Seasonal and interannual variability of macroinvertebrate reference communities and its influence on bioassessment in different Mediterranean stream types

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INTRODUCTION

• The European Water Framework Directive (WFD) emphasizes that natural variability of quality elements in high-status water bodies needs to be quantified and understood if the impact of human pressure on water bodies of lower status is to be determined.

• Temporal variation in macroinvertebrate communities is often high in stream system due to flow and habitat variation among other factors. Such fluctuation may be expected to be highest in areas which show relatively high environmental variability such as the Mediterranean climate areas. In Mediterranean areas, the variability and seasonality of precipitation are among their principal attributes (Gasith & Resh 1999), and the resulting hydrology influences the structure of stream communities (e.g. Bêche et al. 2006). These variations can affect both biotic integrity metrics and multivariate predictive models. In this study, we examine temporal (seasonal and interannual) variations in the macroinvertebrate communities in reference sites.

• The specific aims of this study were:
i)to examine temporal (seasonal and interannual) variations in macroinvertebrate community in previously selected reference sites in the established stream types.
ii) to assess the effects of this temporal variability on macroinvertebrate metrics in each stream type and
iii) to select robust metrics according to their low temporal variation.

METHODOLOGY

STUDY AREA AND SAMPLING SITES

• To analyse seasonal variations, we studied 23 basins located on a latitudinal, thermal and pluviometric gradient along the Spanish eastern coast and the Balearic Islands (Figure 1), and ranging in size from large (>14000 km2), such as the Júcar and the Segura rivers, to small (<70 km2) such as the Jara and Pollença streams, were studied. To analyse interannual variations, 6 out of the 23 basins were studied.

Figure 1. Map of distribution of references sites showing their typology. Black and white symbols show seasonal reference sites (n=88) and white ones show interannual reference sites (n=14).

• We examined two series of data to assess the temporal variation in the macroinvertebrate community of each stream type:
i) To detect seasonal changes, a total of 88 reference sites (seasonal reference sites) distributed in 23 basins (Table 1) were sampled on three sampling occasions (spring, summer and autumn) in 2003. These seasonal reference sites belonged to four different Mediterranean stream types (Table 1).
ii) To analyse interannual changes, a subset of 14 reference sites (interannual reference sites) out of the 88 were sampled on three sampling occasions, in the autumn of 2003, 2004 and 2005 (Table 1). These reference sites belong to T3 and T4.

Stream type		Hydrologic state	Stream order	Altitude (m)	Seasonal R. S.	Interannual R. S.
T1	Temporary streams	Intermittent/Ephemeral	1.1 ± 0.3	645 ± 523	16	0
T2	Evaporite calcareous at medium altitude streams	Perennial seasonal	1.9 ± 0.8	541 ± 188	8	0
T3	Siliceous headwaters at high altitude streams	Perennial seasonal	1.3 ± 0.6	720 ± 225	21	6
T4	Calcareous headwaters at medium and high altitude streams	Perennial seasonal	1.7 ± 0.9	689 ± 192	43	8
Total					88	14

Table 1. Main characteristics of the studied Mediterranean stream types and number of seasonal and interannual reference sites (R.S.) studied in each stream type.

BIOLOGICAL AND ENVIRONMENTAL DATA

• A set of 249 macroinvertebrate samples taken from the 88 seasonal reference sites and 14 interannual reference sites were considered.
• A multi-habitat semiquantitative kick-sample, was taken on each sampling occasion using the PRECE protocol.
• Eighteen benthic macroinvertebrate metrics were calculated for all the reference sites for each sampling occasion (Table 2).
• To explain potential temporal variation in macroinvertebrate metrics two hydro-morphological variables were measured: discharge and Fluvial Habitat Index (IHF).

CATEGORIES	METRICS	DEFINITION
RICHNESS	S	Total number of families
	S insectae	Total number of insectae families
	S non insectae	Total number of non insectae families
	EPT	Number of Ephemeroptera, Plecoptera and Trichoptera families
	EPTC	Number of Ephemeroptera, Plecoptera, Trichoptera and Coleoptera families
	OCH	Number of Odonata, Coleoptera and Heteroptera families
	EPT/OCH	Number of Ephemeroptera, Plecoptera and Trichoptera families / Number of Odonata, Coleoptera and Heteroptera families
	GOLD	Number of Gasteropoda, Oligochaeta and Diptera families
	CM	Number of Coleoptera and Mollusca families
	PT	Number of Plecoptera and Trichoptera families
INDEXES	IBMWP	Iberian Biological Monitoring Working Party (Alba-Tercedor & Sánchez-Ortega 1988, Alba-Tercedor et al. 2004)
	IASPT	Iberian Average Score per Taxon (Alba-Tercedor & Sánchez-Ortega 1988, Alba-Tercedor et al. 2004)
MULTIMETRIC INDEXES	ICM-11	Intercalibration Common Metric index (European Commission 2007)
TOLERANCE/INTOLERANCE METRICS	S10	Number of families with IBMWP score of 10
	S8+10	Number of tolerant taxa (IBMWP score of 8 and 10)
	S1+2	Number of intolerant families (IBMWP score of 1 and 2)
DIVERSITY	D	Margalef Diversity Index
	H'	Shannon Diversity Index

Table 2. Macroinvertebrate metrics calculated in each reference site for all sampling occasions.

DATA ANALYSIS

• To investigate the effects of temporal variability (seasonal and interannual) on macroinvertebrate composition within each stream type, an analysis of similarity **ANOSIM** was performed on Bray-Curtis similarity distances using presence-absence.
• We used a non-metric multidimensional scaling **(NMDS)** (Kruskal & Wish 1978) to visualize spatial patterns of the community structure using the Bray-Curtis similarities matrix (presence/absence data).
• Seasonal and interannual differences in the studied macroinvertebrate metrics were assessed using a **Kruskal-Wallis non-parametric ANOVA test** (Chi-square statistic) in each stream type.
• **Coefficients of variation** (CV=SD/Mean*100) expressed as percentages were determined for each macroinvertebrate metric to compare indicator metric variability for the three seasons and the three years in order to select those metrics which presented low variability.

RESULTS

SEASONAL VARIATION

	Seasonal ANOSIM		Spring-Summer		Spring-Autumn		Summer-Autumn	
Stream type	Global R	p (%)	R	p (%)	R	p (%)	R	p (%)
T1	-0.022	61.5	0.135	23.8	-0.054	93.3	0.058	35.3
T2	-0.074	91.6	-0.056	75.2	-0.094	87.9	-0.08	85.3
T3	0.059	0.8	0.049	5.2	0.022	18.5	0.104	0.4
T4	0.051	0.01	0.044	0.6	0.056	0.2	0.055	0.2

Table 3. ANOSIM results for global and pair-wise comparisons among seasons for the four stream types using macroinvertebrate presence-absence data.

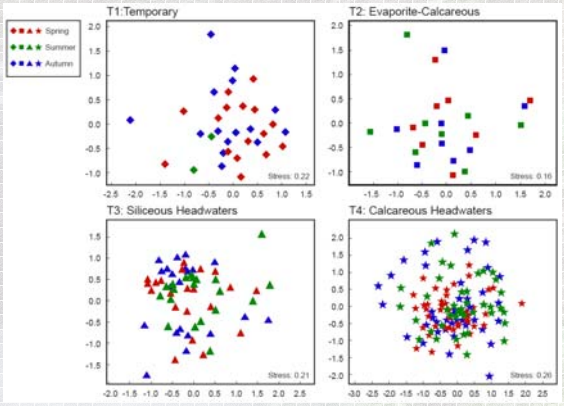


Figure 2. Non-metric multidimensional scaling (NMDS) ordination of the seasonal reference sites based on Bray-Curtis similarities using presence/absence data for the four stream types. It is observed a clear overlap among seasons, showing no seasonal patterns in all stream types.

KRUSKAL-WALLIS TEST
T1: no significant differences
T2: no significant differences
T3: significant differences S1+2 and H´
T4: significant differences EPT, OCH, EPT/OCH and PT

Table 4. Results of seasonal Kruskal-Wallis non-parametric ANOVA test ($\chi 2$) using the three seasons for the four stream types.

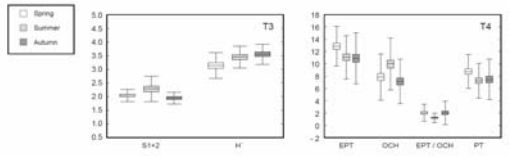


Figure 3. Box plots for macroinvertebrate metrics which showed significant seasonal differences for each stream types. Boxes are mean ± standard error, range bars show mean ± standard deviation and lines represent mean values.

INTERANNUAL VARIATION

	Interanual ANOSIM		2003-2004		2004-2005		2005-2006	
Stream type	Global R	p (%)	R	p (%)	R	p (%)	R	p (%)
T3	-0.177	94.60	-0.094	77.9	-0.147	91.3	-0.08	74.9
T4	-0.037	69.9	-0.062	77.3	0.009	40.6	-0.051	68.8

Table 5. ANOSIM results for global and pair-wise comparisons among years for the two stream types.

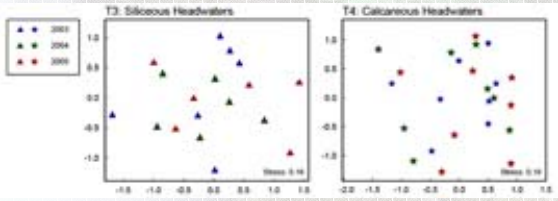
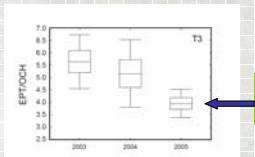


Figure 4. Non-metric multidimensional scaling (NMDS) ordination of the interannualreference sites based on Bray-Curtis similarities using presence/absence data for the two stream types. It is observed a clear overlap among years.

KRUSKAL-WALLIS TEST
T3: significant differences EPT/OCH
T4: no significant differences

Table 6. Results of seasonal Kruskal-Wallis non-parametric ANOVA test ($\chi 2$) using the three years for the two stream types.



LOWER
Discharge
IHF score
Frequency of riffle

Figure 5. Box plots for EPT/OCH which showed significant interannual differences for stream type 3. Boxes are mean ± standard error, range bars show mean ± standard deviation and lines represent mean values.

SELECTION OF ROBUST METRICS

METRIC	Seasonal CV				Interannual CV	
	T1	T2	T3	T4	T3	T4
S	12.2	15.2	11.2	14.0	7.7	15.3
S insectae	12.9	16.8	12.0	15.0	7.9	19.2
S non insectae	13.3	27.6	23.3	24.4	25.9	41.4
EPT	19.1	16.0	11.6	17.8	7.4	16.8
EPTC	15.2	13.9	11.7	16.0	9.6	10.7
OCH	31.2	35.4	28.1	26.9	27.9	11.6
EPT/OCH	36.2	39.4	26.3	30.9	26.2	31.8
CM	28.2	34.4	30.7	26.7	30.8	37.9
PT	20.0	27.1	15.9	21.0	7.7	23.0
GOLD	10.2	27.6	14.2	19.7	9.6	16.0
ICM-11	10.7	10.0	8.1	10.8	5.6	24.4
IBMWP	15.2	14.2	11.3	14.1	7.2	8.7
IASPT	4.7	4.0	4.0	5.1	1.8	15.2
S10	28.9	18.6	18.2	26.1	8.5	23.1
S8+10	5.4	11.8	9.5	19.6	12.5	12.6
S1+2	32.8	14.3	19.5	20.6	11.8	3.8
D	12.8	15.9	11.4	14.5	18.3	20.3
H'	16.6	11.6	12.4	10.2	17.5	18.9

Table 7. Seasonal coefficient of variation of macroinvertebrate metrics for the four stream types and interannual coefficient of variation for stream types 3 and 4.

• Seasonal CV of macroinvertebrate metrics for all stream types were low CV (< 50%). Very low values seasonal CV (<15.3 %) were observed for in taxa richness (S) and macroinvertebarate indexes (ICM-11, IBMWP and IASPT) in all stream types.
• Interannual CV showed that all metrics displayed low CV (< 50%). S, EPTC, IBMWP, IASPT, S8+10 and S1+2 showed very low interannual variability (CV <15.4 %) in both stream types.

CONCLUSIONS

• No seasonal patterns in macroinvertebrate reference communities were detected in base on analysis of similarities in the four stream types. However, seasonal changes were detected in EPT and OCH taxa metrics in some of the stream types.
• No interannual patterns in macroinvertebrate reference communities during three years in the two headwaters stream types were found. EPT and OPH taxa metrics were the most sensitive metrics to this temporal variability. The great variability in annual rainfall in Mediterranean regions suggests that three years period may be too short to evaluate the effect of interannual variability on the assessment of the ecological status.
• Lower temporal variability of the indices IBMWP and IASPT and S in all studied stream types, suggest that they are appropriate a priori metrics for water quality assessment in Mediterranean streams.