nº Families	BMWP'	Year	Representative Families	Source
Rib. da Fonte de Espinho	2	14-23	112- 160	1998/1999	Leuctridae, Nemouridae, Chironomidae	Graça et al. 2001
Rib. do Cabeço	2	18-26	125-159	1998/1999	Leuctridae, Chironomidae, Nemouridae	Graça et al. 2001
Rib. do Candal	3	27-28	181-185	1998/1999	Leuctridae, Goeridae, Chironomidae	Graça et al. 2001
Rib. de Cerdeira	3	27-35	168-237	1998/1999	Leuctridae, Chironomidae, Hydropsychidae	Graça et al. 2001
Rib. Pé da Lomba	3	19-27	109-175	1998/1999	Chironomidae, Sphaeridae, Sericostomatidae	Graça et al. 2001
Rib. de Espinho (Cadaixo)	4	30-33	229-240	1998/1999	Chironomidae, Sphaeridae, Limnephilidae	Graça et al. 2001
Rib. da Sra da Piedade (Pereira)	4	34-42	210-270	1998/1999	Baetidae, Elmidae, Tricladida	Graça et al. 2001
Rib. da Avessada	4	33-34	188-212	1998/1999	Chironomidae, Baetidae, Limnephilidae	Graça et al. 2001
Rib. de S. João (Lousã)	5	27-29	166-181	1998/1999	Chironomidae, Hydropsychidae, Leuctridae	Graça et al. 2001
Rio Sotão (Ponte do Seladinho)	5	30-33	180-242	1998/1999	Baetidae, Chironomidae, Leuctridae	Graça et al. 2001
Rio Ceira (Serpins)	6	24	152	1998/1999	Baetidae, Simuliidae, Philopotamidae	Graça et al. 2001
Rio Ceira (Azenha)	6	21-22	122-127	1998/1999	Hydropsychidae, Philopotamidae, Baetidae	Graça et al. 2001
Rio Soure 1 (Alberg. dos Doze)	-	14-22	80-108	1984/1985	*Potamopyrgus*, *Baetis*, *Caenis*	Graça et al. 1989
Rio Soure 2 (Vermoil)	-	18-25	88-159	1984/1985	*Potamopyrgus*, Chironomidae, *Baetis*	Graça et al. 1989
Rio Soure 3 (Almagreira)	-	15-24	61-101	1984/1985	Simuliidae, *Baetis*, Chironomidae	Graça et al. 1989
Rio Soure 4 (V.N. de Anços)	-	8-18	35-82	1984/1985	Chironomidae, Hydracarina, Simuliidae	Graça et al. 1989
Rio Alva 1 (Sabugueiro)	-	15-27	93-150	1984/1985	*Leuctra*, *Amphinemura*, *Hydropsyche*	Graça et al. 1989
Rio Alva 2 (Sandomil)	-	14-21	76-124	1984/1985	Chironomidae, *Baetis*, *Leuctra*	Graça et al. 1989
Rio Alva 3 (Coja)	-	14-21	82-121	1984/1985	Hydracarina, *Hydropsyche*, Chironomidae	Graça et al. 1989
Rio Alva 4 (Pombeiro da Beira)	-	12-18	75-96	1984/1985	*Caenis*, *Baetis*, Chironomidae	Graça et al. 1989
Rio Alva 5 (Foz do Alva)	-	7-16	37-98	1984/1985	*Baetis*, *Choroterpes*, Simuliidae	Graça et al. 1989
Rio Ceira (Foz de Arouce)	-	15	75	1999	*Baetis*, *Potamopyrgus*, *Chimarra*	Oliveira & Coimbra unp.
Rio Ceira (Vendas de Ceira)	-	8	48	1999	Lumbriculidae, *Hydropsyche*, *Boyeria*	Oliveira & Coimbra unp.
Rio Dueça (Sobral)	-	11	51	1999	*Baetis*, *Atyaephyra*, Simuliidae	Oliveira & Coimbra unp.
Rio Dueça (Tremôa)	-	15	60	1999	*Athyaephyra*, Lumbriculidae, *Caenis*	Oliveira & Coimbra unp.
Rio Alva (Coja)	-	9	48	1999	*Ephemerella*, *Baetis*, *Nemoura*	Oliveira & Coimbra unp.
Rio Alva (Sabugueiro)	-	14	81	1999	*Leuctra*, *Baetis*, Limnephilidae	Oliveira & Coimbra unp.
Rio Mondego (Trinta)	-	19	114	1999	Simuliidae, *Sericostoma*, *Baetis*	Oliveira & Coimbra unp.
Rio Mondego (P. da Rainha)	-	18	89	1999	Chironomidae, *Caenis*, *Baetis*	Oliveira & Coimbra unp.
R. da Mata da Margaraça 1	1	32-35	187-198	1991/1992	Chironomidae, *Leuctra*, Naididae	Abelho & Graça 1996
R. da Mata da Margaraça 2	3	31-34	201-216	1991/1992	*Leuctra*, Chironomidae, *Baetis*	Abelho & Graça 1996
R. da Fraga da Pena	3	28-29	181-187	1991/1992	*Leuctra*, Chironomidae, *Ephemerella*	Abelho & Graça 1996
R. Sótão (Ponte do Seladinho)	5	31-36	208-225	1996	Chironomidae, *Baetis*, *Caenis*	Carvalho & Coimbra unp.
R. S. João (Lousã)	5	39-48	242-294	1996	Chironomidae, *Baetis*, *Leuctra*	Carvalho & Coimbra unp.

Table 4 - Percentage of taxa classified as shredders in several studied sites of the Mondego basin

Name	Order	% of shredder taxa	Source
Rio Soure 2 (Vermoil)		0-3	Graça et al. 1989
Rio Soure 3 (Almagreira)		0	Graça et al. 1989
Rio Soure 4 (V. N. de Anços)		0-1	Graça et al. 1989
Rio Alva 1 (Sabugueiro)		9-33	Graça et al. 1989
Rio Alva 2 (Sandomil)		2-35	Graça et al. 1989
Rio Alva 3 (Coja)		0-37	Graça et al. 1989
Rio Alva 4 (Pombeiro da Beira)		1-21	Graça et al. 1989
Rio Alva 5 (Foz do Alva)		0-20	Graça et al. 1989
Rio Ceira (Foz de Arouce)		15	Oliveira & Coimbra unp.
Rio Ceira (Vendas de Ceira)		8	Oliveira & Coimbra unp.
Rio Dueça (Sobral)		11	Oliveira & Coimbra unp.
Rio Dueça (Tremôa)		15	Oliveira & Coimbra unp.
Rio Alva (Coja)		9	Oliveira & Coimbra unp.
Rio Alva (Sabugueiro)		14	Oliveira & Coimbra unp.
Rio Mondego (Trinta)		19	Oliveira & Coimbra unp.
Rio Mondego (P. da Rainha)		18	Oliveira & Coimbra unp.
R. da Mata da Margaraça 1	1	8-55	Abelho & Graça 1996
R. da Mata da Margaraça 2	3	19-35	Abelho & Graça 1996
R. da Fraga da Pena	3	28-37	Abelho & Graça 1996
R. Sótão (Ponte do Seladinho)	5	4-5	Carvalho & Coimbra unp.
R. S. João (Lousã)	5	6-9	Carvalho & Coimbra unp.

Table 5. Percentage of shredders in terms of biomass m^{-2} at 12 sites ranging from 2nd to 6th order (Lousã region) (after Graça et al. 2001)

Stream order	Shredder density (μg AFDM m^{-2})	% AFDM of shredder taxa
2	65	45
3	138	41-44
4	92	20-21
5	17	21-24
6	8	2

matter (Abelho and Graça 1998). Streams and rivers may differ in their retentiveness and hydrologic regime and these differences may condition the seasonal abundance of shredders. This relationship was not yet tested in our stream systems.

Some streams and small rivers had a high water quality, according to the application of biotic index. The BMWP' was adapted for the Iberian Peninsula, but based in studies carried out in Spain. Indices developed for a particular area have been applied, apparently with success, in other geographical areas (e.g. the BBI, developed for Belgium, applied in Portugal, Indonesia, Canada and other areas: Fontoura and Moura 1984, Krystiano and Kusjantono 1991, Barton and Metcalfe-Smith 1992, De Pauw et al. 1986). However, before the application of the indices developed for other areas, it is necessary first to test them according with the local ecological, hydrologic and geological conditions (e.g. Coimbra and Graça 1998, Graça and Coimbra 1998). The results of the application of the BMWP' were consistent with the chemical information of the studied sites and therefore, the index is likely to be a useful tool for the water quality assessment in Central Portugal.

For rapid biological monitoring proposals, several studies have shown that aquatic invertebrates identified to the family level are good indicators of water quality. (Graça et al. 1995) showed that reducing the identification of invertebrates to the family level instead of species / genus level saved 50% of identification effort with no information loss in terms of water quality. The BMWP score system used to evaluate water quality in British rivers (Armitage et al. 1983) rely on families of aquatic invertebrates. Hughes (1978) showed that the diversity (H') of species, genus, family and orders where highly correlate. Osborne et al. (1980) analysing macroinvertebrate samples identified to species, genus and family levels from contaminated and clean sites showed that identification to family level was sufficed to detect inter-site diversity differences.

Invertebrates in streams and rivers fill numerous ecological niches, feed on aquatic producers and on allochthonous organic matter and serve as food to other aquatic and terrestrial / flying organisms. They are therefore an important energetic component transferring energy and material from the producers and the detritus pool to upper levels in the food chains. Aquatic invertebrates have also been used to test numerous ecological theories (e.g. Allan 1984).

The information here provided resulted from several independent and small-scale investigations. We suggest that macroinvertebrates and environmental conditions of a larger set of clean sampling sites should be investigated in order to provide reference conditions to which impacted or potentially impacted areas could be compared for the propose of water quality evaluation.

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