Community structure and water quality in the Mediterranean streams of a natural park (St. Llorenç del Munt, NE Spain).

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ABSTRACT

The macroinvertebrate community in the streams of the Natural Park of Sant Llorenç del Munt and Serra de l'Obac (Barcelona, NE Spain) and its relationships with the stream flow were studied twice in one year, in winter and summer 1996. 78 localities were visited for flow examination, although samples of macroinvertebrates were taken in only 26 of them. While in winter, 63% of the stream's length had continuous flow, and the rest had at least pools, in summer only 26% had continuous flow, 20% was totally dry and the rest maintained permanent pools. Despite this, the total number of macroinvertebrate families increased from 54 in winter to 94 in summer. Trichoptera and Plecoptera lost relative importance from winter to summer, while Heteroptera, Coleoptera, Odonata and Diptera were dominant in summer. In general, collector-gatherers were the most abundant, although, in summer, an increase in the number of scrapers and predators was observed. The study of the abundance of the different families in the two periods, using canonical correspondence analysis, revealed that flow and temperature, together with those factors related to the increase in primary production in summer (pH, oxygen) explained most of the community change between wet and dry seasons, while other physicochemical-factors were unimportant. The biotic index BMWP' did not show significant changes between periods. High values of BMWP' in summer can be explained by the high diversity of the macroinvertebrate community during this season, despite individual scores of families being smaller than in the wet period.

Keywords: Macroinvertebrates, temporary streams, Mediterranean streams, biodiversity, water quality.

RESUMEN

Se estudian las comunidades de macroinvertebrados de los ríos del Parque Natural de Sant Llorenç del Munt i la Serra de l'Obac (Barcelona, NE España) y su relación con las condiciones de flujo de los ríos. Hasta 78 localidades se visitaron en dos ocasiones (invierno y verano de 1996) y en 26 de ellas se tomaron muestras de macroinvertebrados. Mientras en invierno el 63 % de los kilómetros investigados tenía flujo continuo y menos del 1% estaba seco, en verano solo el 26% tenía flujo continuo, un 20% estaba totalmente seco y el resto presentaba pozas en su lecho. A pesar de ello el número de familias de macroinvertebrados fue de 54 en invierno y 94 en verano, siendo dominantes en este último caso los heterópteros, coleópteros, odonatos y dípteros, mientras que en invierno los tricópteros y plecópteros eran más diversos. En general, la comunidad presentó una estrategia trófica recolectora aunque la proporción de los ramoneadores y depredadores aumentó en verano. El estudio de las comunidades mediante el análisis de su abundancia en los dos períodos, mostró que las variables temporales (flujo, temperatura) o las relacionadas con el incremento de la producción primaria (oxígeno, pH) explicaban la mayor parte de la variabilidad con los elementos mas reófilos propios de invierno y los leníticos de verano, mientras que otros factores fisicoquímicos no eran relevantes. Calculado el índice biológico BMWP' se demostró que los valores en verano eran superiores o similares a los de invierno lo que se explica por la mayor diversidad aunque la calificación individual de cada una de las familias encontradas en verano fuera menor que las halladas en invierno.

Palabras clave: Macroinvertebrados, ríos temporales, ríos Mediterráneos, biodiversidad, calidad del agua.

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INTRODUCTION

Macroinvertebrates in temporary fresh waters and Mediterranean streams have been largely neglected in many parts of the world (Boulton & Suter, 1986; Williams, 1996) despite the comprehensive reviews of Williams & Hynes (1976, 1977), Williams (1996) and Giudicelli *et al.* (1985). In Spain, there are several studies of Mediterranean streams in which inventories of macroinvertebrates are included (Prat *et al.*, 1985, 1986; Puig *et al.*, 1986; Vidal-Abarca *et al.*, 1992; Gallardo, 1993; Prenda & Gallardo, 1996; Martínez-López *et al.*, 1996; Domínguez *et al.*, 1997; Del Moral *et al.*, 1997), as well as papers on the "ramblas" of the semi-arid south-eastern Spain (Ortega *et al.*, 1991; Vidal-Abarca *et al.*, 1992; Moreno *et al.*, 1996).

The stream networks of Mediterranean basins are characterised by high slope, high drainage density and, in several cases, the absence of flow in summer, especially in the lower parts where water has been used intensively for many years. During the dry period, Mediterranean streams can be reduced for several months to a succession of pools which act as a refuge for many plant and animal species, including fish (Delucchi, 1989; Ortega *et al.*, 1991). The carbonaceous geology and the karstic nature of most of these streams in Spain increase the probability and duration of the dry period.

As a whole, in Mediterranean streams the typical rheophilous insect groups (Plecoptera, Ephemeroptera and Trichoptera) are not as dominant as they are in more permanent streams, and other groups (Hemiptera, Coleoptera and Odonata) can become more abundant. This situation has been described in several Spanish watersheds (Suárez *et al.*, 1986; Vidal-Abarca *et al.*, 1991; Moreno *et al.*, 1996, 1997) and in other Mediterranean climate zones like South-Australia (Boulton & Suter, 1986) or California (Resh *et al.*, 1990). A comprehensive review of the differences in the distribution of major insect groups in Spanish rivers can be found in Alba-Tercedor *et al.* (1992). All these studies have shown the importance of the length of the dry period in conforming the communities, the large changes occurring between the wet and dry periods and the reset of ecological succession after major floods (Williams & Hynes, 1977; Fisher *et al.*, 1982, Ortega *et al.*, 1991).

Our study was performed in Mediterranean streams and brooks in the Sant Llorenç Natural Park area (Catalonia, NE Spain). Our main objective was to understand the changes in the macroinvertebrate community structure occurring between the dry and wet periods. The study was carried out in a protected area, in which human disturbance has been very low for the past 30 years, although the area was not designated as Natural Park until 1987. The karstic geology increases the possibility that streams will dry up in summer. The area offers a good study site to investigate how drought disturbance may affect the macroinvertebrate community of Mediterranean streams in pristine or semi-pristine conditions.

STUDY AREA

Sant Llorenç del Munt Natural Park is located north of Barcelona metropolitan area (NE Spain) and comprises a surface area of 9630 ha. The area has Mediterranean climate, with irregular torrential rains concentrated in spring and autumn. Summer is normally a very dry period. The geology is karstic and therefore the substrate is highly permeable. Thus, surface flow in streams ceases rapidly, in hours or days after rains. There are permanent streams in areas where discharge from karstic aquifers exists. Vegetation is dominated by evergreen oak, except in the steepest areas or in places with rocky outcrops. Forest fires are common in the Mediterranean, and several were experienced recently in areas close to the Park. However, the Park itself has not had fires in the last 40 years. The mountanous areas of Sant Llorenç del Munt and Serra de l'Obac included in the Park protection boundaries are largely located between 280 and 1100 metres a.s.l. There are several towns around the Park, with a total population of

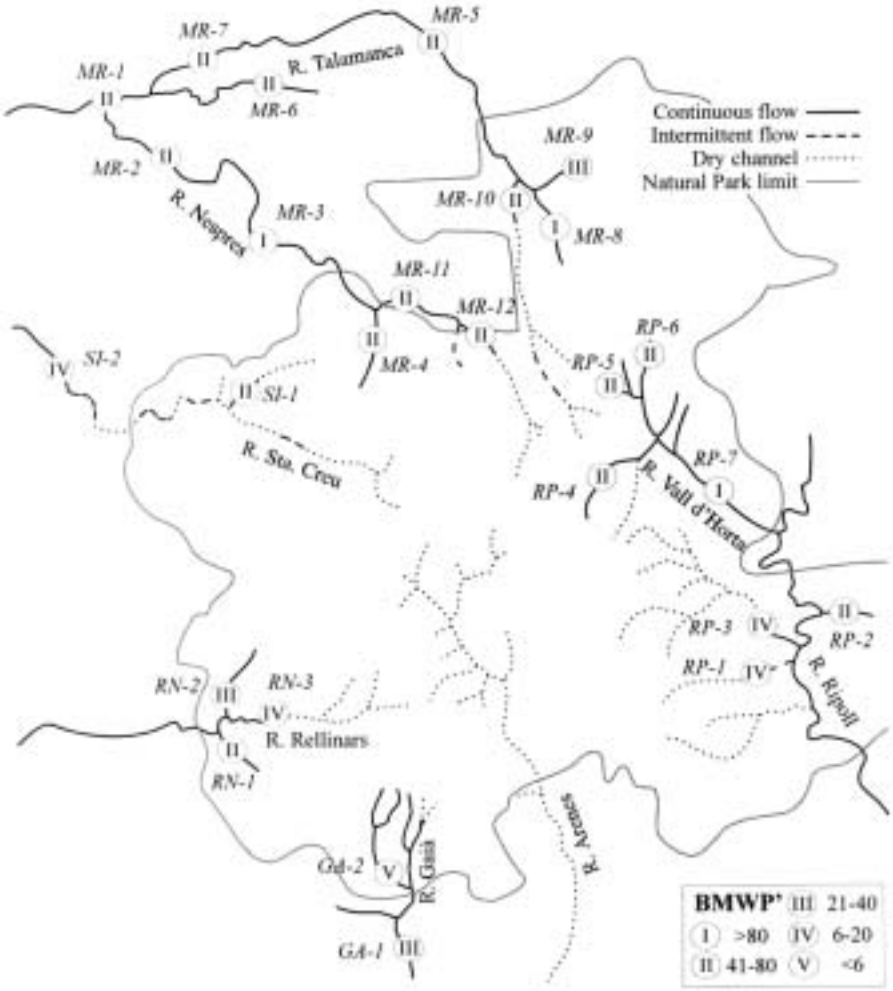

Figure 1. Map of flow types (February) and water quality defined by the BMWP' biological index of the study area. *Mapa de tipos de flujo (Febrero) y de calidad del agua según el índice biológico BMWP' del área estudiada.*

ca 200 000 inhabitants. The Park is thus quite a popular area for hiking, with several small tourist resorts located in the surroundings. The number of visitors registered by the park service is close to 80 000 per year. The Southeast area of the Park belongs to the River Besòs watershed, while the rest of tributaries washing the Park area discharge into the River Llobregat catchment. Both rivers, Besòs and Llobregat, and their major tributaries have been previously studied (Prat *et al.*, 1986, 1996, 1997). However, the macroinvertebrate fauna of the small streams in the present study have not been investigated yet (Real *et al.*, 1989).

MATERIAL AND METHODS

Seventy eight localities were visited in February (wet period) and August 1996 (dry period). In both dates, the flow condition was recorded (i.e. dry bed, continuous flow and intermittent flow). Twenty six stations of the total of 78 were sampled for chemistry and macroinvertebrates, 20 of them inside the Park area and 6 in surrounding areas. The sampling stations and streams sampled are shown in Figures 1 and 2.

Water velocity was measured using a flow meter. Several measures of velocity were made

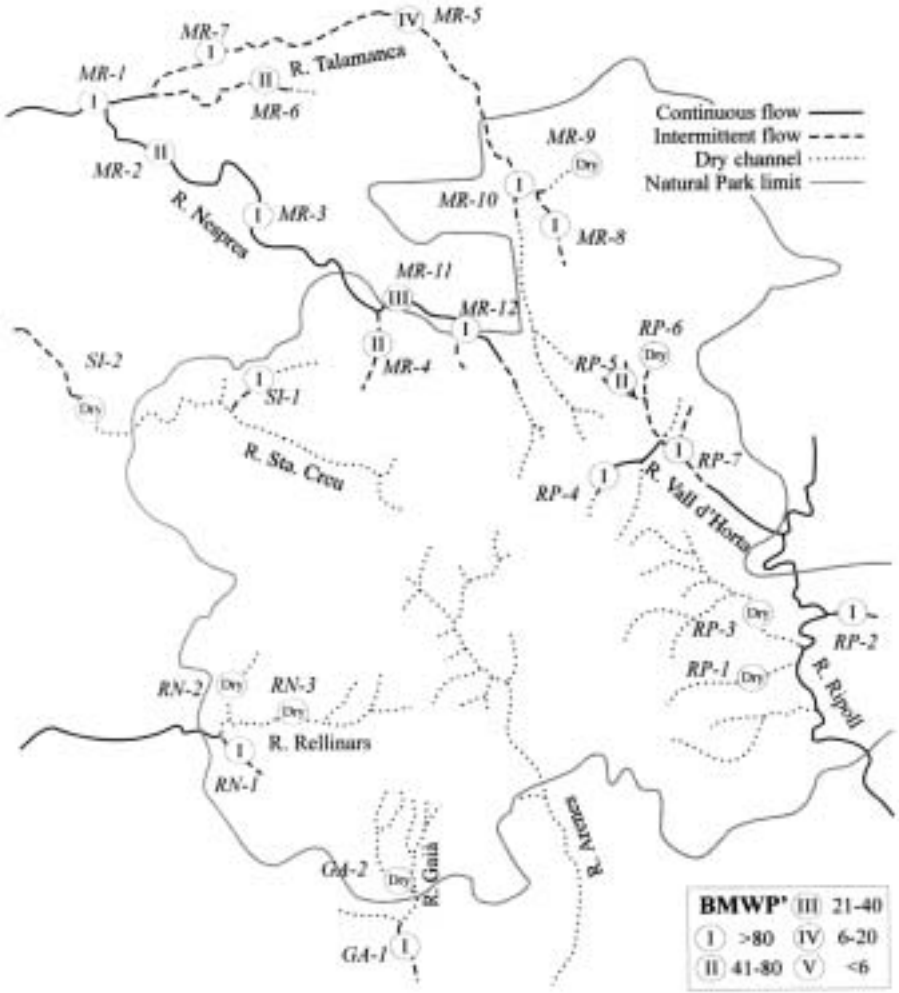

Figure 2. Map of flow types (August) and water quality defined by the BMWP' biological index of the study area. *Mapa de tipos de flujo (Agosto) y de calidad del agua según el índice biológico BMWP' del área estudiada.*

across a transect at each sampling station, at varying distances from the margins and at different depths. Discharge of streams was estimated from these parameters. *In situ* measurements of conductivity, pH, temperature and dissolved oxygen were also taken. A 1-L sample of water was collected, kept cool and analysed in the next few days for concentrations of chloride, sulphate, ammonia, nitrite, nitrate, total phosphorus and weight of total suspended solids.

Macroinvertebrates were sampled using a circular net of 250 µm mesh size. All substrates available to macroinvertebrates were sampled using the kick method, expending a similar time effort at each sampling site. The sample was preserved with formalin for sorting and identification in the laboratory. For the purposes of this paper, identification of animals was kept at the level of family. This taxonomic level of identification expresses the overall biodiversity of the community and can be used

Tabla 1. Proportions (in %) of the total stream length studied with the three types of flow. See text for details. *Proporción relativa (en %) de la longitud total de río estudiada que presentaban distintos tipos de flujo.*

	FEBRUARY	AUGUST
Continuous flow	63 %	26 %
Intermittent flow	35.5 %	54 %
Without flow	0.5 %	20 %

in studies of water quality (Bournaud *et al.*, 1996). The biotic index of water quality used in this paper is the index BMWP' (Alba-Tercedor & Sanchez-Ortega, 1988). For each family, abundance (individuals/sample) was recorded and used in more detailed numerical analyses of community structure.

Pattern in the structure of the macroinvertebrate community was analysed with a CCA (Correspondence Canonical Analysis) using the CANOCO program (Ter Braak, 1987). There were numerous zeroes in the matrix and the data were transformed with the expression ln (x+1), where 'x' are the abundances. Only the most significant variables were used in the graphical representation of CCA results.

RESULTS

Temporality

Every summer, several streams in the Park dry up, due to both climate and geology. Pools remain in some of them. The study year 1996, was a relatively wet year, with a total precipitation of 1195 mm, which is clearly higher than the long-term average of 700 mm. Despite this, several streams and brooks in the Park ceased to flow this year although pools could still be found in many of them. The flow condition of the streams in Sant Llorenç Natural Park during the wet and dry periods is shown in figures 1 (wet period) and 2 (dry period). Three situations are illustrated in each figure, i.e. 1 - Flowing water (from 1 to 600 L s^{-1}; continuous line), 2 - River courses with pools but without surface flow (dashed lines), and 3 - Dry beds (line of points). A summary of the percentage of total length (in kilometres) falling within each of the three categories during both sampling periods (i.e. winter or wet period, and summer or dry period) is provided in Table 1.

Within the natural Park almost all streams were dry in summer, and the few flowing streams had very low flows (max 10 L s^{-1}). Several brooks and streams maintained pools. The main streams which had permanent flows (26 % of total length surveyed) were outside or near the Park limits, downstream of permanent springs of karstic origin. Although 1996 was a wet year, 20 % of the total length surveyed was totally dry, i.e. without pools (see Fig. 2 and Table 1).

Biodiversity

The lack of flowing water in Mediterranean streams during summer may portray an image of poor, low diversity environments, thus suggesting these ecosystems are of low conservation value. However, the number of taxa found in the streams of the St. Llorenç Natural Park and surrounding areas in 1996 was higher in summer, the dry period, than in winter (see Fig. 3). The total number of different macroinvertebrate families found in streams in winter was 54, compared to 76 in summer. The increase in biodiversity was due to the summer occurrence of typically lentic species (e.g. species of Heteroptera, Coleoptera and Odonata), together with a large increase in Diptera families. Families of Plecoptera and Trichoptera, on the other hand, were less in winter than in summer. Species richness of Coleopterans and Hemiptera was higher in February than that of Ephemeroptera and Plecoptera. The latter are dominant in permanent, temperate rivers (Fig. 3). These results highlight the importance of typically lentic taxa in streams of the Mediterranean.

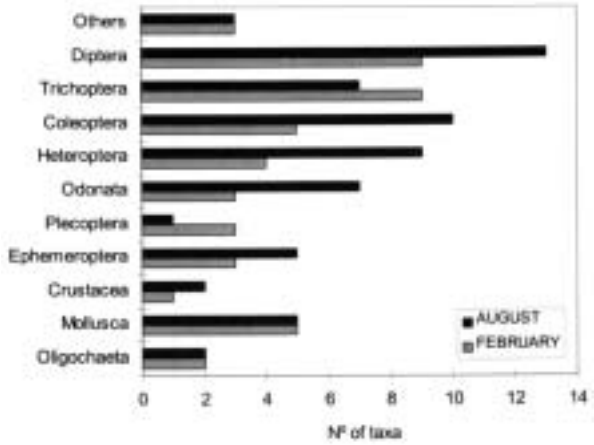

Figure 3. Number of taxa found in each invertebrate taxonomic order in February and August. *Número de taxones de cada orden de invertebrados hallados en Febrero y en Agosto.*

Water quality

Water quality was evaluated by means of the biotic index BMWP' (Alba-Tercedor & Sánchez-Ortega, 1988) with some modifications in its quality ranges. In temporary streams increases in the number of low-score groups (e.g. Heteropterans, Coleopterans, ...), and the disappearance of high-score families (e.g. Trichopterans, Plecopterans, ...) can lead to low values of the index even if conditions are thought to be pristine. In a previous study (Prat *et al.*, 1996), we recalculated quality ranges for the case of Mediterranean streams, lowering the maximum value the index could achieve. Thus, values higher than 80 could indicate good water quality, instead of the previous 100 score required. According to the water quality ranges of the index in Table 2, only 8 sampling sites in February, and 2 in summer, fall into the lower quality classes.

Functional feeding groups

Abundances of each family have been grouped according to feeding habit, from information gleaned from the literature (Merritt & Cummins, 1996; Bournaud *et al.*, 1996). In some cases (e.g. chironomids), the subfamily level was used. Most of the animals present in our streams were collector-gatherers (Fig. 4), especially in winter. Then, the abundance of detritus is probably greater in the forested streams of the Park. Algal mats are not developed in the karstic permanent rivers due to the low temperature of winter, either. In summer, the encrusting and filamentous algae are frequent in the Mediterranean streams and their production can be high (Sabater *et al.*, 1995). As a result, the relative abundance of scrapers increased to values similar to those of collectors (Fig. 4). Predators also increased during summer, due to the increase in abundance of Odonata, Hemiptera and Coleoptera. This shows a more complex community develops in the dry season than in the wet.

Tabla 2. Number of sampling sites classified within each quality class. Numbers are shown for winter and for summer. *Número de estaciones de muestreo en cada categoría de calidad del agua, en invierno y verano.*

		All localities		Localities in the Natural Park	
BMWP' value	**Quality Class**	**FEBRUARY**	**AUGUST**	**FEBRUARY**	**AUGUST**
>80	I	3	12	2	9
41 to 80	II	15	4	10	2
21 to 40	III	3	1	3	1
6 to 20	IV	4	1	4	0
<6	V	1	0	1	0

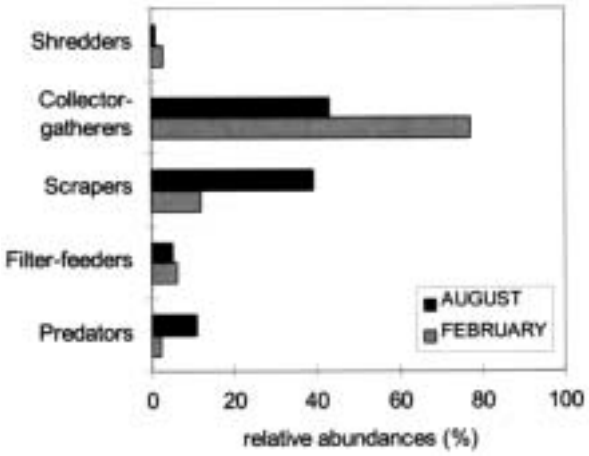

Figure 4. Relative abundance of functional feeding groups. *Abundancia relativa de los distintos grupos funcionales de invertebrados.*

Community structure

We performed a Canonical Correspondence Analysis CANOCO (Ter Braak, 1987) using the abundance of each macroinvertebrate family and the physicochemical parameters measured (Fig. 5). Chloride, sulphate, conductivity, ammonia, nitrate and nitrite were not significantly different between sampling sites. Phosphate was always below detection level (0.2 mg L^{-1}). Therefore, water chemistry is quite similar throughout the area and does not explain the abundance and presence of the different species. Temperature, oxygen, flow and pH were retained as parameters, as they were significant changes between sampling stations or/and between dates. Calcium and potassium were also used as indicators of regional changes in water chemistry (Fig. 5).

The results of the analysis show the importance of temporal change in the matching of the communities. Samples taken in August are grouped together and separated from those of February (Fig. 5). The first axis explains 43% of the total variance in abundance data and was related to seasonality of the macroinvertebrate community. Structure shifted from Plecoptera/ Trichoptera to Odonata/Coleoptera/ Heteroptera dominance and changes were clearly related to temperature increases (Fig. 6). The second axis explained 25 % of total variance, and was associated to the effects of flow and algal activity on water physicochemistry and macroinvertebrate community composition. During high-flow conditions and low temperature (i.e. winter), oxygen concentration and pH increased, while calcium carbonate tended to precipitate. Species typical of riffle habitats (bottom in Figure 6) were better related to these conditions than species more typical of pool habitats (top in Figure 6). Families only found in winter (i.e. when low temperatures and high flows) are on the left in figure 6, while those present only in summer (i.e. when temperatures are higher and flows are low or non-existent) are situated to the right in figure 6. Those present in both periods at a similar abundance, are located in the centre of figure 6.

DISCUSSION

Temporary Mediterranean streams may have similar levels of biodiversity to those in permanent streams of temperate areas (Legier & Talin, 1976; Boulton & Suter, 1986; Boulton & Lake, 1992b; Williams, 1996). Our results, and data from other Mediterranean streams in Spain (see Table 3) support the hypothesis that biodiversity in semi-permanent or intermittent streams is comparable to that in permanent streams, as noted in other studies in Spain (Puig *et al.*, 1991; Alba-Tercedor *et al.*, 1992). At the level of family, biodiversity of Mediterranean streams is quantitatively not different from the total richness of some streams in England, for instance (Wright *et al.*, 1997), despite the lower species richness per family of some groups (e.g. Plecoptera and Trichoptera; Giudicelli *et al.*, 1985). However, highly humanised basins without pristine headwaters (e.g. River Foix, Prat *et al.*, 1985), rivers with high salinity or very polluted (Prenda & Gallardo, 1996) or semi-arid streams (e.g. "Ramblas") experiencing strong disturbances (i.e. large floods and severe droughts) have lower family and species richness

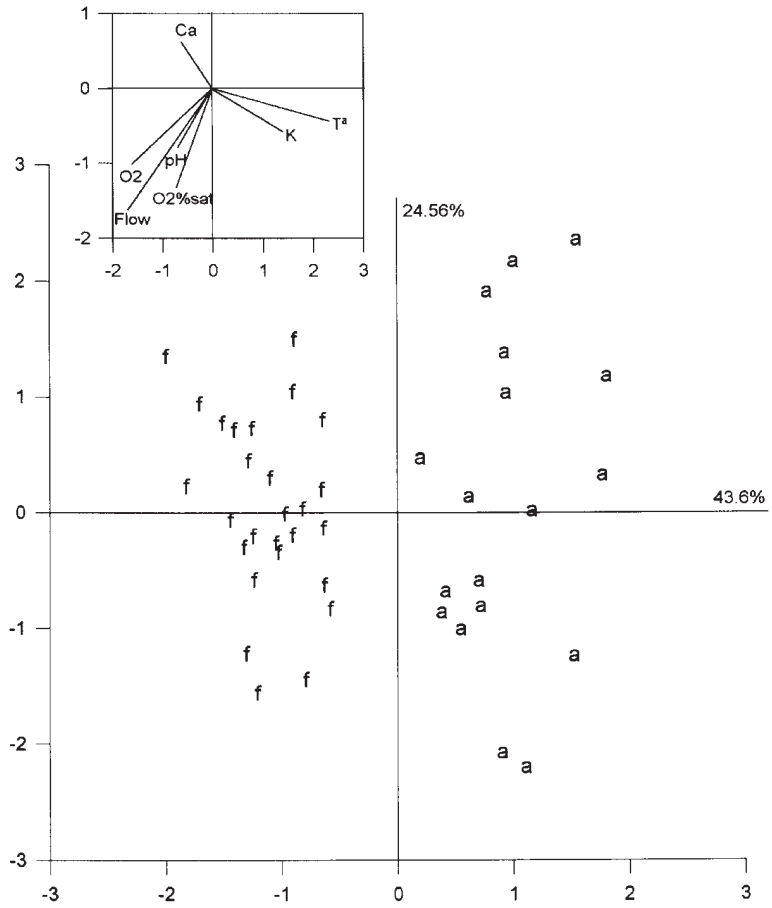

Figure 5. Distribution of physico-chemical parameters and sampling sites in February (f) and in August (a) on the first two axes defined by CCA analysis. *Distribución de los parámetros fisicoquímicos y de las estaciones de muestreo estudiadas en Febrero (f) y en Agosto (a) sobre los dos primeros ejes de coordenadas definidos por el análisis CCA.*

Tabla 3. Number of macroinvertebrate families in different Mediterranean streams and semi-arid "Ramblas". E=Ephemeroptera; P=Plecoptera; T=Trichoptera; O=Odonata; C=Coleoptera; H=Heteroptera. *Número de familias de macroinvertebrados presentes en varios ríos mediterráneos y en ramblas. E=Ephemeroptera; P=Plecoptera; T=Trichoptera; O=Odonata; C=Coleoptera; H=Heteroptera.*

Stream	Stream length studied (Km)	E+P+T	O+C+H	Others	TOTAL
Besòs	314	25	27	35	87
St. Llorenç	65	18	28	25	71
Foix	100	16	16	24	56
Sierra Espadán	29	20	24	36	80
Cabriel	95	14	24	36	74
Palancia	104	21	19	29	69
Mundo	200	26	21	32	79
Rambla del Moro	5	2	18	13	33
Salado	40	5	7	17	29
Guadalete-Guadaira	420	30	32	35	93
England	-	31	23	53	117

(Ortega *et al.*, 1991; Moreno *et al.*, 1996) than Mediterranean streams having permanent pristine headwaters. For example, the River Mundo, which is situated in the same geographical area as the family-poor Rambla del Moro, presents a family biodiversity which is comparable to that in other Mediterranean streams or in English rivers. This is thanks to the presence of permanent streams in the headwaters of its catchment, and of temporary streams in some of its tributaries at lower altitude (Table 3). This underlines the importance of preservation of small headwater streams, such as those in Sant Llorenç Natural Park. Also summer pools in all the basin act as refuges for the biodiversity of macroinvertebrates in Mediterranean catchments (Vidal-Abarca *et al.*, 1992) and should be preserved, too.

In summer, although a few typically rheophilous species (mostly Plecoptera and Trichoptera), may have disappeared from the St. Llorenç stream network, other species appear of Hemiptera, Coleoptera, Odonata and Diptera, maintaining high diversity values. Such changes have been noted in temporary streams (Boulton & Lake, 1992a and b) and in other Mediterranean streams in Spain, both at family and at species level (Table 3).

The trophic structure of the macroinvertebrate community in streams in Sant Llorenç del Munt is dominated by collector-gatherers, both in the wet and in the dry season, as pointed out in other studies (Boulton & Suter; 1986; Williams, 1996). However, a marked increase in the number of scrapers was also observed during summer, due to higher primary production in rivers with scarce riparian vegetation cover, in downstream parts of streams. Shredders are scarce in St. Llorenç streams, perhaps explained by the scarcity of palatable leaves from riparian habitats. In these small, high gradient rivers, the riparian forest is, at most, a narrow strip along the river and is absent in many stretches. Evergreen oak is the most common tree species and its leaves are thought to be difficult to colonise by microorganisms. Also, most leaves are washed out by autumn and winter floods following seasonal storms. Most of the allochthonous material is processed as fine detritus collected in pools and used by collector-gatherers. Few leaf packs are usually available for shredders in these streams. Scarcity of shredders in temporary streams has been reported in other studies (Boulton & Lake, 1992b), although evidence is controversial and shredders can be very abundant in some temporary streams (e.g. Dieterich *et al.*, 1997). On the other hand, predators (e.g. Odonata and Hemiptera) increase in abundance during summer. These taxa are more abundant in summer in small intermittent streams where fishes are absent.

From our results, the biotic index BMWP' (Alba-Tercedor & Sánchez-Ortega, 1988) can be applied in permanent and temporary Mediterranean streams and brooks of Sant Llorenç Natural Park without great modification and could, therefore, be a useful tool for qualifying streams for conservation, at least in wet years like 1996. The absence of several high-score groups (Plecoptera, Trichoptera) in such streams is compensated for by the increase in the number of macroinvertebrate low-score families inhabiting pools (e.g. Heteroptera, Coleoptera and Odonata). These groups lead to high values of the index in both winter and summer, or even marginally higher in summer than in winter. The lowest values of the index were recorded in summer, downstream of a small village, due to pollution by sewage (see Fig. 2). Special care in the interpretation of biotic index results should be taken in two cases: firstly, when the summer pools are very small and, secondly, during the first recolonization phases of the dry channels beginning the wet period. In both cases, BMWP' index values are usually low (Table 2). In winter, 8 sampling sites presented quality class lower than III, in areas where water pollution was absent. Low values of the index due to environmental constraints rather than pollution, have been reported in other Mediterranean rivers (Martínez-López *et al.*, 1996; Domínguez *et al.*, 1997). In our case, regionalisation of freshwaters within the basin should be carried out and reference conditions for communities and biological indices defined if biotic indexes are to be used. Water

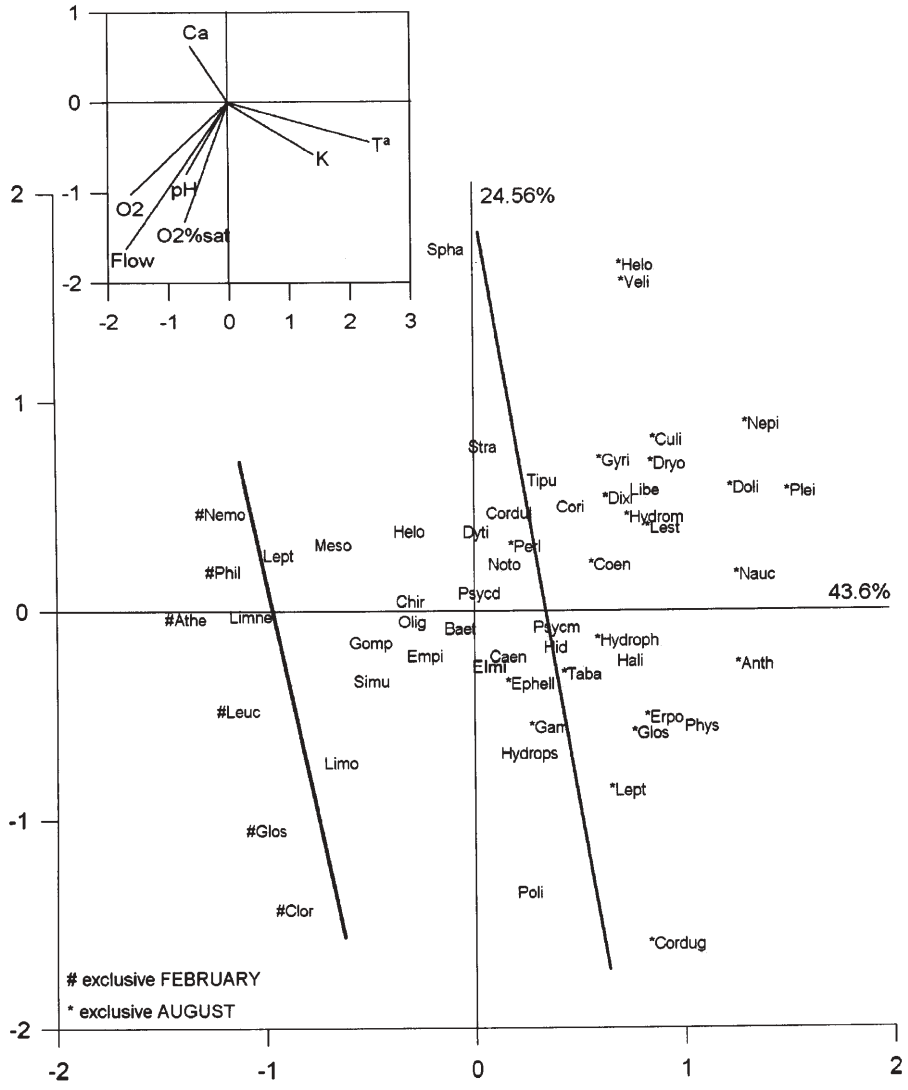

Figure 6. Distribution of macroinvertebrate families on the first two axes defined by a CCA analysis. *Distribución de las familias de macroinvertebrados sobre los dos primeros ejes de coordenadas definidos por el CCA.*

quality should be referred to an appropriate control site and, in the case of temporary waters without permanent flow or in large pools, lower values of the BMWP' index or, for that matter, any other index, should be expected .

Finally, we should consider that hydrological conditions can be drastically changed by the intensive use of water in Mediterranean catchments. Intensive use may explain the disappearance of pools in small streams or the constant flow downstream of sewage facilities, leading to drastic changes in river water quantity and quality. In protected areas such as the study site Sant Llorenç del Munt, we can still find examples of pristine Mediterranean streams. However, in many coastal areas of the Mediterranean basin, the future of most streams is uncertain when the development of

tourism, agriculture and industry continues without restriction. Such as been the case for the past 20 years.

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