THE DADIA–LEFKIMI–SOUFLI FOREST NATIONAL PARK, GREECE: BIODIVERSITY, MANAGEMENT AND CONSERVATION

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Macroinvertebrate communities of intermittent and ephemeral streams of Dadia–Lefkimi–Soufli Forest National Park and the impact of small release dams

Anna Argyroudi, Konstantinos Poirazidis and Maria Lazaridou

Seventeen sites on intermittent and ephemeral streams of the Dadia–Lefkimi–Soufli Forest National Park were studied with respect to (a) the structure of their benthic macroinvertebrate communities, hydromorphology and physico-chemical parameters and (b) the downstream impacts of small release dams. At the ephemeral sites, tolerant and sensitive taxa were almost equally abundant, but sensitive taxa were less abundant than at the intermittent ones. During the high-flow season, the intermittent sites were characterized primarily by Simuliidae (Diptera), Caenidae (Ephemeroptera) and Taeniopterygidae (Plecoptera). The studied ephemeral sites exhibited lower taxon diversity with high dominance values (according to K-dominance curves). CANOCO analysis revealed that the faunas of the two categories of stream have different structural and functional characteristics and differ in drought tolerance. The small release dams seemed to have an impact on the evenness of the distribution of taxa (Pielou's index), the water quality, and the feeding groups of the macroinvertebrate communities (a decrease in shredders downstream of the dams).

Keywords: Intermittent streams, ephemeral streams, release dams, macroinvertebrates, shredders, Dadia National Park, PM5, ICM7RM, ICM10RM

Introduction and scope

The Water Framework Directive (2000/60/EC) requires that the European countries assess the ecological quality of their freshwater ecosystems using biological quality elements (e.g. benthic macroinvertebrates, fish, macrophytes) and also the hydromorphological and physico-chemical elements that support the biological ones. Benthic macroinvertebrates are considered as the most appropriate bioassessment indicators for running waters (Metcalfe 1989, Mason 1991).

Many studies have given insights into the structure or function of the benthic macroinvertebrate communities in Mediterranean streams (Bazzanti et al. 1989, Coimbra et al. 1996, Bonada 2003, Arab et al. 2004, Morais et al. 2004, Bêche et al. 2006) and throughout the world (Williams and Hynes 1976, Boulton and Lake 1992a, b, Meyer et al. 2003). As far as Greece is concerned, however, there is very little information on the benthic macroinvertebrate communities of its streams (Lazaridou-Dimitriadou et al. 2003).

Many streams of the Evros river basin can be characterized as temporary. These can be divided into intermittent, which form chains of isolated pools, and ephemeral, which dry up completely during the low flow season (Bonada 2003, Uys and O'Keeffe 1997). The dry period (summer–autumn) of the above streams in the Dadia–Lefkimi–Soufli Forest National Park (hereafter DNP) ends in November when flow continuity is restored.

A study in DNP has shown that the degree of flow temporality of 11 temporary streams (intermittent and ephemeral) influences the composition of their benthic macroinvertebrate communities (Argyroudi et al. 2009). In that study various metrics and indices, and multivariate analyses in particular, confirmed a clear distinction between the two stream types (ephemeral and intermittent). However, according to the intercalibration exercise (Van de Bund et al. 2004), which has been organized for the purposes of the implementation of the Water Framework Directive 2000/60/EC, the Mediterranean ephemeral and intermittent streams belong to one type, the R-M5 type (small Mediterranean temporary streams), regardless of their degree of flow temporality.

In the present paper we studied the structure of the benthic macroinvertebrate communities, the hydromorphology and the physico-chemical parameters of intermittent and ephemeral streams of the DNP, recognizing that they belong to two different types (Argyroudi et al. 2009) and not to the single type (RM5) of the inter-calibration exercise (Van de Bund et al. 2004). In addition, we also studied the downstream impact of small release dams, built on ephemeral streams, on the trophic characteristics of the streams and on their biodiversity. We also studied the influence of the dams on the sensitivity of their benthic macroinvertebrates as well as on the streams' water quality.

Study area

The sites were chosen in the wider drainage basin of DNP (Fig. 1). All the studied sites were considered as reference sites based on the fact that their catchments were exclusively forest covered, there was an absence of human settlements as well as of any kind of pollution input. There was no water abstraction or diversion (REFCOND Guidance 2003) according to the mapping of the land uses of the area (Adamakopoulos et al. 1995).

The present study was carried out at 17 sites, seven belonging to the category intermittent streams (in the buffer zone of DNP) and 10 to the ephemeral category (in the core zone of DNP). The intermittent sites were sampled during both the low flow period (in October 2004) and the high flow season (in March 2005, i.e. four months after the drought, a period sufficiently long to allow the system to recover), whereas the ephemeral sites were sampled during the high flow season only. On the ephemeral streams, four small release dams were constructed in order to retain water during the summer period (Fig. 1) and thereby serve the avifauna of the area. In order to study any possible impact of these dams on the benthic macroinvertebrate fauna, one site upstream and one site downstream of each dam was sampled, as well as two additional sites 100 and 150 m downstream of dam 4. The sites downstream of the dams were not considered as reference sites (REFCOND Guidance 2003).

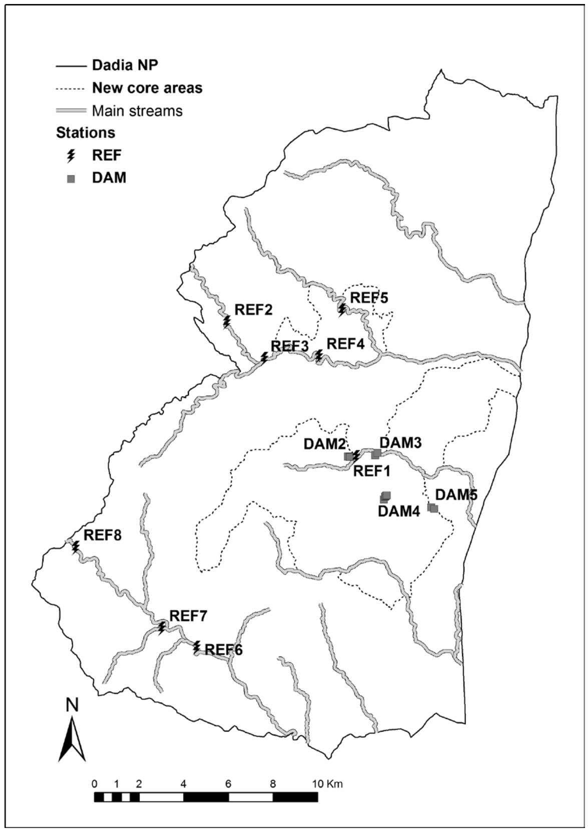


Fig. 1. The sampling sites along the streams of DNP (REF: Intermittent streams, DAM: Ephemeral streams on which dams were located. The distance between the sites upstream and downstream of the dam is 500 m).

The intermittent sites differed significantly from the ephemeral ones (Mann-Whitney U test, $p<0.05$, df 10) by showing higher values for discharge, depth, drainage basin area, slope, dissolved oxygen (D.O. %), pH levels and percentage of bank vegetation (Argyroudi et al. 2009).

Materials and methods

Measurements of pH, dissolved oxygen (D.O. % and mg/l), water temperature, conductivity and Total Dissolved Solids (TDS) were taken using the digital polymeter YSI 650 MDS equipped with the appropriate probe (SONDE 6600-M). Concentrations of P-PO_4 (mg/l) and Total Suspended Solids (TSS mg/l) were measured according to A.P.H.A. (1985). One sample of benthic macroinvertebrates was taken at each site with the 3-minute kick-sweep method (with the addition of one minute where vegetation was present, Armitage et al. 1983) using a standard pond net (575 cm^2, mesh size 0.9 mm, depth 40 cm; ISO 7828, 1985). All the habitats at each site (submerged macrophytes, bankside macrophytes at riffles and pools and bare substrate) were sampled proportionally according to the Habitat Richness Matrix (Chatzinikolaou et al. 2006). In order to assess the ecological quality of each site we used (a) the Hellenic Evaluation System (HES) (Artemiadou and Lazaridou 2005) and (b) the multi-metric Indices for Mediterranean temporary streams ICMi10RM and ICMi11RM (Munné and Prat pers. comm.) and ICMi7RM (Buffagni et al. 2005). The calculation of the above ICMiRM indices results in three water quality classes (M: Medium, G: Good, H: High) and includes several separate metrics such as the IASPT (the Iberian average score per taxon), the EPT (the number of families of Ephemeroptera (E), Plecoptra (P) and Trichoptera (T), the number of taxa, the $\log_{10}$(SelEPTCD+1) (the log-transformed abundance of the above taxa plus Plecoptera (P) and Coleoptera (C)), Pielou's index (which represents the evenness of the distribution of taxa), the $\log_{10}$(SelETD+1) (the log-transformed abundance of selected taxa of Ephemeroptera (E), Trichoptera (T) and Diptera (D), see Table 3.

The degree of riparian integrity was estimated by using the Spanish QBR index (Munné et al. 2003) and the integrity of the fluvial habitat by the IHF index (Pardo et al. 2002).

Taxa's sensitivity to pollution was assessed according to HES scores (Artemiadou and Lazaridou 2004) with sensitive taxa having scores >80, tolerant <40 and moderately sensitive 40–80.

Data were analysed by using univariate Mann-Whitney tests, while multivariate analyses included the ordination method of Canonical Correspondance Analysis (ter Braak and Šmilauer 1998), which examined the relationship between the macroinvertebrate taxa or the sampling sites and the physico-chemical parameters. In addition, SIMPER analysis (program PRIMER, version 5.1.2., Clarke and Warwick 1994) was used to determine the major families contributing to the average Bray–Curtis dissimilarity between clusters of sites. K-dominance curves were also constructed to allow direct comparison of family diversity and dominance characteristics between sites (Clarke and Warwick 1994). Functional feeding groups were identified according to Cummins and Klug (1979).

Results

Abiotic conditions and vegetation indices in the temporary streams

Intermittent Mediterranean streams have high flow predictability, while the ephemeral ones do not (Uys and O'Keeffe 1997). In DNP this was attributed to the larger basin area of the former, which results in a higher and more predictable discharge.

Riparian quality (QBR index) was excellent or good (54.28±2.51) at the ephemeral and intermittent sites and, similarly, the Fluvial Habitat Quality (IHF Index) indicated good or moderate conditions (85.56±2.79).

Characteristics of benthic macroinvertebrate communities

Temporary systems are inhabited by taxa showing adaptations to drought such as a highly flexible life cycle, temperature-linked development, possession of diapausing or otherwise protected eggs, and high powers of dispersal (Stanley et al. 1994, Williams 1996). The benthic macroinvertebrate taxa recorded in the temporary streams of DNP are shown in Table 1. Taxa sensitive to pollution (according to the Hellenic Evaluation scores, Artemiadou and Lazaridou 2005) generally prevailed at all sites at the temporary streams. At the ephemeral sites, tolerant and sensitive taxa were present in almost equal abundances, but sensitive taxa were significantly fewer than at the intermittent sites, probably because they had not been able to recover after the dry season even though the sampling took place in March, four months after the drought (intermittent sites: Sensitive Taxa = 65, Moderately Sensitive = 32, Tolerant = 24 and ephemeral sites: 23, 7 and 19, respectively).

According to the Simper analysis, the clear differentiation between the benthic macroinvertebrate communities of DNP is explained by the large contribution of specific families that characterize intermittent and ephemeral streams (Table 2). In particular, during the high flow season, the intermittent sites were characterized primarily by Simuliidae (Diptera), Caenidae (Ephemeroptera) and Taeniopterygidae (Plecoptera) (Tables 1 and 2), known as lotic/moderately sensitive and sensitive taxa. Simuliidae fly in to oviposit as soon as water reappears, after having survived the dry period as eggs (Fredeen 1958) while Taeniopterygidae resist the drought in temporary streams as diapausing nymphs (Harper and Hynes 1970).

Table 1. Benthic macroinvertebrate taxa found in samples from sites in Dadia NP (October 2004 and March 2005) (P: Plecoptera, E: Ephemeroptera, T: Trichoptera, O: Odonata, D: Diptera, CO: Coleoptera, ME: Megaloptera, A: Amphipoda, I: Isopoda, MO: Mollusca, AN: Annelida, HE: Hemiptera, CR: Crustacea, AR: Arachnida). P: Present (0–1%), C: Common (1.01–10%), A: Abundant (>10%) according to the Natura 2000 data forms. Sensitivity to pollution of taxa is marked according to HES scores where S = Sensitive (score >80), T = Tolerant (score <40) and MS = Moderately Sensitive (score 40–80).

	Family	The taxon's sensitivity to pollution	Low flow intermittent	High flow intermittent	High flow ephemeral upstream of dams	High flow ephemeral downstream of dams
P	Nemouridae	S	–	C	A	C
P	Perlodidae	S	–	C	P	P
P	Leuctridae	S	P	P	P	P
P	Taeniopterygidae	S	–	A	C	C
P	Capniidae	S	–	P	P	P
E	Heptageniidae	S	C	C	–	P
E	Ephemerellidae	MS	P	–	–	–
E	Ephemeridae	S	P	P	–	–
E	Siphlonuridae	S	P	C	A	A
E	Leptophlebiidae	S	C	C	P	–
E	Caenidae	MS	A	C	–	–
E	Baetidae	MS	P	C	–	–
E	Potamanthidae	MS	P	–	–	–
T	Philopotamidae	S	P	P	–	P
T	Hydropsychidae	MS	P	P	–	–
T	Psychomyidae	S	P	P	P	
T	Hydroptylidae	MS	P	P	A	P
T	Polycentropodidae	S	C	P	–	–
T	Limnephilidae	S	P	P	P	P
T	Lepidostomatidae	S	–	P	–	–
T	Sericostomatidae	S	P	P	–	–
T	Leptoceridae	S	C	P	–	–
O	Gomphidae	MS	C	P	–	–
O	Aeshnidae	S	P			–
O	Calopterygidae	MS	C	P		–
O	Coenagrionidae	T	P	P	P	–
O	Platycnemididae	MS	A	C		–
O	Corduliidae,	S	–	P	P	–
O	Libelulliidae,	S	P	–	–	–
D	Tipulidae	T	P	–	–	P
D	Athericidae	S	P	P	P	–
D	Tabanidae	MS	P	P	–	–
D	Simuliidae	MS	–	A	P	P
D	Dixidae	S	P	P	–	–
D	Stratiomyidae	MS	–	P	–	–
D	Ceratopogonidae	MS	–	P	P	P

Table 1. Continued.

	Family	The taxon's sensitivity to pollution	Low flow intermittent	High flow intermittent	High flow ephemeral upstream of dams	High flow ephemeral downstream of dams
D	Chironomidae	T	A	C	C	A
D	Psychodidae	MS	–	–	–	P
D	Limoniidae	T	–	P	P	P
D	Raghionidae	–	–	–	P	P
CO	Dytiscidae	T	P	P	C	C
CO	Hydrophilidae	T	–	–	–	P
CO	Elminthidae	MS	C	–	–	P
CO	Curculionidae	MS	–	–	P	–
CO	Gyrinidae	S	–	–	–	P
CO	Haliplidae	MS	P	–	–	–
CO	Dryopidae	MS	–	–	–	P
CO	Hydrochidae	MS	–	–	–	P
ME	Sialidae	S	P	–	–	–
A	Gammaridae	MS	C	C	P	–
I	Asellidae	T	P	P	–	P
MO	Sphaeriidae	T	P	–	–	–
MO	Planorbidae	T	C	–	–	–
AN	Oligocheata	T	C	P	C	C
HE	Corixidae	T	–	P	P	P
HE	Gerridae	T	P	P	P	P
HE	Notonectidae	T	–	–	P	P
CR	Potamonidae	S	P	P	–	–
AR	Arachnida	–	P	P	P	P

The ephemeral streams were typified mostly by the lotic/sensitive taxa Siphlonuridae (Ephemeroptera) and Nemouridae (Plecoptera) (Tables 1 and 2). The latter two taxa, although sensitive, dominated the fauna of the DNP ephemeral streams during the high-flow season. They reached high abundances and seemed not to be affected by the previous drought of the stream. Siphlonuridae and Nemouridae are known to resist the summer drought by undergoing a long diapause as eggs (Harper 1973, Voshell 1982). In addition, the ephemeral streams of DNP could not support the family Simuliidae (Table 1) given that simulid distribution and particularly oviposition are restricted to sites that are shaded by trees and riparian vegetation (Lautenschläger and Kiel 2005), which were present only at the intermittent sites. Sensitive taxa, which generally occurred in high densities during the high flow season, were replaced by tolerant ones during the summer lentic period (Morais et al. 2004). The latter occurred in the receding intermittent summer pools of DNP, which were characterized by Chironomidae (Diptera) and Platycnemydidae (Odonata), lentic/tolerant and moderately sensitive taxa, respectively (Tables 1 and 2). Odonata exhibit long life cycles (Williams 1996) and survive as adults during the dry period (Williams and Hynes 1977), while Chironomidae diapause as larvae or eggs (Thienemann 1954) and are considered as characteristic of such habitats throughout the world (Williams 1997). Caenidae, although sensitive according to the HES, were more abundant during the low flow. However, they usually occur in quiet and even stagnant water with silty bottoms. Their gills are specially adapted for silty environments and unlike other mayflies, these so called squaregills can be found in degraded conditions (Elliott and Humpesch 1983).

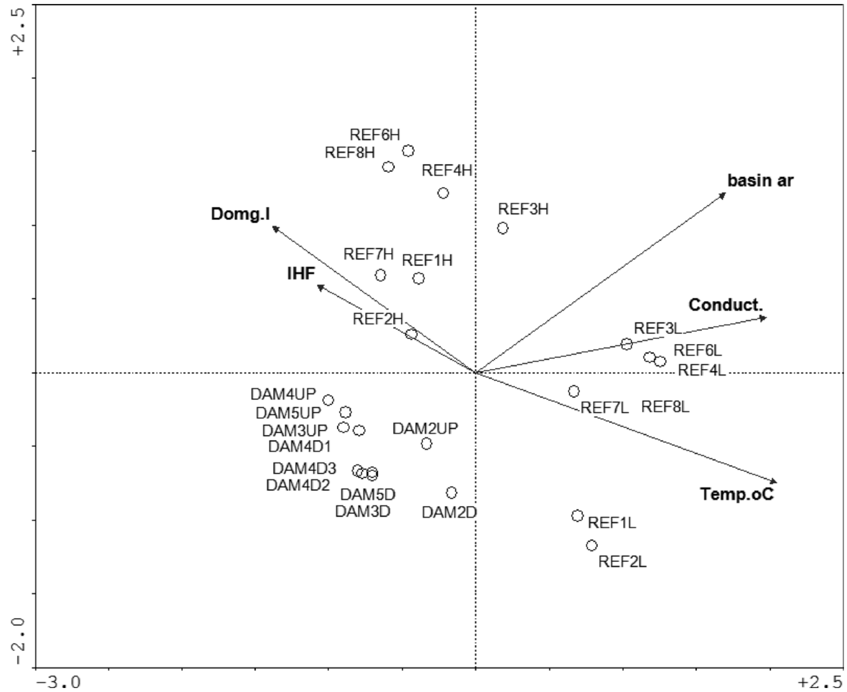
Table 2. Results of Simper analysis comparing (a) the low-flow and high-flow situations at intermittent sites and (b) intermittent and ephemeral sites during the high-flow period. In (a) dissimilarity was 75.12% and in (b) 68.35%.

(a)	Mean abundance, low flow	Mean abundance, high flow	% contribution
Simuliidae	0.00	101.43	7.68
Taeniopterygidae	0.00	56.71	7.49
Chironomidae	177.29	5.29	5.75
Platycnemydidae	64.86	5.00	5.06
Elminthidae	17.29	0.00	3.89
Oligochaeta	22.00	0.86	3.76
Leptoceridae	30.14	1.00	3.65
Leptop/biidae	26.14	2.86	3.39
Gammaridae	24.29	12.43	3.31
Caenidae	64.57	12.14	3.18
(b)	Mean abundance, intermittent	Mean abundance, ephemeral	% contribution
Simuliidae	101.43	3.25	9.09
Siphlonuridae	2.86	349.00	7.89
Caenidae	12.14	0.10	5.72
Taeniopterygidae	56.71	17.50	5.58
Nemouridae	9.29	50.30	5.19
Gammaridae	12.43	0.10	4.92
Oligochaeta	0.86	7.90	4.22
Dityscidae	0.29	7.80	3.94
Perlodidae	4.43	3.00	3.28
Heptageniidae	4.71	0.30	3.12

Lower diversities occur where the dry season lasts longer (Williams and Hynes 1976, Williams 1996) since a long dry period decreases the size of the inhabitable habitat (Arab et al. 2004). The studied ephemeral sites exhibited lower diversity along with high dominance (according to K-dominance curves). Taxon richness, indicated by the number of taxa, has usually been found to be very low at ephemeral sites in Catalonian reference streams (Bonada 2003), but in the current study this was not the case. EPT values did not differ statistically between the two types of stream (intermittent-ephemeral) (Mann-Whitney U test, df 10, $p>0.05$) even though a strong correlation between EPT and flow permanence has been recorded elsewhere (Feminella 1996).

The ecological quality (SemiHES) according to the Hellenic Evaluation System (HES) varied from excellent to good at the intermittent sites and from good to moderate at the ephemeral ones. The moderate condition of the ephemeral sites is probably related to the length of the recovery time, which is something natural for these systems. The existing European ecological quality indices are not capable of distinguishing natural variability from human-induced stressors in temporary streams (Argyroudi et al. 2009).

According to the weighted intraset correlations of Canonical Correspondence Analysis (CCA), five environmental variables were selected, viz. water temperature (°C), D.O. (mg/l), the area of the drainage basin (km^2), conductivity (μS/cm) and Fluvial Habitat Quality (IHF) (Fig. 2). The first two axes of the ordination explained 66.1% of the variance in the relationship between species and environmental variables. The communities were differentiated according to the catchment area of the studied intermittent and ephemeral streams (correlated mainly with Axis 2) and water temperature (low or high-flow season) (correlated mainly with Axis 1; Fig. 2). Consequently, in the low-flow season (high temperature) the intermittent sites (REFL) were clustered along the positive part of Axis 1, in contrast to the high-flow season when both the intermittent and



	Axis I	Axis II	Axis III	Axis IV
Eigenvalues	0.450	0.214	0.157	0.103
Species-environment correlations	0.961	0.943	0.877	0.882
Cumulative percentage variance:				
in species data	19.4	28.6	35.4	39.8
in species-environment relation	44.8	66.1	81.8	92.0
Weighted intra-set correlations:				
Water temperature (°C)	0.8732	-0.4053	-0.0071	0.1642
D.O. (mg/l)	-0.6008	0.4939	0.0611	-0.3543
Size of drainage area (km²)	0.7488	0.6153	-0.2318	-0.0260
Conductivity (μS/cm)	0.8537	0.1514	0.4346	-0.2413
Fluvial habitat index, IHF	-04703	0.3513	0.3983	0.6940

Fig. 2. Ordination of sampling sites and environmental variables along the streams in DNP in October 2004 and March 2005 using Canonical Correspondence Analysis. REF: Intermittent streams, L: Low flow season, H: High flow season, DAM: Dams in ephemeral streams, UP: Upstream of the dam and DOWN: Downstream of the dam. Weighted intraset correlations between each of axes 1 to 4 and the five environmental variables (with inflation factor less than 20) are also presented.

Table 3. Values obtained at the dam sampling sites for the Intercalibration Multimetric Indices for Mediterranean Streams (ICMiRM). IASPT is the Iberian average score per taxon; EPT is the number of families of Ephemerptera (E), Plecoptra (P) and Trichoptera (T); $\log_{10}$(SelEPTCD+1) is the log-transformed abundance of the above taxa plus Plecoptera (P) and Coleoptera (C); Pielou's index represents the evenness of the distribution of taxa; $\log_{10}$(SelETD+1) is the log-transformed abundance of selected taxa of Ephemeroptera (E), Trichoptera (T) and Diptera (D). Stream quality is indicated as M = Medium, G = Good and H = High in the ICMiRM and SemiHES indices. UP and DOWN refers to upstream and downstream of the dams, respectively, and D1 to D3 to the three downstream sites at dam no. 4.

	IASPT-2	EPT	No. of taxa	Log_{10}sel (EPTCD+1)	J-PIELOU	Log_{10} sel(ETD+1)	SemiHES		ICM7RM		ICM10RM		ICM11RM	
DAM2UP	3.5	2	4	0.54	0.89	0.12	2.5	M	0.63	M	0.58	M	0.51	M
DAM2DOWN	4.6	3	5	0	0.64	0	3.5	G	0.56	M	0.55	M	0.68	M
DAM3UP	4.2	9	20	0.62	0.54	1.64	3.5	G	1.07	H	1.03	H	1.04	H
DAM3DOWN	4	6	11	0.95	0.53	0	3	M	0.65	M	0.93	H	0.8	G
DAM4UP	3.56	4	9	0.55	0.58	0.62	3	M	0.73	G	0.7	G	0.65	M
DAM4D1	3.15	5	13	1.11	0.51	0.3	3	M	0.64	M	0.9	H	0.69	M
DAM4D2	4.2	7	15	1.3	0.54	0.48	4	G	0.81	G	1.13	H	0.9	G
DAM4D3	3.4	6	15	1.72	0.59	0.6	3.5	G	0.76	G	1.16	H	0.78	G
DAM5UP	4.4	8	15	0.64	0.34	1.53	3.5	G	0.95	H	0.97	H	0.96	H
DAM5DOWN	3.67	7	18	1.3	0.49	1.08	3.5	G	0.89	G	1.12	H	0.88	G

ephemeral sites fell on the negative part of Axis 1 (REFH and DAM) (Fig. 1). Additionally, all the ephemeral sites (DAM) were distributed along the negative part of Axis 2, whereas most of the intermittent sites (REF), belonging to a bigger drainage basin area, were placed on the positive side of Axis 2. The ordination shows that the fauna of these streams have different structural and functional characteristics and tolerance to drought. The latter finding supports the fact that these streams belong to different types and not to the single one (RM5) of the Intercalibration Exercise (Van de Bund et al. 2004).

Impacts of the small release dams

The physico-chemical parameters, the riparian quality (QBR) and the Fluvial Habitat Quality (IHF) indices as well as the metrics and indices of Table 3 did not differ significantly between sites upstream and downstream of the dams (Mann-Whitney U test, df 9, $p>0.05$). Additionally, according to the CCA analysis the upstream and downstream sites were placed in the same quadrant and showed no structural difference in their faunal composition (Fig. 2).

Table 4. Results of Simper analysis comparing feeding groups upstream and downstream of the small-release dams. The dissimilarity between upstream and downstream sites was 56.9%.

Family (*feeding group*)	Mean abundance, downstream	Mean abundance, upstream	% contribution
Siphlonouridae (*collectors*)	349.00	129.25	10.50
Nemouridae (*shredders*)	101.25	8.25	9.90
Hydroptilidae (*piercers*)	85.00	0.5	7.38
Oligochaeta (*collectors*)	6.75	8.75	7.06
Taeniopterygidae (*scrapers*)	17.50	17.25	7.04
Chironomidae-Tanypodinae (*predators*)	21.50	32.75	5.78
Dityscidae (*predators*)	7.25	5.00	5.15
Perlodidae (*predators*)	4.50	2.50	5.00
Ceratopogonidae (*predators*)	2.75	2.25	3.85

With respect to the abundance and number of taxa sensitive to pollution no statistically significant differences were found (Mann-Whitney U test, df 9, $p>0.05$) and the same was true for all the various metrics used.

However, the small release dams seemed to influence the evenness of the distribution of taxa (Pielou's index), water quality (especially assessed by SemiHES and the ICM7RM) (Table 3), and the feeding groups of the macroinvertebrate communities, however not significantly so. According to the Simper analysis, shredders (Nemouridae) and collectors (Siphlonuridae) with their high average abundances contributed considerably to the dissimilarity between sites upstream and downstream of the dams (Table 4). Similarly, the percentage of shredders and piercers was higher upstream of the dams, while that of collectors was either higher downstream of the dams or did not differ (Table 5). A similar pattern was found for a small release dam in the headwaters of a stream in Spain (Camargo et al. 2005). Dams alter the downstream flow regimes by changing the current and the discharge, or both. In doing so, they change the proportions of coarse-particle organic material (CPOM) and fine-particle organic material (FPOM) on which benthic macroinvertebrates feed (Gore 1994). Thus, the decrease of shredders downstream of the dams of DNP might be attributed to the lentic conditions downstream the reservoir that hinder the transportation of the coarse-particle organic material on which shredders feed. However, recovery seems to have been regained 150 m downstream of dam 4 as judged from the evenness of the distribution of taxa (Pielou's index), indices of water quality and presence of feeding groups (Table 3, Table 5).

Conclusions

In conclusion, intermittent and ephemeral streams belong to two different types and their fauna differs in structural and functional characteristics and tolerance to drought. Discrimination between these two ecologically different types of temporary stream is crucial to ensure reliable quality assessments and management as the WFD 2000/60 EC demands. As DNP has been a nature reserve since 1980 and a national park since 2003, a thorough study of its streams must be done in the near future in order to build a specific quality evaluation system adapted for these highly variable systems that takes into account their degree of flow temporality.

The small dams built on the ephemeral streams of DNP seemed to affect the water quality and the composition of the invertebrate feeding groups although this impact had already disappeared 150 m downstream one of the studied dams.

The conservation of the intermittent and the ephemeral streams in the DNP is very important since summer pools of the intermittent streams also serve as macroinvertebrate biodiversity refuges, especially in Mediterranean basins (Vidal-Abarca et al. 1996). Moreover, there is a high likelihood that temporary ponds contribute to maintaining the gene pool of species that occur in both temporary and permanent waters (Williams 1997) which may be crucial for their survival in the face of future climate change and poor water management practise in agricultural landscapes.

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Table 5. Percentage of each trophic group of benthic macroinvertebrates upstream and downstream of each dam in March 2005. Downstream dam 4 (1) and downstream dam 4 (2) represent sampling sites 100 m and 150 m, respectively, downstream of the dam.

	Shredder	Predator	Scraper	Collector	Piercer
Upstream dam 2	50.00	37.50	0.00	12.50	0.00
Downstream dam 2	6.25	0.00	6.25	87.50	0.00
Upstream dam 3	25.60	9.74	3.31	40.75	20.55
Downstream dam 3	4.23	54.17	1.59	13.98	1.06
Upstream dam 4	43.80	7.44	4.13	44.63	0.00
Domnstream dam 4	7.94	10.58	9.52	71.96	0.00
Domnstream dam 4 (1)	10.78	16.17	5.99	67.07	0.00
Downstream dam 4 (2)	19.03	9.70	22.76	48.51	0.00
Upstream dam 5	6.31	2.95	2.53	78.87	9.26
Downstream dam 5	5.76	10.91	11.32	77.02	0.00

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