Effects of a major flood on the mayfly and stonefly populations in a Mediterranean stream (Matarranya Stream, Ebro River basin, North East of Spain)

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Abstract

Changes due to a large flood in a mountain stream were investigated and evaluated from the perspective of macroinvertebrate responses (permanence and resilience) and food-web community structure. This study was conducted on the upper reaches of Matarranya Stream (Parrizal and Vallderroures), where heavy rainfalls in October 2000 caused severe damages (within three days the flow increased from 0.2 to 450m^3/s).
After the flood, densities decreased of more than 97% in the two study sites. Nearly in all cases, detritus became the preferential food for the macroinvertebrates, with diatoms as a complementary part of the diet.

Keywords: Ephemeroptera, Plecoptera, flood, disturbance, food web.

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Introduction

Investigating the effects of discharge fluctuations is important to understand how they affect the river ecosystem equilibrium and, in particular, the macroinvertebrate community composition and diversity (Puig *et al.*, 1986; Closs and Lake, 1994).

In Mediterranean regions, up to the 80% of the rain is concentrated during a short period of time, and a variation of the 50% in the total annual precipitations is not uncommon. Under these conditions floods are frequent (Gasith and Resh, 1999).

Different researches revealed that the sudden increase in discharge affects the macroinvertebrate community and the density of aquatic larvae decrease (Badri *et al.*, 1987; Scrimgeour 1988; Hendricks *et al.*, 1995.) though, in Mediterranean rivers, the richness, considered as the number of species present in the ecosystem, is not deeply affected and maintains its equilibrium, without disruptive effects (Malo and Puig, 1993; Gasith and Resh, 1999). Floods, in Mediterranean climate, do not last too long and the aquatic larvae have time to recover (Gasith and Resh, 1999) especially Ephemeroptera and Plecoptera that, thanks to their rapid movements and because they do not need a specific substrate, are considered quick colonizers (Brooks and Boulton, 1991).

This study focused on examining the effects of an exceptional flood on the macroinvertebrate communities in a Spanish Mediterranean stream, observing and describing the changes induced on Ephemeroptera and Plecoptera populations, their early re-colonization patterns, their adaptation to large floods and the changes in their diets.

The study area

Matarranya River has a basin of 1815.6 Km^2. It is located in the North-Eastern part of the Iberian Peninsula and it is one of the most important righter tributary of the Ebro River basin. This river has a Mediterranean regime, with high discharge during fall and small draught during summer. The climate of the region has also some continental influence, with a broad range in the annual temperature.

To conduct this study we selected two stations: Parrizal and Vallderroures (Fig. 1), which are located in the upper part of the River, 8 and 18 km far from the springs, respectively. These two sites are placed in the perennial part of the stream at an altitude of 500 and 600 m a.s.l..

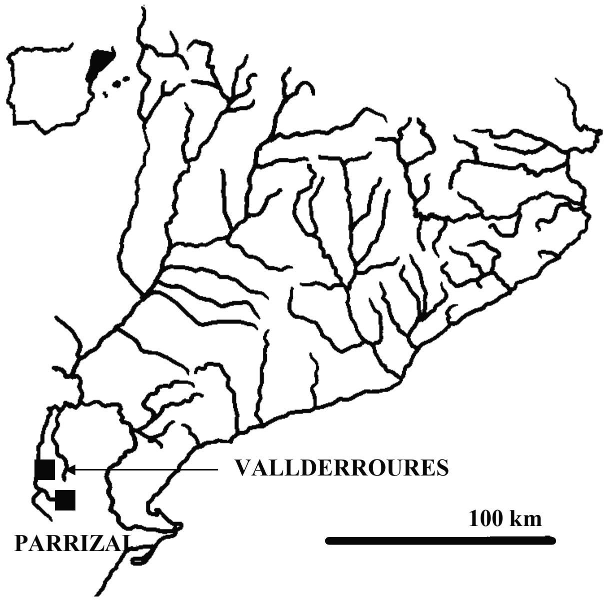

Fig. 1 - Map of Matarranya Catchment Basin

In a normal condition in Vallderroures, Matarranya Stream autumnal floods have an average magnitude of 24-56 m^3/s and occur with intervals of 6/7 years. A particularly intense flood was registered nearly fifty years ago, with a discharge of 80m^3/s, in the same site.

At the end of October 2000, intense meteorological events caused an extraordinary flood estimated as the greatest of the last 500 years. In upper reaches, within three days, fell an average of 466.5 litre/m^2. In Vallderroures the river discharge passed from a base-flow of 0.2 m^3/s to 450 m^3/s, and the water level in the narrowest gorges rose up to more than 4.7m (Beceite upstream station for example). The high energy of the fast flowing water increased erosion and transport, damaged human constructions and inundated cultivated fields.

Material and Methods

The samplings were conducted in November 2000, 24 days after the flood (fall period), which is the time required to settle for the majority of the species that compose the winter community of the Iberian Peninsula (Camarasa *et al.*, 1993). A second set of samples was collected at the end of March 2001, in late winter.

In the field were measured the following physical and chemical parameters: temperature, pH, dissolved oxygen, conductivity, current velocity (on the surface and on the bottom), the river width at the sections sampled, substrate composition, and the algal cover. To determine the concentration of silicate, phosphate, nitrite and nitrate were taken samples of water, in both stations on both dates.

Algal samples (three replicates) were collected scrapping the surface of stones and conserved in formalin 4%, were taken to laboratory to study the algal community. The abundance of each algal genera was expressed as relative frequency percentage per sample, which is based on the proportion between the abundance of each algal genus and an specific counted number (250) of algae present in the sample.

For the macroinvertebrate community two surbers were collected at each sampling station on both dates (surber sampler of 250 μm mesh and of 0.1 m^2 surface). The samples were preserved with 4% formalin. The invertebrates were identified to the range of family, genus and, where possible, to species. The organic matter present into the eight samples was separated, dried at 60°C and weighted.

The gut contents of 32 Ephemeroptera and 15 Plecoptera, which represented the 100% of the individuals belonging to these two orders accounted in November, were analysed together with those of 119 mayflies and 63 stoneflies that represent the 60.7% and 12.9% of the mayfly-stonefly population determined in March. The organisms were dissected to prepare the alimentary canal or, when the dimensions were too small to separate the different parts of the body, were crushed under the cover-slip. To examine the effect of the October 2000 flood, pre- and after-flood community composition and diets were compared with data collected in December 1998 fall period and in February 1999 (winter time) [Puig unpublished data].

Results

In Parrizal, in November 2000 and March 2001 at both sampling stations the river width was around 8-9 meters (Fig. 2), while previous data collected in 1998 and 1999, during fall period and winter time, accounted maximum widths of 6.58 m, with the river divided in two channels. In Vallderroures the river width changed from 10 m in November 2000 to 8-16 m in March 2001 and it was always wider than in 1998/99. Maximum depths were similar between before- and after-flood measurements. In November 2000 and March 2001 both in Parrizal and Vallderroures stretches current velocities were always higher compared with the two previous sampling periods.

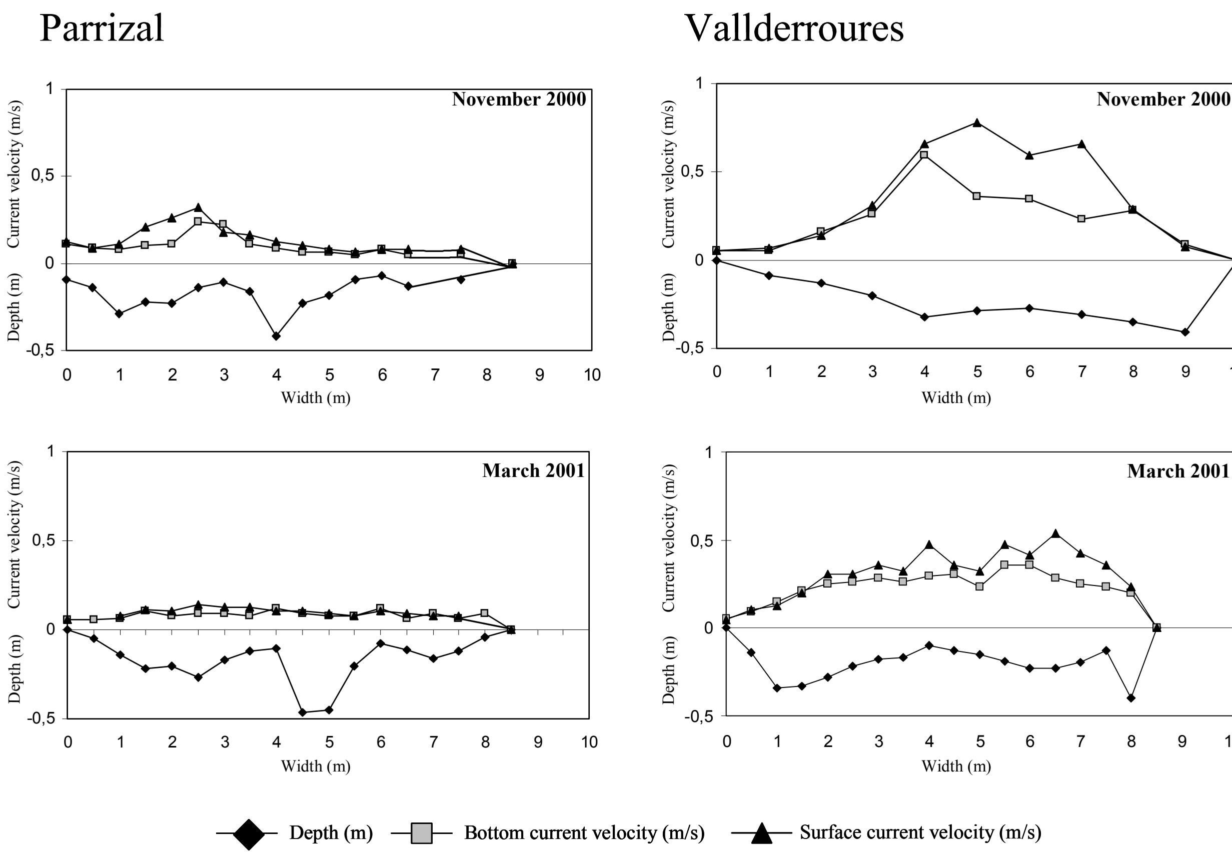

Fig. 2 - Graphs of the bottom-surface water current velocities, River width and Depth of Parrizal and Vallderroures streaches on both dates (November 2000 and March 2001).

Table 1 - Chemical analysis of the water. Silicate, Phosphate, Nitrite and Nitrate concentrations in the samples collected in November and March 2000/20001, compared with the data of December and February 1998/1999.

	Silicate µmol/L	Phosphate µmol/L	Nitrite µmol/L	Nitrate µmol/L	pH	Temp ºC	Cond (µS)	Oxygen (mg/L)
Parrizal 12-98	67.65	0.1	0	15.55	8.74	9.8	419	5.08
Valderroures 12-98	88.08	0.73	0.18	79.84	9.3	10	475	6.2
Parrizal 02-99	64.18	1.36	0.14	12.47	8.92	10.1	423	7.49
Vallderroures 02-99	82.66	0.98	0.53	45.62	9.29	6.9	434	11.28
Parrizal 11-00	43.21	0.38	0.00	9.73	9.2	10.9	430	6.75
Vallderroures 11-00	49.37	0.46	0.07	14.08	9.24	11.7	421	7.69
Parrizal 03-01	45.02	0.21	0.07	13.64	8.83	12.3	437	4.52
Vallderroures 03-01	35.64	0.47	0.18	45.10	8.31	16.2	416	4.58

During the October flood, the high energy of the flowing water removed the epilithic algal community and as a consequence of the reduction of photosynthetic activity, a decrease in oxygen production was recorded (Parrizal and Vallderroures, November 2000) (Table 1). After-flood the nutrient concentrations decreased and it is evident especially in Vallderroures station where before-flood (1998/99), due to agricultural and pig farm activities, the levels accounted were higher.

The high decrease of benthic organic matter on the river bed (Fig. 3), corresponding to after flood samples, can be associated to flow transport downstream. F.P.O.M. was faction of organic matter present after floods , while in 1998/99 the organic matter was mainly coarse (C.P.O.M.).

The riverbed substrata was characterized by a high percentage in cobbles before flood and after flood in both stations (Fig. 4), with the exception of Vallderroures in march 2000. In this case gravel and sand cover the major part of riverbed. It's possible find the origin of this situation in the activity associated to way restoration upstream.

The percentage of algal cover in Matarranya, as observed *in situ*, is graphically represented in Fig. 5. In Parrizal, after the flood, the presence of algae was undetectable, while in previous data it resulted abundant, with AFDW between 2.28 and 6.46 g/m^2. In Vallderroures in the same period the algal AFDW was 1.51-3.82 g/m^2. The AFDW measured in March 2001, compared to previous data, showed a decreased of 95% (Aboal personal communication).

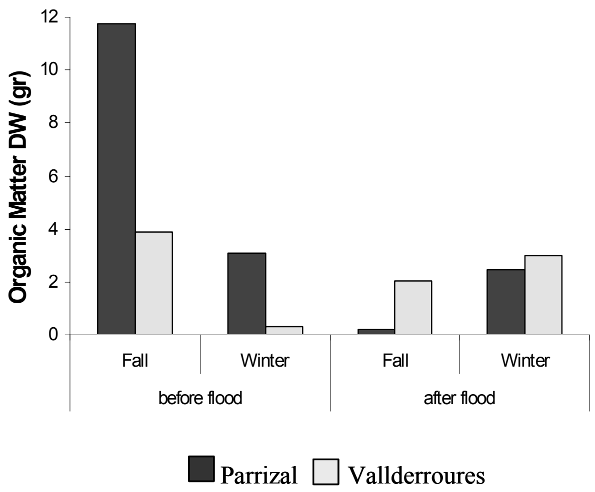

Fig. 3 - Benthic organic matter dry weight. Comparison between the data collected before and after the flood. Seasonal periods: Fall= Fall period; Winter=Winter time

Population dynamic and structure

In November 2000 mean densities of individuals per m^2 were of 355 in Parrizal and of 245 in Vallderroures, while in March were of 5675 in Parrizal and of 16275 in Vallderroures (Table 2). These values, especially in November, were much lower than densities in previous years. In Parrizal (1998 fall period) abundance was of 16360 ind/m^2 and of 15512 ind/m^2 in winter 1999. In Vallderroures, in the same periods, were accounted 108960 ind/m^2 and 86264 ind/m^2, respectively. After the flood, the density of the population decreased of 97.8% in Parrizal and of 99.8% in Vallderroures. In March 2001, referring to before flood values, a recuperation of the 34.4% in Parrizal and of the 18.67% in Vallderroures was observed. In November 2000 the most abundant Orders in Parrizal were Ephemeroptera and Plecoptera, while Diptera and Coleoptera were the most abundant in Vallderroures. In March 2001 mayflies, stoneflies, water midges (Chironomidae) in Parrizal; dipterans and aquatic worms (Naididae) in Vallderroures, represented the most abundant groups.

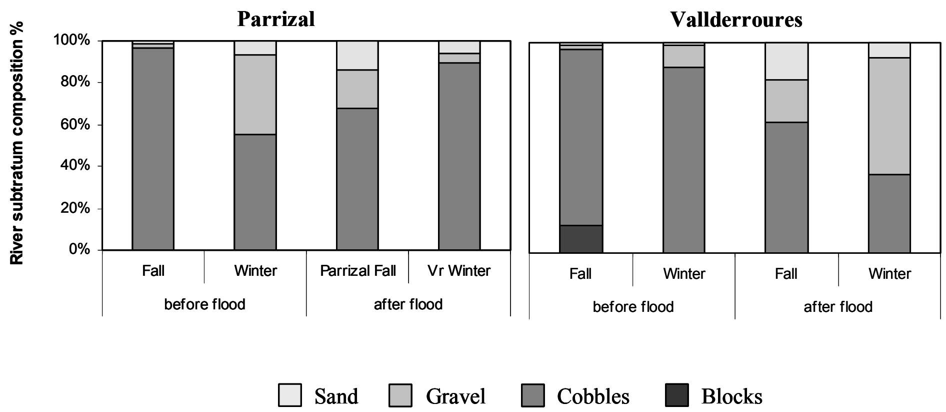

Fig. 4 - Composition of Matarranya riverbed in the area where the Surbers were collected. Comparison between before- and after-flood data.

After the flood, a total 10 species of Ephemeroptera and 4 of Plecoptera were found for all the samples. In November 2000, mayflies and stoneflies composed the 63.3% of the population in Parrizal and the 4% in Vallderroures, with a similar proportion accounted in March 2001 (70.6% and 6.8%). In relation with the densities before flood, mayfly and stonefly populations were decreased of 91.1% in fall and in March 2001 they showed a relate recuperation of 84.5% in Parrizal. In Vallderroures the community lost the 99.9% of these two orders densities, with 6.4% recuperation in March 2001 (Fig. 6).

In Parrizal (November 2000) have remained the reophyle species of Baetidae such as A*lainites muticus* (LINNEO, 1758)*, Baetis gadeai* (THOMAS, 1999) and *Baetis rhodani* (PICTET, 1843). At this date, the typical intertidal species *Capnioneura mitis* (DESPAX, 1932) and *Habroleptoides confusa* (SARTORI & JACOB, 1986) appear together with thefirsts instars of *Electrogena lateralis* (CURTIS, 1834), who inhabit the same habitat. In Vallderroures, in the same period, only one specimen of mayfly (*Baetis rhodani*) and one of stonfly *Leuctra fusca* (LINNEO, 1758) were found.

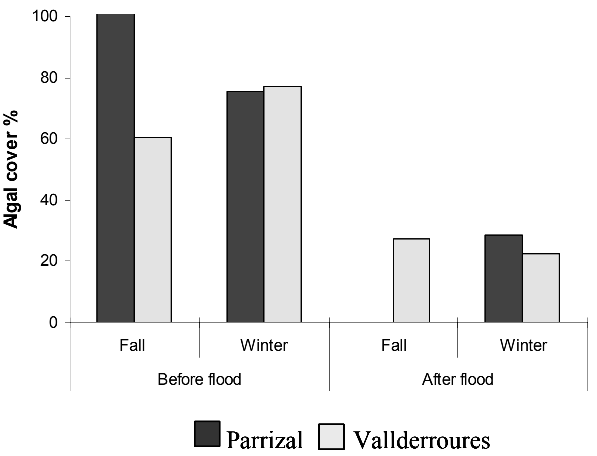

Fig. 5 - Algal cover (percentage) for the areas where the Surbers were collected. Comparison between before- and after-flood data.

Table 2 - Mayflies and stoneflies species mean densities (ind/m^2) at each station together with mean densities of the most abundant macroinvertebrate orders in Matarranya River. P=Parrizal; V=Vallderroures; S1/S2=Surber number; N=November; M=March; 00=year2000; 01=year2001.

Average density Ind/m^2	**PN00**	**PM01**	**VN00**	**VM01**
EPHEMEROPTERA				
Habroleptoides confusa	100	0	0	0
Habroleptoides sp.	0	185	0	0
Electrogena lateralis	25	10	0	0
Baetis rhodani	15	1335	5	120
Baetis scambus	0	0	0	20
Baetis gadeai	0	25	0	20
Baetis vardarensis	0	0	0	15
Alainites muticus	5	10	0	0
Baetis nigrescens	0	0	0	5
Baetis sp.	10	0	0	0
Serratella ignita	0	0	0	50
Total Ephemeroptera	155	1565	5	230
PLECOPTERA				
Leuctra geniculata	0	2440	0	880
Leuctra sp.	5	0	0	0
Leuctra fusca	40	0	5	0
Capnioneura mitis	20	0	0	0
Protonemoura sp.	5	0	0	0
Total Plecoptera	70	2440	5	880
DIPTERA	50	1390	130	8305
COLEOPTERA	35	25	130	80
TRICOPTERA	15	70	10	5
OLIGOCHAETA	0	100	40	6485
GASTEROPODA	0	20	5	75
OTHERS	30	65	25	215
TOTAL Community	**355**	**5675**	**245**	**16275**

In March 2001 *Leuctra geniculata* (STEPHENS, 1835), that dominates in gravel and sandy habitats, was present at both stations. *Baetis vardarensis* (IKONOMOV, 1962), *Baetis nigrescens* (NAVAS, 1931) and *Serratella ignita* (PODA, 1761) where captured only in Vallderroures (March 2001). In the samples collected in March notice the presence of *Baetis nigrescens*, this species has been previously captured only during wet hydrological years (Malo, 1993).

Diets

Of all the individuals gut-contents analysed, only 12 mayflies and 1 stonefly presented the alimentary canal empty, and have not been included in the gut-contents analyses. Same approach was considered for the species represented by only one individual, but those data has been considered in the general study of the feeding behaviours (Table 3).

The percentage of detritus in *Habroleptoides confusa* and *Leuctra fusca* (Parrizal, November 2000), and *B. gadeai* and *B. vardarensis* (Vallderroures, March 2001) was always higher than 90%, and they were considered as mainly detritivorous. The two specimens of *B. gadeai* collected in March 2001 in Parrizal that, with 78.3% of algae in the gut contents, represented the only herbivorous species found. The another species were presented phyto-detritivorous diets in both stations and sampling periods.

However, among all the individuals collected before-flood, only the Leuctricidae *L. fusca* and *L. aurita* (NAVAS, 1919), the Ephemerellidae *Serratella ignita* and the Caenidae *Caenis luctuosa* (BURMEISTER, 1839) presented detritus in their diets.

Comparing the gut contents analysed for the samples of 1998 fall period with those corresponding to the after flood community (November 2000), it was observed that Ephemeroptera passed from a diet composed by diatoms and green algae, with the sporadic presence of detritus, to a diet including only diatoms and detritus in all cases. This trend was maintained in March 2001 too. The passage from a herbivorous to a phyto-detritivorous diet is less evident for Plecoptera species, because detritus has always been a constant part of their alimentation.

Among all mayflies and stoneflies collected *B. rhodani, Habroleptoides* sp., and *Leuctra geniculata* presented the most varied diets, eating from 8 up to 10 different genera of diatoms, in contrast with an average of a bit less than three different diatoms genera for the rest of the species belonging to the community.

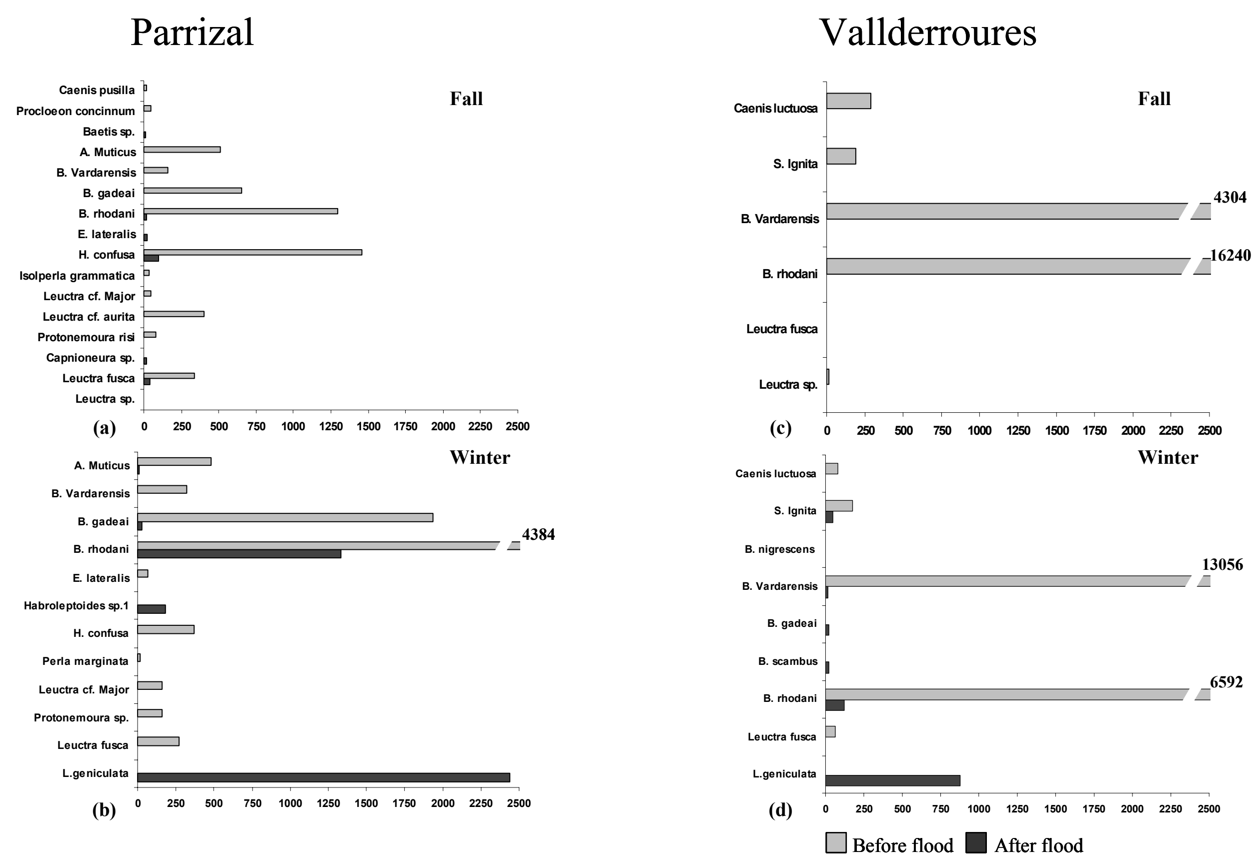

Fig. 6 - Comparison between mayfly and stonefly mean densities for each sampling station before and after the flood. Graphs (a) and (b) show Parrizal community during fall and winter time. Graphs (c) and (d) show mean densities in Vallderroures at the same seasonal periods.

In the two sampling stations diatoms, with a total of 15 genera, were the most abundant algae and they were always present in mayflies and stoneflies gut contents that showed a preference for certain diatom genera such as *Amphora*, *Navicula* (Parrizal, November 2000), *Cyclotella* (Parrizal, March 2001) and *Cocconeis* (Parrizal and Vallderroures, March 2001). Notice that the relative frequencies of these genera in the algal community were always below 1%, with the only exception of *Cocconeis,* whose presence was between 51 and 75% (Vallderroures in March 2001).

In Mayflies and Stoneflies gut contents were not found any cyanobacteria, which were abundant in Parrizal (March 2001) with relative frequencies from 11 up to 75%. At both stations green algae (gen. Bulbochaete), with frequencies between 11 and 25%, were found only in the gut contents of two *Baetis rhodani* captured in Parrizal.

Discussion

Previous studies done in Mediterranean streams from the Iberian Peninsula (Puig *et al.*, 1991; Malo, 1993), have shown that floods of similar magnitude and with a predictable recurrence interval do not significant effects on stream mayfly and stonefly communities due to their high resistance to such events. This pattern is observed either for populations densities and species richness (Malo and Puig, 1993), and it's similar in another areas (Rader and Ward, 1989).

The flood studied is two orders of magnitude larger and less frequent, 500 years possible, than a flood considered as predictable for the Matarranya stream. Nevertheless, species richness in Parrizal was not affected by the flood (from 6 to 5), indicating that these species were highly resistant according to this community descriptor (Malo and Puig, 1993). In contrast, the stream community at the study site located further downstream (Vallderroures) significantly decreased the species richness (from 4 to 1), indicates that the magnitude of the flooding event increase its effect downstream. This pattern is similar to the impacts recorded in Italian Piedmont streams (Fenoglio *et al.*, 2001).

Table 3 - Parrizal and Vallderroures diatoms and detritus relative frequencies in Mayflies and Stoneflies specific diets. (/=<10%; +=11 to 25%; ++=26 to 50%; +++=51 to 75%; ++++=76 to 90%; +++++= 91 to 100%).

	Amphora	*Cymbella*	*Achnantes*	*Gomphonema*	*Diatoma*	*Melosira*	*Meridion*	*Navicula*	*Nitzschia*	*Synedra*	*Surinella*	*Eunotia*	*Cocconeis*	*Fragilaria*	*Cyclotella*	Detritus	%Detritus	%Diatoms
PARRIZAL																		
November 2000																		
H. confusa	++	/						+++								+++++	98,9	1,1
B. rhodani	+++++	+++						+++++								+++++	46,6	53,4
Baetis sp.	++		++					+++++		++						+++++	47,7	52,3
E. lateralis	++++	+					+	+++		++++	+					+++++	67,6	32,4
L. fusca	+						+	+								+++++	97,5	2,6
C. mitis		++						++		++						+++++	67	33
March 2001																		
Habroleptoides sp.	/	+			/			+		/	++		+		/	+++++	94,5	5,5
B. rhodani	+	++	+		+			+		+	+	+	++++		++	+++++	57,3	42,7
B. gadeai		++											+++++		+++	+++	21,7	78,3
A. muticus				++									++		++	+++++	63,8	36,2
L. geniculata	/	/	/					+	/	+			+		++	+++++	89,2	10,8
VALLDERROURES																		
March 2001																		
B. rhodani	+										/		+++++		/	+++++	47	53
B. scambus		++								++	++		+++			+++++	42,3	57,7
B. gadeai													++			+++++	90	10
B. nigrescens																++++	100	0
B. vardarensis													+++++			+++++	49,6	50,4
S. ignita	+												+			+++++	51	49
L. geniculata		/	/								/		++++			+++++	87	13

Table 4 - Algal presence in Matarranya river (relative frequencies percentage) in November 2000 and March 2001. (+<1% frequency; 1=1 to 10%; 2=11 to 25%; 3=26 to 50%; 4=51 to 75%; 5=76 to 100%).

PARRIZAL	11/2000	03/2001	**VALLDERROURES**	11/2001	03/2001
DIATOMS			DIATOMS		
Amphora	+	+	*Amphora*		+
Meridion	3		*Cyclotella*	+	
Synedra	3	3	*Synedra*	4	
Fragilaria	3	+	*Fragilaria*	+	
Nitzschia	+		*Navicula*	4	
Achnantes	+		*Achnanthes*	+	
Navicula	+		*Surirella*	+	
Cyclotella	+	3	*Meridion*	4	
Cymbella	3	3	*Melosira*	4	+
Anomoeoneis	+		*Cocconeis*	+	4
Gomphonema	+		*Nitzschia*	4	
Eunotia	+	+	*Gomphonema*	+	
Pinnularia	+		*Cymbella*	+	+
Gyrosigma	+		*Diatoma*		4
Ephitemia		+	*Navicula*		+
Cocconeis		+	CYANOBACTERIA		
CYANOBACTERIA			*Phormidium*	+	+
Leptolyngbya	+	4	*Leptolyngbya*	2	4
Rivularia	+	2	*Chamaesiphon*		+
Chroococcus	+		GREEN ALGAE		
GREEN ALGAE			*Chaetophoral*	+	
Cosmarium	+		*Gongrosira*		3
Ulothrix	+		*Spirulina*	+	
Spirogyra		3	*Spirogyra*		3
Mougeotia		2	*Ulothrix*	+	
Zygnema		2			
Oedogonium		+			
Bulbochaete		2			
RED ALGAE					
Audouinella/Chantransia		+			
Batrachospermum		2			

Effects of this exceptional flood on macroinvertebrate communities are evidenced by a dramatic decrease in mayfly and stonefly densities, these results are supported by some previous records (Fisher *et al.*, 1982; Neckless, 1990; Hendricks *et al.*, 1995; Gasith and Resh, 1999). The population decrease to reach the removal of 98 %

In March 2001 the higher richness of mayfly species observed in Vallderroures respect to previous sampling period (November 2000), and the difference in species composition to Parrizal site should be related to transport them by drift of the individuals from two upstream tributaries.

Our data, compared with those referred to the autumnal community of Australian streams (Closs and Lake, 1994), revealed a wide variety in mayfly and stonefly diets showing good adaptation of the larvae to the after-flood conditions with limited food resources. Moreover, the choice of certain diatom genera such as *Amphora*, *Navicula* and *Cyclotella*, which were poorly represented in the general algal community, reveal that the larvae select actively their diet.

Even if after the flooding event the quantity of detritus in the river did not increase, in contrast to other results (Neckles *et al.*, 1990), must be underlined that Plecoptera and Ephemeroptera gut contents analysis revealed feeding behaviour with detritus as a constant and abundant component of the diet. Notice that, before the flood occurred, a part stoneflies and the mayflies belonging to the genus *Habroleptoides,* which are usually mainly detritivorous, all the other individuals belonging to these two taxa were nearly 100% herbivorous.

Energetically, the food webs based on detritus might be more important than the food webs based directly on autotrophyc production, because it serves as a reservoir of nutrients which are released at a constant rate influencing positively the resilience to perturbation of the living part of the ecosystem (De Angelis, 1992). This affirmation and the results listed in this study, compared with other observations on Iberian benthic larvae diets (Riaño, 1998) suggest to keep on study the role played by detritus in Spanish freshwater food webs, not only as the last resource, but also as an important part of the benthos diet.

For these reasons, the results of this study will be checked in further researches to obtain wider information about the significance of detritus into the complex Mediterranean benthic macroinvertebrates food web.

Acknowledgements
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References

Badri A., Giudicelli J., Prevot G., 1987. Effect d’une crue sur la communité d’invertébrés benthiques d’une riviére méditerranéenne, le Rdat (Maroc). Oecol. Gener. 8: 481-500.

Brooks S.S., Boulton A.J., 1991. Recolonization Dynamics of Benthic Macroinvertebrates after Artificial and Natural Disturbances in an Australian Temporary Stream. Australian Journal Of Marine and Freshwater Research. 42: 295-308.

Camarasa J.M, del Castillo M., Comelles M., Drucker G., Ferrés L., Folch R., Franquesa T., Junyent C., Martinez-Rica J.P., Puig M.A., Ruiz J., de Sostoa A., Vallejo R., Vigo M., 1993. Mediterrànies. Enciclopedia Catalana. S.A. Barcelona. Spain. pp. 152-161.

Closs G.P, Lake PS., 1994. Spatial and Temporal variation in the structure of un intermittent-stream food web. Ecological Monographs. 64(1): 1-21.

DeAngelis D.L., 1992. Dynamics of nutrient cycling and food webs. Chapman & Hall. London. England.

Fenoglio S., Agosta P., Bo T., Malacarne G., 2001. Direzioni e modalità di colonizzazione della fauna macrobentonica di un torrente appenninico.. XI Congresso Nazionale S.It.E.. Sabaudia. Italy. 63-64.

Fisher S.G, Gray L.J, Grimm N.B., Bush D.E., 1982. Temporal succession in a desert stream ecosystem following flash flooding. Ecological Monographs. 52(1): 93-110.

Gasith A., Resh V.H., 1999. Streams in Mediterranean regions: abiotic influences and biotic responses to predictable seasonal events. Annual Rev. Ecol. 30: 51-81.

Hendricks A.C, Lawrence D.W, Snyder C., 1995. Impact of flooding on the densities of selected aquatic insects. Hydrobiologia. 299**:** 241-247.

Malo J., 1993. Comunidades bentónicas de ríos Mediterráneos. PhD Thesis, Departamento de Biología Animal y Ecología. Universidad de Murcia. Spain.

Malo J., Puig M. A., 1993. Efectos de las fluctuaciones sobre la estabilidad de la comunidad de macroinvertebrados de un tramo permanente de un cauce mediterraneo (Rio Matarranya, cuenca del Ebro). Actas VI Congreso Español de Limnología. 347-354.

Neckles H.A., Murkin H.R., Cooper J.A., 1990. Influence of seasonal flooding on macroinvertebrate abundance in wetland habitats. Freshwater Biology 23:311-322.

Puig M.A., Ferreras-Romero M., Rojas A.M., 1986. Ecosistemas de ríos temporales: ecología de las poblaciones de efemerópteros de la cuenca del Río Bembézar (Sierra Morena). Anales de Biología **8**: 65-69.

Puig. M. A, Aboal M, de Sostoa A., 1991. New approaches to Mediterranean fluvial communities. In : Ros J.D., Prat N., (eds). Homage to Ramon Margalef, or, Why there is such a pleasure in studying nature. Barcelona: Publ. Univ. de Barcelona. pp. 13-20.

Rader R.B., Ward J.V., 1989. The influence of environmental predictability / disturbance characteristics on the structure of a guild of mountain stream insects. Oikos 54: 107-116.

Riaño P., 1998. Ciclos biológicos y ecología trófica de los macroinvertebrados del bentos fluvial (Plecoptera, Ephemeroptera y Trichoptera). PhD. Thesis, Departamento de Biología y Ecología, Universidad del País Vasco. Spain.

Scrimgeour G.J, Davidson R.J, Davidson J.M., 1988. Recovery of benthic macroinvertebrate and ephilitic communities following a large flood, in an unstable, braided, New Zealand river. New Zealand Journal of Marine and Freshwater Research 22: 337-344.