Invertebrate communities in Temporary streams of the island of Majorca: a comparison of catchments with different land use.

Maruxa Alvarez', I. Pardo[1], G. Moyá[2], G. Ramón[2] & A. Martínez-Taberner[2]

'Area de Ecologia, Universidad de Vigo, 36200 Vigo, Spain.
[2]Departament de Biologia Ambiental, Universitat de les Illes Balears, 07071 Palma de Mallorca, Spain.

ABSTRACT

This study compares the invertebrate communities in two catchments in the Mediterranean island of Majorca. The Sóller catchment is highly urbanised, with areas of intensive agriculture. The catchment of stream Sant Jordi is covered in a large part by a mature forest of Mediterranean *Quercus*. Upper and middle reaches of the latter were chosen as reference sites of well-preserved environmental conditions. Diptera was the richest taxon in both catchments, followed by Coleoptera and Trichoptera in the Sant Jordi catchment, and by Mollusca in Soller. Overall, invertebrate species richness was similar in the two catchments. Species composition and representation differed and Crustacea were proportionally more abundant in the Sant Jordi catchment sites than in Sóller. In the latter catchment, Diptera (mainly Chironomidae) and Oligochaeta were more abundant than in the Sant Jordi catchment. Main factors influencing community structure in both catchments were identified, i.e. allochthonous organic inputs from riparian vegetation and land use effects on this, local wastewater discharge, length of the dry period, saltwater intrusion and watertable lowering due to increasing groundwater extraction at downstream sites.

Keywords: Temporary streams, Mediterranean islands, invertebrates, land use.

RESUMEN

En este estudio se comparan las comunidades de invertebrados acuaticos en dos cuencas de la isla de Mallorca, situada en el mar Mediterraneo. La cuenca de Sóller, incluye diversos núcleos de población y presenta un desarrollo agricola elevado. La otra cuenca, la cuenca del torrente de Sant Jordi, se caracteriza por presentar un alto porcentaje de cobertura de vegetacidn climácica mediterránea de Quercus *adyacente al torrente. En esta última cuenca alguno de los tramos altos y medios de sus torrentes han sido considerados como puntos de referencia de condiciones ambientales en buen estado de conservacidn. En general, el orden Diptera present6 la mayor riqueza faunistica, seguido por los órdenes Coleoptera y Trichoptera en la Cuenca del Sant Jordi, y por el orden Mollusca en la cuenca del Sóller. A pesar de que la riqueza faunistica fue similar en las dos cuencas estudiadas, la abundancia relativa de los diferentes grupos taxondmicos fue distinta, siendo los crustaceos el grupo más abundante en las localidades de la cuenca del torrente de Sant Jordi. Sin embargo, en la cuenca del Sóller, los dípteros (principalmente los quironómidos) y los oligoquetos fueron los mejor representados. Las diferencias observadas en la estructura de las comunidades entre las dos cuencas parecen determinadas por la variacidn en la naturaleza de los aportes alóctonos desde la vegetacidn adyacente a los torrentes como consecuencia de diferencias en el uso del suelo, al efecto local de vertidos urbanos sobre la calidad del agua de los mismos, a la duracidn del periodo de sequía, a la intrusion marina en los tramos finales de algunos torrentes y al descenso de la capufreatica debido a la extraccidn de agua.*

Palabras clave: torrentes, rios temporales, islas mediterráneas, invertebrados, uso del suelo

INTRODUCTION

Dry lands occupy arid and semiarid regions throughout the world. These areas have a large variety of running waters, only flowing at certain times of the year (Comin & Williams, 1994). Temporary streams have been defined as freshwater bodies experiencing a recurrent dry phase of varying duration which is sometimes predictable (not always) in both its time of onset and duration (Williams, 1987). This flow-regime predictability determines their floral and faunal com-

Limnetica 20(2): 255-266 (2001)
 ISSN: 0213-8409

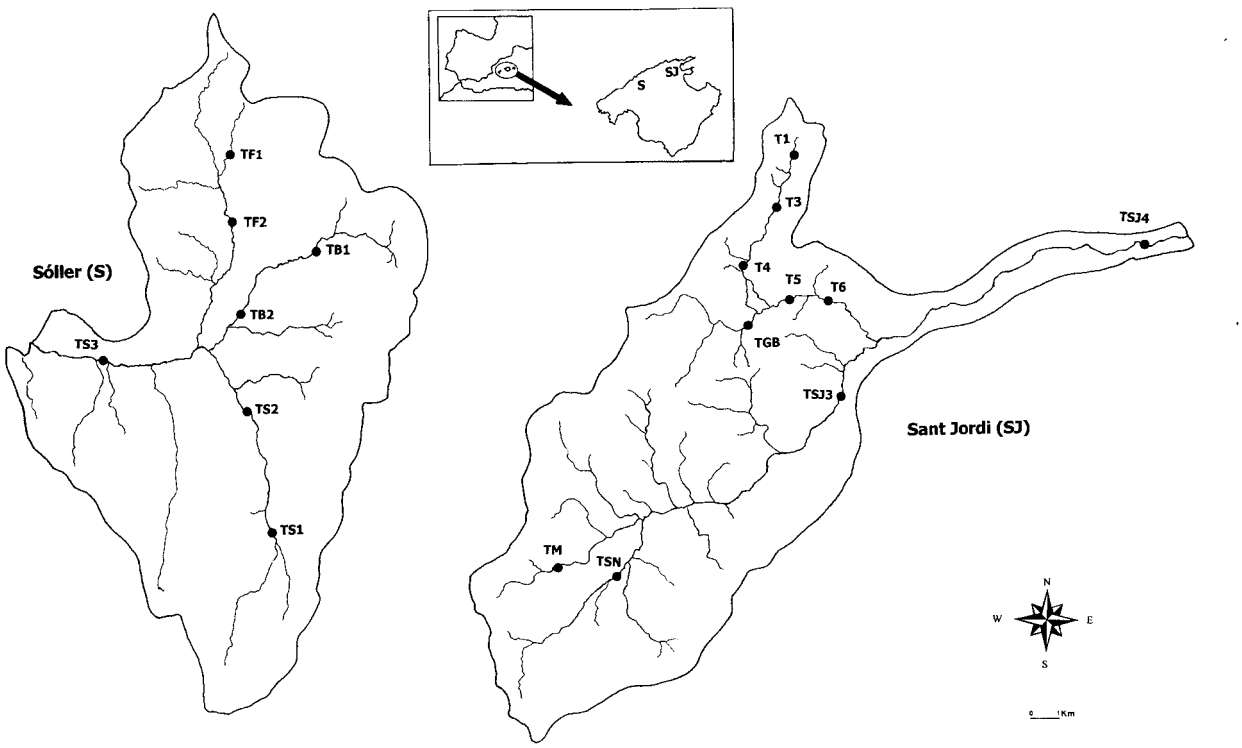

Figure 1. Location of the study area and sampling sites on two catchments of the island of Mallorca. **SJ:** Sant Jordi catchment, **S:** Sóller catchment. *Localización del área de estudio y localidades muestreadas en las dos cuencas estudiadas de la isla de Mallorca.*

position, their community structure and the life-history strategies adopted by the resident species (Boulton & Suter, 1986). In intermittent streams, loss of water during dry seasons is probably the most influential environmental parameter affecting the aquatic biota (Boulton, 1989).

The Balearic Islands are located in the Western part of the Mediterranean Sea, in a Mediterranean-type semiarid region. Majorca is the largest (3640.16 km^2) and highest (1443 m a.s.l.) of the Balearic Islands. The region has Mediterranean climate, with most precipitation between autumn and spring. During the hot, dry summer, most of the streams (commonly called "torrents") cease to flow, except those sustained by springs. In Majorca, permanent running waters are almost absent and temporary streams constitute the most important surface freshwater ecosystems. Several factors determine the existence of these temporary water bodies in the island, i.e. pronounced seasonal irregularity in rainfall levels; predominance of karstic geology, determining the high infiltration capacity of the stream bed and surrounding soil; high relief, which when combined with short channel length, results in quick surface runoff; water extraction from aquifers, resulting in the lowering of the groundwater table, and the reduction of springs, some of which provided water to temporary streams.

In this study, the invertebrate community structure was compared within and between two catchments from the island of Majorca, affected by different levels of agricultural intensity and differing population density. We studied reference sites with well-preserved ecological conditions and sites considered "impaired" along the temporary streams, with an aim to evaluating how land- use and human activity have impacted invertebrate communities in the island.

AREA OF STUDY

Two catchments were chosen from Majorca, i.e. the Sant Jordi **(SJ)** and Soller **(S)** catchments (Fig. 1). In both, flow was initiated by autumn rainstorms, which sustained stream flow for about 5 months in parts of the temporary streams. The temperature-rainfall regime is typically Mediterranean, with warm spells in autumn and spring, featuring primary and secondary rainfall maxima, respectively. Summers are hot and dry and winters relatively cool and dry.

The Sant Jordi catchment is located in Northeast Majorca and receives a mean annual rainfall of 800-900 mm, although means of 1100 mm and more are attained in the upper reaches (Guijarro, 1986). Mean evapotranspiration (EPT) is about 1400 mm. This catchment includes well-preserved temporary streams, such as Ternelles (TT) and Gorg Blau (TGB). Their upper-middle reaches were selected as reference sites based on their relatively good environmental state. These temporary streams support native vegetation, dominated by evergreen oak *(Quercus ilex* L.) and Aleppo pine *(Pinus kalepensis* Mill.). Within this catchment, Sant Jordi Torrent (TSJ) was chosen as an impacted stream with lower reaches running through lowland agricultural areas and receiving urban wastewater. Downstream reaches, nevertheless, are sprinkled with *Quercus ilex* corridors.

The Sóller catchment is in the Northwest of the island. Mean annual precipitation is about 800 mm and mean EPT 1300 mm (Guijarro, 1986). Most of the streams within this catchment flow through villages and rural areas with *Olea europaea* L., *Ceratonia siliqua* L. and various *Citrus* species. Semi-natural areas of the island of Majorca are dominated by evergreen oak *(Quercus ilex)* and Aleppo pine *(Pinus halepensis)*. The riparian vegetation in the studied catchments is poor.

METHODS

Invertebrates were sampled in January, March, and May 1999 during various flow conditions. Seventeen sites were chosen for this study. Only 6 sites had flowing water throughout the study. 5 sites could be sampled only in January. Animals were collected using a kick net (250 mm mesh). Sampling procedure involved taking a three-minute kick sample from each site. An attempt was made to sample all available habitats in proportion to their occurrence. Previous standardisation tests confirmed that a three minute-collection sample provide a near-complete taxa list for the sites. Concurrently, several environmental variables were estimated. These included current velocity, mean depth and stream width. Discharge was determined by multiplying mean velocity by the cross-sectional area of flow. Other standard physico-chemical parameters, including pH, conductivity (corrected for 20ºC), water temperature, air temperature, turbidity and dissolved oxygen, were measured *in situ* on each visit, using field electrodes. Water samples were taken and preserved at low temperature for later analysis in the laboratory. Calcium, magnesium, sodium, potassium and iron were analysed by mass spectrometry (ICP-Plasma 2000; Perkin-Elmer). Nitrites, nitrates, ammonia, sulphates and phosphates were analysed using colorimetric methods (SMART Colorimeter LaMotte).

Animals were identified to family, except for Oligochaeta, Hydracarina, Ostracoda, Copepoda and Branchiopoda. The following indices were applied to the data obtained in impaired and reference sites: taxa richness, insects and other invertebrate species richness taxa (i.e. non-insects), EPT (Ephemeroptera + Plecoptera + Trichoptera) family richness, the Spanish version of the Biological Monitoring Working Party (BMWP) index (Helawell, 1976), i.e. the BMWP' index (Alba-Tercedor & Sanchez-Ortega, 1988), and the Average Score Per Taxon (ASPT') biotic index.

Classification analysis of samples were done with the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) agglomerative clustering of Jaccard's similarity index. Relations between biotic and abiotic variables were estimated using Pearson correlation analyses. Most

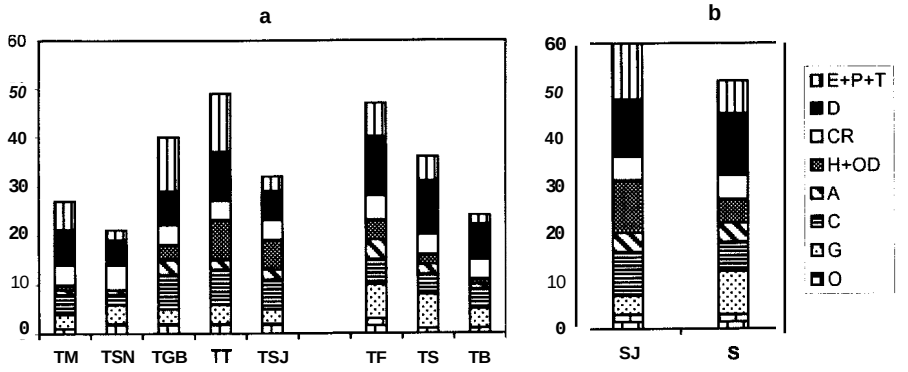

Figure 2. Taxa richness of major faunistic groups, (a) per torrent, and (b) per catchment, based on total composite richness throughout the year. H+OD, Heteroptera and Odonata; E+P+T, Ephemeroptera, Plecoptera and Trichoptera; G, Gastropoda; C, Coleoptera; D, Diptera; CR, Crustacea; **A,** Annelida; **O,** Other, non-insects. Torrents: TM, Mortixet; TSN, without name; TGB, Gorg Blau; TT, Ternelles; TSJ, Sant Jordi, TB, Biniaraitx; TF, Fornalutx; TS, Soller. Catchments: S, Soller; **SJ,** Sant Jordi. *Riqueza de los principales grupos faunísticos por torrente (a) y cuenca (b) basada* ***en*** *la composición de taxones a lo largo del año. H+OD, Heteropteros y Odonatos; E+P+T, Efemerdpteros, Plecópteros y Tricopteros; G, Gasterópodos; C, Coleópteros; D, Dípteros; CR, Crustaceos; A, Anélidos; O, Otros no insectos.*

variables were log-transformed, except pH, BMWP' and ASPT'. Classification analysis was performed with the NTSYS-pc package (version 1.6, Applied Bioestatistics, Inc., 1990).

RESULTS

Taxa richness

A total of sixty-seven taxa were recorded. Total number of taxa and composite richness within each faunistic group per torrent and per catchment are represented in figures 2a and 2b, respectively. The macroinvertebrate communities of both study catchments were of similar richness (i.e. sixty taxa were found in the Sant Jordi catchment and 52 in the Soller catchment). Twenty two taxa were uniquely present in either catchment. The following taxa were only found in Sant Jordi: 4 families of Trichoptera (Philopotamidae, Glossosomatidae, Hydropsychidae, Leptoceridae), 1 family of Plecoptera (Leuctridae), *3* families of Odonata (Aeschnidae, Coenagrionidae, Lestidae), *3* families of Heteroptera (Gerridae, Hydrometridae, Mesoveliidae), *3* families of Coleoptera (Elmidae, Haliplidae, Hydrochidae) and one family of Diptera (Tabanidae). Seven taxa were found in the Soller catchment but not in Sant Jordi, 5 were Mollusca and 2 were Diptera (Empididae and Ephydridae). One major group, the Plecoptera, was not found in the samples taken. However, its presence in catchments was confirmed earlier (unpublished data), and by field observation during this study. In general, Diptera was the group with the highest taxa richness, followed by Trichoptera and Coleoptera in Sant Jordi, and by Mollusca in Soller (Fig. 2).

The richest water bodies, the Torrents of Ternelles and Gorg Blau, in the Sant Jordi catchment, appeared least disturbed. Ternelles contained the richest fauna with 49 taxa (Fig. 2). The Torrent of Fornalutx (TF), in the Soller catchment, had the richest invertebrate fauna, with 47 families. Thirty-seven taxa were common to both temporary streams. Insects comprised over 66.5% of total number of taxa collected.

Relative faunal abundance

Relative abundance of invertebrate communities was calculated on the total number of individuals collected per site on each sampling date. Despite little apparent change in total invertebrate richness, differences in taxa dominance were evident

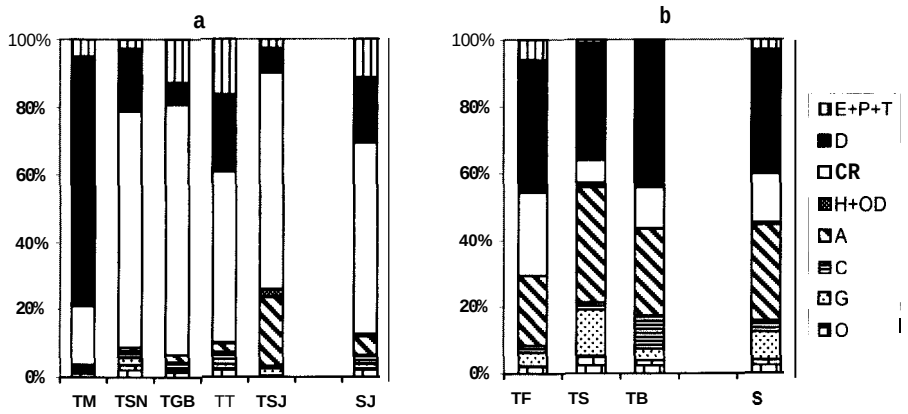

Figure 3. Relative abundance of invertebrate faunistic groups. a, mean values for each torrent (TM, TSN, TGB, TT, TSJ) in Sant Jordi catchment, and per catchment **(SJ).** b, mean values for each torrent (TF, TS, TB) in Soller catchment, and per catchment (S). H+OD, Heteroptera and Odonata; E+P+T, Ephemeroptera, Plecoptera and Trichoptera; G, Gastropoda; C, Coleoptera; D, Diptera; CR, Crustacea; A, Annelida; O, Other, non-insects. *Abundancia relativa de los principales grupos faunísticos. a. Valores medios obtenidos en la cuenca del Sant Jordi para cada uno de los torrentes (TM, TSN, TGB, TT, TSJ) y en el total de la cuenca (SJ). b, Valores medios en la cuenca del Sóller por torrente (TF, TS, TB)y cuenca (S). H+OD, Heterópteros y Odonatos; E+P+T, Efemerópteros, Plecdpteros y Tricdpteros; G, Gasterópodos; C, Coleópteros; D, Dípteros; CR, Crustaceos; A, Anélidos; O, Otros no insectos*

between catchments (Fig. 3). In the Sant Jordi catchment (Fig. 3a), crustaceans, particularly the amphipod *Echinogammarus sicilianus* Karaman & Tibaldi (1973), dominated the Ternelles (TT) and the Gorg Blau (TGB) sites, making up 56.6 % of the total in this catchment. The dominance of crustaceans in the rest of the catchment (Torrent Sin Nombre (TSN), Mortixet (TM) and Sant Jordi (TSJ)) was due to Copepoda, Branchiopoda and Isopoda. Diptera was best represented at sites which only had water during the first sampling date (e.g. Torrent of Mortixet, TM). In the Soller catchment (Fig. 3b), crustaceans were not as abundant and fauna was dominated by Diptera, with high abundance of Chironomidae, and Oligochaeta. Together these two taxa accounted for 66.3 % of the total in this catchment. The general assemblage representation of major faunistic groups appeared remarkably constant within each catchment.

Relations between biotic and abiotic features

Similarity among studied sites was assessed according to their faunistic composition, using the presence-absence data matrix. The similarity matrix was estimated using Jaccard's coefficient. The UPGMA classification on the similarity matrix provided 6 major groups of sites based on the similarity of their faunal composition (Fig. 4). Two main groups were first clustered, group 6, comprising all samples from middle reaches of Ternelles and Gorg Blau, and group 5, including most samples from the Soller catchment and some samples from the Sant Jordi catchment. The rest joined the cluster at higher dissimilarity and contained samples from both catchments. Mean and standard errors of abiotic variables were estimated for each group in the classification (Fig. 5). Box plots of biological indicators calculated for each group are presented in figure 6.

Group 1 included sites from the Soller catchment. Some are from headwater sites (TS1-1 and TB1-1) having water only in January. These reaches naturally have few taxa. Pollution-sensitive taxa Ephemeroptera, Plecoptera and Trichoptera (EPT) were scarce in this group (Fig. *6)*. This group also included the sample collected in TS3 during May, when discharge was at its minimal value. This site was placed downstream from a wastewater treatment plant,

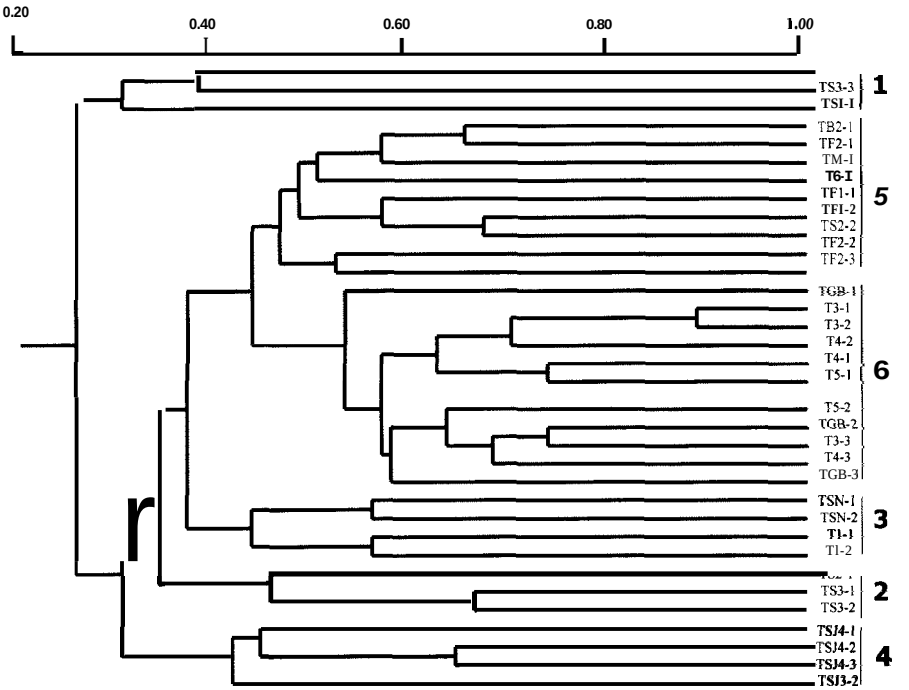

Figure 4. Cluster analysis based on presence of **67** taxa in 34 samples taken from 8 temporary streams on the island of Majorca. Sample numbers 1-3 indicate the three sampling dates, January, March and May 1999, respectively. *Análisis de clasificación basudo en la presencia de 67 taxones en las 34 muestras tomadas en 8 torrentes de la isla de Mallorca. Los números 1-3 indicun las tres campañas de muestreos reu lizadas, enero, marzo y mayo, respectivumente.*

and mean nutrient concentrations were high (Fig. *5).*

Group 2 comprised middle and lower sites from the Torrent of Soller, characterised by high human disturbance. Sites in this group presented low faunal richness and water quality (Fig. 6). Water quality was better than in sites of group 1 (Fig. 5), because of dilution by high discharges in January and March at TS3.

Group 3 was made up of sites from upper reaches of the Torrent of Ternelles, which is surrounded by agricultural fields, and by a site from the Sant Jordi catchment, fed by groundwater. Water biological quality was better in this group than in Groups 1 and 2 (Fig. 6). There was an appreciable increase in nitrate concentrations (Fig. *5),* possibly related to the drainage of fertilisers in neighbouring fields from irrigation-water return and from groundwater.

Group 4 included lower sites in the Torrent of San Jordi. which receives wastewater and are located in lowland agricultural areas. Faunal richness and biological indices were low and similar to those in group 3 (Fig. 6). Nutrient concentrations and conductivity were the highest of all groups (Fig. *5).*

Group *5* comprised all sites in the Torrent of Fomalutx (TF1 and TF2), sites in the Sant Jordi catchment (i.e. T6-1 and TM-1) sampled during January, and middle reaches sampled in the Soller catchment (i.e. TS2 and the Torrent of Biniarait TB). Faunal richness and biological quality were high (Fig. 6), with a BMWP' mean score of 94. In this group the number of non-insect taxa reached its maximum value. Sites from the Torrent of Fornalutx (TF) are either located downstream of urban areas or surrounded by agriculturally transformed lands. The resulting effects on water chemistry were reflected in high nitrate contents (Fig. *5).*

Group 6 comprised middle sites in the Torrent of Ternelles. Sites were used as reference sites

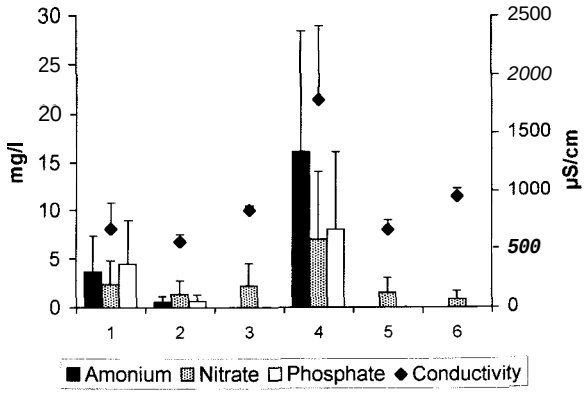

Figure 5. Mean values and standard error (+SE) of physico-chemical variables for each group of the classification. Ammonium, nitrate and phosphate are measured in mg l^{-1}. Conductivity is expressed in µS cm^{-1}. *Valor medio mas el* ***error*** *estándar de las* ***variables*** *fisico-químicas medidas para cada uno de los grupos obtenidos en el análisis de clasificación. Amonio, nitrato y fosfato se expresan en mgl^{-1}. La conductividad se representa en µS cm^{-1}.*

and most of them flowed for at least 5 months per year. In these sites, water quality was optimal, and faunal richness and biotic indices reached their highest values (i.e. mean BMWP' score was 128; Figs. 5 & 6). The number of EPT taxa (mean of 8.2) and insect taxa (mean of 20.6) reached their highest mean values in this group.

Groups 1 to 5 are considered impaired, while group 6 was considered unimpaired. Group 6 had the highest physical, chemical, and biotic quality, as well as well-preserved riparian corridors. Groups 1 to are characterized by a longer dry period, altered surrounding land, poor physical and chemical water quality, or lower biotic quality than reference group 6.

EPT and BMWP' reached maximum values in the reference sites group (Fig. 6). Taxa richness and the BMWP' biotic index were strongly correlated ($r=0.95$, $p=0.0001$), indicating a strong dependence of the biotic index on number of taxa. Similar correlations were found between insect abundance and insect species richness ($r=0.93$, $p=0.0001$), and between insect abundance and BMWP' ($r=0.95$, $p=0.0001$). EPT was also strongly correlated with taxa richness ($r=0.80$, $p<0.0001$), insect abundance ($r=0.84$, $p<0.0001$) and BMWP' ($r=0.88$, $p<0.0001$). Among environmental variables, ammonium and

Table 1. List of taxa collected in a study of the invertebrate communities in two catchments (Sóller and Sant Jordi) on the island of Majorca during one year. *Listado de los taxones encontrados en los sitios de muestreo.*

PLATYHELMINTHES
TURBELLARIA
Tricladida
Dugesiidae
Glossossomatidae
NEMATODA
MOLLUSCA
GASTROPODA
Prosobranchia
Polycentropodidae
Bithyniidae
Pulmonata
Basommatophora
Physidae
Lymnaeidae
Planorbiidae
Ancylidae
BIVALVIA
Sphaeriidae
ANNELIDA
CLITELLATA
Oligochaeta
Hirudinea
Glossiphonidae
Erpobdellidae
ARACHNIDA
Acari
Hydracarina
INSECTA
Ephemeroptera
Baetidae
Caenidae
Odonata
Zygoptera
Lestidae
Anisoptera
Coenagrionidae
Aeschnidae
Cordulidae
Libellulidae
Plecoptera
Leuctridae
Heteroptera
Gerromorpha
Hydrometridae
Veliidae
Gerridae
Nepomorpha
Corixidae
Nepidae
Notonectidae
Coleoptera
Adephaga
Haliplidae
Hygrobiidae
Gyrinidae
Dytiscidae
Polyphaga
Hydraenidae
Hydrochidae
Hydrophilidae
Chrisomelidae
Dryopidae
Elmidae
Helodidae
Limnebiidae
Diptera
Nematocera
Tipulidae
Limoniidae
Psychodidae
Culicidae
Dixidae
Simuliidae
Ceratopogonidae
Chironomidae
Brachycera
Stratiomyidae
Tabanidae
Empididae
Dolichopodidae
Muscidae
Ephydridae
Trichoptera
Rhyacophilidae
Hydroptilidae
Philopotamidae
Hydropsychidae
Psychomyidae
Limnephilidae
Leptoceridae
CRUSTACEA
Branchiopoda
Ostracoda
Copepoda
Malacostracea
Peracarida
Isopoda
Asellidae
Amphipoda

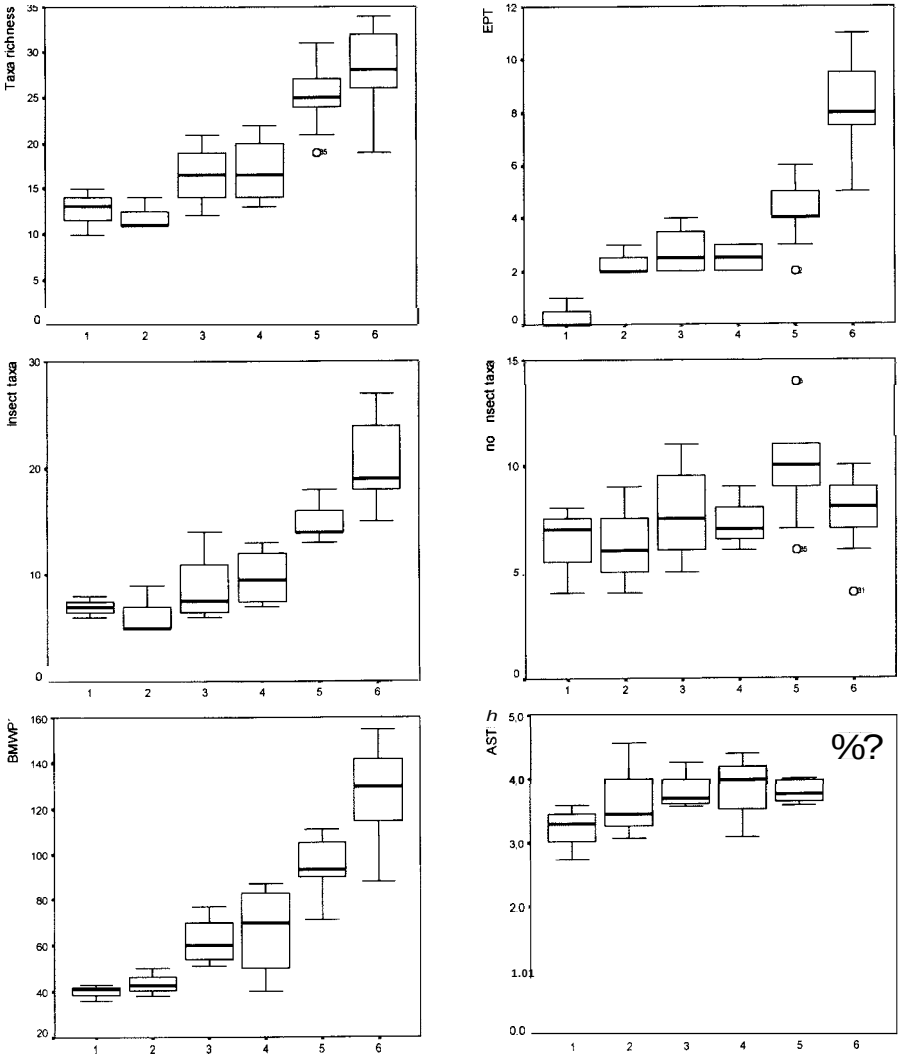

Figure 6. Box plots of the biotic indices for each group given by cluster analysis. *Diagramas de cajas para las variables bióticas de los grupos obtenidos en el análisis de clasificación*

phosphates were inversely related with most biotic attributes of the community. This indicates the effect of pollution on invertebrate benthic assemblages (Table 1).

Total taxa, insect abundance and BMWP' were highly correlated and therefore there is a degree of redundancy in their combined use. EPT and ASPT' indices proved to be the best for discriminating between all groups (Fig. 6 and Table 2). Groups 5 and 6 had dissimilar species composition despite similar total taxa richness (Fig. 6) and water quality (Fig. 5). The latter two groups differed mostly in their EPT values, in their mean taxa tolerance within groups, represented by the ASPT' index, and by overall changes in taxa dominance.

Table 2. Summary of Pearson correlation coefficients between biotic and abiotic variables measured or calculated in a study of the invertebrate communities in two catchments (Sóller and Sant Jordi) on the island of Majorca during one year. Only variables showing significant correlations are shown. Bold numbers indicate significance at the 0.01 level, while regular font indicates p<0.05. *Coeficientes de correlación de Pearson obtenidos para las correlaciones significativas de las variables objeto de estudio. Números en negrita p<0.01, números en formato normal p<0.05.*

	Phosphate	Ammonium	Nitrite	Sulphate	Mg	K
Taxa richness	-0.37	-0.36		0.37	0.36	-0.34
insects	-0.42	-0.40			0.41	-0.34
non insects						
EPT	-0.45	-0.41	-0.38	0.37	0.51	
BMWP'	-0.42	-0.41		0.35	0.40	-0.36
ASPT'	-0.42	-0.44	-0.50		0.39	

DISCUSSION

This study compares invertebrate communities of two catchments on the island of Majorca, affected by different land uses adjacent to their temporary streams. In the less disturbed catchment (the Sant Jordi catchment), reference sites from upper-middle reaches were characterised. Differences in community structure between sites, such as those found in this study, may be the result of a wide variety of factors, both abiotic and biotic. Identified factors affecting structure and functioning of temporary streams include poor water quality (pollution, salinisation), length of dry period, lowering water table at downstream sites and impacts of land use.

A fundamental paradigm of stream ecology (Vannote *et al.*, 1980; Ward & Stanford, 1983) is that lotic communities respond to changing environmental conditions along the longitudinal gradient of river systems. Majorca is drained by temporary streams experiencing a seasonal dry phase. Dry periods give rise to a variety of patterns in both longitudinal patchiness and degrees of fragmentation of the stream continuum (Lake, 2000). Environmental conditions of intermittent streams tend to be more variable than those affecting permanent lotic habitats (Ward, 1992; Boulton & Suter, 1986; Williams, 1987). Environmental variability may be an important determinant of the structure and composition of macroinvertebrate assemblages in these streams (Boulton & Suter, 1986).

Taxa richness (i.e. number of taxa) measures the overall variety of the invertebrate assemblage (Barbour *et al.*, 1999). A reduction in species richness cannot always be attributed to discharge of polluted water (Suter, 1984), especially in temporary streams, where the irregular flow regime further complicates the situation (Boulton & Suter, 1986). Trends are also seen of higher species richness with increasing permanence of water; especially where pools persist providing important over-summering refuges for aquatic insects (Boulton & Suter, 1986). In this study, temporary streams with higher water permanence, such as TF, TT or TGB, supported higher richness than other, less permanent, streams within the catchments (e.g. TB, TM or TSN). Within a torrent, sites having water only in January (T6) had the lowest taxa richness (e.g. TT). EPT richness measures the insect orders thought to be the least tolerant to environmental perturbations in streams (Plafkin *et al.*, 1989), and can accurately classify benthic assemblages under a variety of disturbance regimes (Resh *et al.*, 1995). Although in this study, total invertebrate richness did not appear to change between the two catchments, EPT richness did, reaching its highest values in the reference sites of the Sant Jordi catchment. Thus, ETP richness differences between the two catchments studied could have been the result of different degrees of environmental perturbation affecting their watersheds.

Discharge of wastewater into lower parts of streams (e.g. in TSJ4 and TS3), and return of

nutrient-rich agricultural water, may lengthen flow periods or even transform intermittent reaches into perennial ones (Gasith & Resh, 1999). Nitrates were found in all clustered groups, being lowest in sites from the Torrent of Ternelles, and highest in the Torrent of San Jordi, where human impacts are more intense. As the dry season progressed, the sites affected by wastewater discharges from villages developed more growth of the filamentous alga *Cladophora* spp. As a result, these sites were much more eutrophic at low flows, as occurred in site TF2 during May, where nitrates reached the highest values measured in this torrent.

Water abstraction causes a lowering of the water table. This occurs in middle-lower reaches of the Torrent of Sant Jordi, resulting in the intrusion of seawater into coastal aquifers, increasing salinity (e.g. site TSJ4). Water quality in these sites was better in winter, when discharge was high. As the water flow decreases towards summer, larger evaporation can cause concentration of dissolved ions and affect pH.

Flow in Mediterranean-type streams is naturally reduced during summer, and the dilution capacity of streams is lowered. Consequently, small discharges of poor quality water into streams may have disproportionally large adverse effects (Gasith & Resh, 1999). As the dry period progresses the biota gradually becomes dorninated by species tolerating low discharge, warm water and relatively bad water quality. During this period, most of the fauna consists of species tolerant of organic pollution. During May, when discharge was at its minimum and biotic indices reached their lowest values, only species highly tolerant of organic pollution were found at sites TSJ4 and TS3.

Substitution of native vegetation occurred in most sites from both the Soller catchment (i.e. group 2 and most samples in group 5) and from the Torrent of Sant Jordi (group 4). Land transformation may result in overall reduction of shading, with more light reaching the water surface, and decreased inputs of allochtonous detritus and large woody debris (Gasith & Resh, 1999; Young & Huryn). Thus, in catchments dominated by agricultural practices, the influence of terrestrial energy sources on riverine structure and function may be reduced, and autochthonous inputs may be a significant energy source (Harding *et al.*, 1999). This may result in water quality deterioration and loss of the natural biota. Total invertebrate richness was similar in the two catchments. However, examination of relative faunal abundances revealed differences.

Amphipods dominated the forested non-impaired sites of Ternelles and Gorg Blau. In the Soller catchment, neither isopods nor amphipods were common, and Diptera and Oligochaeta were the most abundant taxa. The general scarcity of amphipods, known shredders, as confirmed by diet observation in this study, may reflect low inputs of riparian plant material (Davis *et al.*, 1993) Land transformation in Torrent of Fornalutx (TF), Biniaraitx (TB), Soller (TS) and Mortixet (TM), involved a change in litter quality, as the natural evergreen oak woods were replace by riparian vegetation dominated by *Olea, Citrus* and *Ceratonia.* The percentage of total abundance of mayflies, stoneflies and caddisfly larvii also differed between the two catchments, being higher in the Sant Jordi than in the Soller catchment. Changes in the invertebrate community structure may have been the result of differing land-use transformations between catchments, altering sources and relative importance of organic matter inputs to streams (Wilcock, 1986; Quinn et al., 1992). Such change in energy sources may alter the functional organisation of stream communities from a predominance of shredders, feeding on the large amount of coarse detritus present in the reference sites, to an abundance of collectors, using fine food materials in the more impaired sites.

Classification of sites based on indices using presence/absence of invertebrate taxa was in agreement with descriptions using abiotic and biotic descriptors. Most biotic variables were highly correlated because they were based on richness (i.e. number of taxa). Some were redundant. EPT discriminated well among groups (Hewlett, 2000). In contrast, taxa richness could not discriminate well between groups with similar water quality

(e.g. groups 5 and 6), while EPT and ASPT' could. In agreement with Harding *et al.* (1999), these results suggest the importance of assessing taxonomic composition based on quantitative data, rather than relying on index values, such as taxonomic richness, when evaluating the effects of land transformation on biotic stream quality.

ACKNOWLEDGEMENTS

This study was supported by a grant (HID98-0323-CO5-02) from the Spanish Education Council, as part of a project on the ecology of Spanish Mediterranean streams. We are very grateful to Sam Lake for his enthusiasm and motivation to initiate study of the temporary streams of Majorca, and to A. Olsen for his comments on the manuscript. We also thank Leonor March for facilities, which allowed study of the few remaining natural temporary streams (Ternelles and Gorg Blau) on the island of Majorca.

LITERATURE CITED

ALBA-TERCEDOR, J. & A. SÁNCHEZ–ORTEGA, 1988. Un método rapido y simple para evaluar la calidad biologica de las aguas corrientes basado en el de Hellawell (1978). *Limnetica,* 4: 51-56.

BARBOUR, M. T., J. GERRITSEN, B. D. SNYDER, & J. B. STRIBLING, 1999. *Rapid Bioassessment Protocol for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition.* EPA 841-B-99-002. U. S. Environmental Protection Agency; Office of Water; Washington, D. C.

BOULTON, A. J. & P. J. SUTER, 1986. Ecology of temporary streams- An Australian perspective-. In: *Limnology in Australia.* P. De Decker, W.D. Williams (eds.): 313-327. Melbourne. Australia.

BOULTON, A. J. 1989. Over-summering refuges of aquatic macroinvertebrates in two intermittent steams in central Victoria. *Transactions of the Royal Society of South Australia,* 113: 23-34.

COMIN, F. A. & W. D. WILLIAMS, 1994. Parched continents: our common future?. In: *Limnology now: a paradigm of planetary problems.* R. Margalef (ed.): 473-527.

DAVIS, J. A., S. A. HARRINGTON, & J. A. FRIEND, 1993. Invertebrate Communities of Relict Streams in the Arid Zone: the George Gill Range, Central Australia. *Aust. J. Mar: Freshwater Res.,* 44: 483-505.

GASITH, A. & V. H. RESH, 1999. Streams in Mediterranean climate regions: Abiotic influences and biotic responses to predictable seasonal events. *Ann. Rev. Ecol. Syst.,* 30: 51-81.

GUIJARRO, J. A. 1986. *Contribución a la bioclimatología de Baleares.* Thesis. Universitat de les Illes Balears. 583 pp.

HARDING, J. S., R. G. YOUNG, J. W., HAYES, K. A. SHEARER, & J. D. STARK, 1999. Changes in agricultural intensity and river health along a river continuum. *Freshwat. Biol.,* 42: 345-357.

HELAWELL, J. M. 1976. *Biological surveillance of rivers. A biological monitoring handbook.* Stev. Lab. Herts.

HEWLETT, R. 2000. Implications of taxonomic resolution and sample habitat for stream classification at a broad geographic scale. *Journal of the North American Benthological Society,* 19: 352-361.

LAKE, S. 2000. Disturbance, patchiness and diversity in streams. *Journal of the North American Benthological Society,* 19: 573-592.

PLAFKIN, J. L., M. T. BARBOUR, K. D. PORTER, S. K. GROSS, & R. M., HUGHES, 1989. Rapid bioassessments protocols for use in streams and rivers. Benthic macroinvertebrate and fish. EPA/444/489/001, US Environmental Protection Agency, Office of Water Regulation and Standards, Washington DC.

QUINN, J. M., R. B. WILLIAMSON, R. K. SMITH, & M. L. VICKERS, 1992. Effects on riparian grazing & channelisation on streams in Southland, New Zealand. 2. Benthic invertebrates. *New Zealand Journal of Marine and freshwater Research,* 26: 259-273.

RESH, V. H., R. H. NORRIS, & M. T. BARBOUR, 1995. Design and implementation of rapid assessment approaches for water resource biomonitoring using benthic macroinvertebrates. *Australian Journal of Ecology*, 20: 108-121.

SUTER, P. J. 1984. *The effect of winery wastes discharges on the macroinvertebrate fauna of the North Para River, South Australia.* South Australian Engineering and water Supply department, report EWS Library Ref. 84/41.

VANNOTE, R. L., G. W. MINSHALL, K. W. CUMMINS, J. R. SEDELL, & G. E. CUSHING, 1980. The River Continuum Concept. *Can. J. Fish. aquat. Sci.*, 37: 130-137.

WARD, J.V. 1992. *Aquatic Insect Ecology 1. Biology and habitat.* John Willey & Sons (Eds.). United States of America. 438 pp.

WARD, J. V. & J. A. STANFORD. 1983. The serial discontinuity concept of lotic ecosystems. In: *Dynamics of lotic ecosystems.* T.D Fointaine, S.M. Bartell, (Eds.). Ann Arbor, Michigan: Ann Arbor Science, 494 pp.

WILCOCK, R. J. 1986. Agricultural Runoff: a source of water pollution in New Zealand?. *New Zealand Agricultural Science,* 20: 98-103

WILLIAMS, D. D. 1987. *The ecology of temporary waters.* Timber Press, Portland, Oregon. 205 pp.

YOUNG R. G. & A. D. HURYN. 1999. Effects of land use on stream metabolism and organic matter turnover. *Ecological Applications,* 9: 1359-1376.