Web Ecology 3: 20–32.

Seasonal variation of the water quality of rivers and streams of eastern Mediterranean

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Lazaridou-Dimitriadou, M. 2002. Seasonal variation of the water quality of rivers and streams of eastern Mediterranean. – Web Ecol. 3: 20–32.

Biotic and abiotic data on undisturbed or moderately disturbed lotic sites from a number of studies carried out in northern Greece showed that large rivers differ from small rivers, streams or creeks in terms of diversity, dominant groups and the kind of taxa (concerning the sensitivity of the taxa according to Biological Monitoring Working Party (BMWP) biotic scores). This is mainly due to the differences in their physical characteristics. Correlation of the environmental variables using MDA (multiple discriminant analysis) showed that the chief differentiating factors among the above water bodies are substrate, total suspended solids (TSS), conductivity, slope and temperature. Additionally, there is no clear phenological seasonality in the majority of the dominant benthic macroinvertebrate groups when undisturbed or moderately disturbed sites of mountainous creeks and small rivers are examined. By contrast, in downstream sites of long rivers, seasonality characterizes the dominant benthic macroinvertebrate groups, as it does for other Mediterranean animals.

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The use of biological methods for monitoring (biomonitoring) the ecological quality of running waters is already a widespread approach in Europe. It provides information on water quality and ecology both before and during sampling, in contrast to chemical approaches which only characterize the water system during sampling (Metcalfe 1989). However, a combination of both approaches, physicochemical and biotic, has been shown to be the most appropriate method for pollution monitoring (Hellawell 1986, Metcalfe 1989, Mason 1991).

Biomonitoring includes both sublethal changes at the cellular or tissue level (Vukmirovic et al. 1994, Cajaraville et al. 1995) and changes in community (Metcalfe 1989, Graca et al. 1989, Castella et al. 1995). The use of changes in community structure for monitoring freshwater pollution, commonly involves benthic macroinvertebrates, because this group is considered as the most appropriate biological indicator of water quality in EU countries (Metcalfe 1989) including Greece (Anagnostopoulou 1992, Anagnostopoulou et al. 1994). Benthic macroinvertebrates are the most appropriate biotic indicators for the following reasons: 1) These organisms are relatively sedentary and are therefore representative of local conditions. 2) Macroinvertebrate communities are very heterogeneous, consisting of representatives of several phyla. The probability that at least some of these organisms will react to a particular change of environmental conditions, is therefore high (De Pauw and Vanhooren 1983, Hellawell 1986, Metcalfe 1989, Mason 1991). Other groups of organisms (fish, phytoplakton, etc) possess some, but not all, of these im-

Accepted 21 January 2002

ISSN 1399-1183

portant attributes. 3) Macroinvertebrates are differentially sensitive to pollutants of various types, and react to them quickly; also, their communities are capable of a gradient response to a broad spectrum of kinds and degrees of stress. 4) Their life spans are long enough to provide a record of environmental quality. 5) Macroinvertebrates are ubiquitous, abundant and relatively easy to collect. Furthermore, their indentificaton and enumeration is not as tedious and difficult as that of microorganisms and plankton.

Greece is one of the EU countries that have no specialized institution to undertake the regular monitoring of running waters. During the last seven years, two large rivers (Aliakmon and Axios) and five small ones (Aggitis, Maurolakkas, Basdekis, Kokkinolakas, and Asprolakas) have been studied in the N. Greece in order to assess an appropriate method for biomonitoring the ecological quality of Hellenic freshwater ecosystems as this is determined by the EU Proposal Directive [Commission of the European Communities COM (1998) 76 final] (Anagnostopoulou 1992, Anagnostopoulou et al. 1994, Copeland et al. 1997, Ford et al. 1998, Langrick et al. 1998, Artemiadou et al. 1999, Drouin et al. 1999, Jennings et al. 1999, Yfantis et al. 1999). The above studies involve the comparative application of several European biotic indices, scores and multivariate statistical methods, to establish a Hellenic biotic index, which would be applied to the special hydrological and climatological conditions in Greece (high temperatures during summer, strikingly variable discharge throughout the year) because the applied European biotic indices and scores do not totally match (Lazaridou-Dimitriadou et al. 2000).

In the present study, various undisturbed sites from the above studies were examined at monthly (Axios and Aliakmon rivers) or seasonal basis (Olympias and Skouries streams) in order to find out the factors affecting macrobenthic community structure in rivers and streams and to investigate seasonal patterns of macroinvertebrate abundance and diversity. For the above comparisons the seasonal physicochemical and benthic macroinvertebrate community structure and abundance were analysed from undisturbed or moderately disturbed sites, one at the upper reaches and the other at the downstream stretch, in two rivers (Aliakmon and Axios) and two streams (Piavitsa-Asprolakkas, Kipouristras) of N. Greece.

Materials and methods

Study area

Available data were limited in this region as is mentioned above. Data available from past studies were used in this review (Ford et al. 1998, Langrick et al. 1998, Bobori and Mourelatos 1999, Drouin et al. 1999, Jenning et al. 1999, Yfantis et al. 1999, Lazaridou-Dimtiriadou et al. 2000).

Skouries and Olympias streams

Skouries and Olympias areas are located on the east coast of Chalkidiki in northern Greece. All streams originate from the Stratonikon mountain range and flow through a mountainous landscape, except for some flat areas close to Olympias town.

Concerning the Olympias area, Kipouristras Creek (which has two sampling stations) flows from south to north in a semi-mountainous area before its confluence with Mavrolakkas River (three sampling stations). The latter follows a west-to-east course and then discharges into the gulf of Strimonikos, ca 1 km north of Olympias town. Within the area of Olympias, agricultural activities are relatively developed and concentrated around the flat regions close to Olympias town (Table 1). These areas also support a number of livestock farms with semi-wild pigs and goats. The main human activities in the area are related to ore mining. These include both old and currently active mine shafts, a mill plant for mineral enrichment and a backfilling plant, which are currently not fully operating, ore (mainly arsenopyrite) stockpiles, waste rock deposits (Platia Fire), an old tailings pond and four settling ponds for the precipitation of metals contained in ground water flowing from the old adits.

The Skouries area, is a mountainous region, is largely covered by forest. Its north side is adjacent to an area protected by “Natura 2000” EU Directive, located in between

Table 1. Physical characteristics and sources of pollution of the sampling stations of Kipouristras stream at Olympias area (OL1and OL4) and Piavitsa (SK1) – Asprolakka (SK4) streams at Skouries area.

Station	Longitude	Latitude	Distance from source (km)	Altitude (m)	Slope (m km^{-1})	Sources
OL1	23°42′	40°34′	3.06	299.92	129.12	Livestock farm
OL4	23°44′	40°36′	7.36	39.99	130.32	Tailing ponds
SK1	23°43′	40°31′	0.10	500.03	76.91	Mn-rich deposits
SK4	23°46′	40°27′	12.4	59.98	29.44	Livestock farm

Olympias and Skouries. At present the main human activities within this study area concern woodcutting, and stock-raising (Table 1). Asprolakkas stream is the main stream that runs through Skouries area and derives from the confluence of Kerasia and Piavitsa creeks.

Aliakmon river
The springs of the river Aliakmon is located in Grammos and Vernon Mountains, in northwestern Greece. It discharges into the gulf of Thermaikos. Upstream sites, located along the main course of the river before the artificial lake of Polyphyto, do not receive significant amounts of pollutants apart from Kostarazi (sewage wastes) and Greveniotis (sewage and industrial wastes). Downstream sites, located in tributaries of the Aliakmon (the rivers Moglenitsas, Edesseos and the drainage channel, Canal 66) are subject to agricultural (pesticides and fertilizers), urban (sewage and detergents) and industrial (mainly fruit and vegetable canneries) sources of pollution (Anagnostopoulou 1992, Kouimtzis et al. 1994). The physical characteristics of the studied sites of this river are shown in Table 2.

Axios river
The river Axios originates in the Sar mountains of the Former Yugoslav Republic of Macedonia (FYROM) and discharges into the Thermaikos Gulf to the south-west of the city of Thessaloniki in northern Greece. Of its total length of 320 km only the last 80 km is within Greek territory and the study area is thus confined to the lower reaches of the river. Catchment land-use is predominantly agricultural and diffuse pollution as a result of soil erosion and pesticide and fertiliser run-off may be expected. Local settlements and industries are small, but pollution loads may also arise due to point source domestic wastewaters (including sewage and detergents), industrial effluents (including textile, slaughterhouse and dairy wastes), and polluted tributaries (carrying agricultural drainage waters). The physical characteristics of the studied sites of this river are shown in Table 2.

Sampling of macroinvertebrates and physicochemical parameters

One sample of benthic macroinvertebrates was taken into consideration from one site at the upper reaches and one site at the downstream stretch of each of the rivers or streams mentioned above. This is clearly shown by the difference in the substrate composition between the two sites at least in the long rivers Aliakmon and Axios (Table 3). Details of the sampling procedure, the treatment of samples, and the measurement of the different physicochemical parameters are given in a previous paper (Lazaridou-Dimitriadou et al. 2000).

Statistical analyses

In order to compare the biotic parameters in the above mentioned lotic systems (rivers and streams), seasonal data (physicochemical data) from an upstream site and a downstream stretch were examined and analysed as well (Tables 5–9). Several criteria had to be met for inclusion of these undisturbed or moderately disturbed sites into the dataset (Jennings et al. 1999): 1) Taxonomic resolution had to be comparable throughout the dataset. This forced the recombining of several species to genus or family level. 2) Each site had to be sampled in at least two seasons (spring and autumn) to lessen the chance of seasonal taxa being missed. 3) Sites had to be relatively unstressed.

Adhering to these criteria we produced a dataset of 24 sites (5 from creeks or streams in Olympias area, 8 from creeks or streams in Skouries area, 9 in the Aliakmon and two in the Moglenitsas river which merges with Aliakmon) from a total of 268 studied sites. Only spring and autumn data were used. A list of 131 taxa was compiled, identified mostly to genus level. Exceptions were Oligochaetes (to

Table 2. Physical characteristics and sources of pollution of the sampling stations of Aliakmon (Grevena and Niseli) and Axios rivers (Euzoni and Anatoliko).

Site	Distance from source (km)	Altitude (m)	Longitude	Latitude	Land use
Aliakmon river					
1 Grevena (G)	116.5	520	21°32′	40°13′	Agricultural runoff and urban wastes
2 Niseli (N)	290	10	22°28′	40°35′	Agricultural runoff and urban wastes
Axios river					
1 Evzoni (E)	1*	40	22°32′	41°05′	Agricultural
2 Anatoliko (A)	64*	5	22°42′	40°39′	Agricultural

*This distance is calculated from the borders with FYROM.

Table 3. Substrate categories (1: >70% bolders, cobbles pebbles, 2: >70% gravel, sand and silt, 3: equally represented) of Evzoni and Anatoliko at Axios river, Grevena and Niseli at Aliakmon river, two sites from Olympias area (OL1 and OL4) and Piavitsa (SK1) – Asprolakka (SK4) streams at Skouries area.

	River stations							
Date	SK1	SK4	OL1	OL4	Evzoni	Anatoliko	Grevena	Niseli
November	3	3	2	2	3	2	3	2
January	3	1	3	3	3	2	3	2
March	3	1	1	3	3	2	3	2
June	3	1	3	3	1	2	3	2
August	3	3	3	2	1	2	3	2

class) and Diptera (to family). Sites and species classified by the clustering FUZZY technique (Equihua 1990), based on fuzzy sets, were used in Multiple Discriminant Analysis (MDA) relating the FUZZY site groupings to their environmental variables. MDA was implemented through the discriminant function of the computer program SPSS (Klecka 1975).

Seasonality

In order to examine whether seasonality affects the phenology of benthic macroinvertebrate community structure the abundance of each benthic taxon (sampled with the three min kick/sweep method) was monthly or seasonally followed at two representative sites, one at the upper reaches and the other in the downstream stretch in each of the mentioned above rivers or streams.

Results

Correlation of site groupings with environmental parameters

MDA was used to attempt to predict the FUZZY groups of sites using environmental data only. The examination of the standardised canonical discriminant functions gave an indication of the importance of the various environmental parameters contributions to the prediction (Table 4).

In the first discriminant function the five most important variables (substrate, total suspended solids (TSS), conductivity, slope and temperature) seemed to be related to the longitudinal positioning of a site on a water course.

Seasonality

In all the Greek rivers and creeks, mainly because of reduced river vegetation, total suspended solids (which according to MDA is one of the most important discriminating environmental variables) increase (Bobori and Mourelatos 1999) after a rainy season or after snow melting or both (Tables 5 and 6). This causes differences in the makeup of biocommunities (Tables 5 and 6). High discharge (in January) are favoured by the sensitive macroinvertebtate groups whereas tolerant macroinvertebrate groups appear in the beginning of spring (Table 10A, B). Nutrients exceed the EU limits in the two studied rivers only during summer (Tables 8 and 9).

In Aliakmon river Plecoptera mainly appear in January, Trichoptera mainly in July–August and then in October. Ephemeroptera, although some genera mainly appear from October to February and others in June (Table 10A), as well as Oligochaeta and Chironomidae, appear all the year round (Fig. 1a, Table 10A). In Axios river there are almost no Plecoptera since Axios represents the last 70 km of its length in the Greek territory. As to the other groups some Trichoptera appear mainly in June, Ephmeroptera appear from June to November, Oligochaeta from January to May, Chironomidae from June to February showing one peak in summer and one in winter (Fig. 1b, Table 10B). On the other hand, in Olympiada and Skouries creeks, all the above groups appear throughout the year, except for Ephemeroptera that peak in June and Oligochaeta that peak in August–November (Table 10C, D).

Comparing the sum of the number of families seasonally, over the months January, March, June, August and November, it is clear that it declines ca 70% from the small

Table 4. Standardized canonical discriminant function coefficients of environmental variables. Only the 10 most influencing parameters are shown and ranked.

Parameters	Coefficients
Minimum dominant particle size	–11.06262
Total suspended solids (mg l^{-1})	11.04113
Conductivity (µS)	9.61441
Slope of site (m km^{-1})	9.59768
Mean water temperature (°C)	–7.02949
Mean substrate type	6.01889
Altitude of site (m)	–5.98196
Mean substrate heterogeneity	4. 82803
Total oxidized nitrogen (mg l^{-1})	3.68229
Maximum water velocity (m s^{-1})	–3.38036

Table 5. Physicochemical parameters of sampling stations (Grevena (G) and Niseli (N)) in Aliakmon river.

Date	Aliakmon river	Oxygen (mg l^{-1})	pH	Temp. (°C)	Conductivity (µS)	TSS (mg l^{-1})	Discharge (m^3 s^{-1})
November	Max.	14.1 (G)	8.19 (G)	11.2 (N)	399 (G)	32.8 (N)	37.1 (N)
	Min.	10.0 (N)	7.86 (N)	4.7 (G)	399 (N)	0.2 (G)	3.2 (G)
Site exceeding the EU values							
January	Max.	11.0 (G)	8.22 (G)	7.8 (N)	426 (G)	148.7 (N)	31.8 (N)
	Min.	10.2 (N)	7.87 (N)	6.5 (G)	368 (N)	103.7 (G)	NM (G)
Site exceeding the EU values					Grevena		
March	Max.	11.8 (G)	8.48 (G)	12.1 (N)	501 (N)	7.5 (N)	3.5 (G)
	Min.	8.9 (N)	8.12 (N)	7.3 (G)	470 (G)	2.7 (G)	3.5 (N)
Site exceeding the EU values					Grevena and Niseli		
June	Max.	9.2 (G)	8.50 (G)	22.9 (G)	503 (N)	34.2 (G)	112.3 (N)
	Min.	8.1 (N)	7.92 (N)	20.3 (N)	377 (G)	8.9 (N)	110.5 (G)
Site exceeding the EU values					Niseli		
August	Max.	7.7 (G)	8.30 (G)	21.5 (N)	516 (N)	39.3 (G)	113.9 (N)
	Min.	NM (N)	7.50 (N)	20.9 (G)	436 (G)	10.9 (N)	1.0 (G)
Site exceeding the EU values					Grevena (G) and Niseli (N)		

(Olympias and Skouries areas) to the large rivers (Aliakmon) and up to 85% from the small to the plain parts of long rivers (Axios river) (Table 10). Additionally, comparing the scores of sensitive or moderately sensitive taxa, with BMWP scores (Chesters 1980) of 10 down to 5, seasonally it is noticed that 80% more sensitive taxa are found in small (as Skouries and Olympias) and large rivers (as Aliakmon) than in the plain parts of long rivers (e.g. Axios river).

Table 6. Physicochemical parameters of sampling stations (Euzoni (E) and Anatoliko (A)) in Axios river.

Date	Axios river	Oxygen (mg l^{-1})	pH	Temp. (°C)	Conductivity (µS)	TSS (mg l^{-1})	Discharge (m^3 s^{-1})
November	Max.	12 (A)	8.22 (A)	7.9 (A)	429 (E)	56.8 (A)	105.8 (E)
	Min.	11.4 (E)	8.07 (E)	7.3 (E)	426 (A)	16.3 (E)	89.3 (A)
Site exceeding the EU limits							
January	Max.	15.2 (E)	7.50 (A)	6.8 (A)	421 (E)	66.0 (A)	125.9 (A)
	Min.	11.4 (A)	7.45 (E)	5.2 (E)	408 (A)	32.8 (E)	59.7 (E)
Site exceeding the EU limits					Evzoni (E) and Anatoliko (A)		
March	Max.	9.6 (E)	8.22 (A)	10.8 (A)	385 (A)	73.3 (E)	58.8 (A)
	Min.	8.2 (A)	8.14 (E)	7.7 (E)	378 (E)	61.5 (A)	45.6 (E)
Site exceeding the EU limits							
June	Max.	15.1 (A)	9.47 (A)	30.2 (A)	1100 (A)	174.4 (A)	61.5 (E)
	Min.	9.4 (E)	8.31 (E)	23.2 (E)	501 (E)	20.8 (E)	–
Site exceeding the EU limits				Anatoliko	Evzoni and Anatoliko		
August	Max.	10.4 (A)	9.00 (A)	25.3 (A)	537 (A)	48.6 (E)	7.2 (E)
	Min.	8.6 (E)	8.16 (E)	21.6 (E)	472 (E)	46.0 (A)	35.7 (A)
Site exceeding the EU limits			Anatoliko	Anatoliko	Evzoni and Anatoliko		

Table 7. Physicochemical parameters of sampling stations at Olympias (OL) and Skouries (SK) areas.

Month	Streams		Oxygen (mg l^{-1})	pH	T (°C)	Conductivity (μS)	Flow (m s^{-1})	Discharge (m^3 h^{-1})
November	OL	Max.	11.7 (OL1)	8.45 (OL1)	10.6 (OL4)	487 (OL4)	0.104 (OL4)	146.4 (OL4)
		Min.	11.6 (OL4)	8.36 (OL4)	7.2 (OL1)	409 (OL1)	0.073 (OL1)	78.9(OL1)
Sites exceeding the EU limits						OL1 and OL4		
	SK	Max.	12.3 (SK4)	8.34 (SK4)	9.4 (SK4)	670 (SK1)	0.292 (SK4)	410.8 (SK4)
		Min.	10.9 (SK1)	7.90 (SK1)	8.8 (SK1)	637 (SK4)	0.062 (SK1)	45.8 (SK1)
Sites exceeding the EU limits						OL1 and OL4		
January	OL	Max.	12.0 (OL4)	8.31 (OL1)	5.4 (OL1)	332 (OL1)	0.136 (OL4)	1154.8 (OL4)
		Min.	11.9 (OL1)	8.03 (OL4)	5.1 (OL4)	281 (OL4)	0.103 (OL1)	216.7 (OL1)
Sites exceeding the EU limits								
	SK	Max.	12.0 (SK4)	8.01 (SK1)	7.0 (SK1)	365 (SK4)	0.244 (SK4)	2100.3 (SK4)
		Min.	10.6 (SK1)	8.06 (SK4)	5.1 (SK4)	350 (SK1)	0.141 (SK1)	475.1 (SK1)
Sites exceeding the EU limits								
March	OL	Max.	12.1 (OL4)	8.40 (OL4)	6.6 (OL4)	386 (OL1)	0.117 (OL4)	355.0 (OL4)
		Min.	11.1 (OL1)	8.05 (OL1)	5.7 (OL1)	385 (OL4)	0.093 (OL1)	139.2 (OL1)
Sites exceeding the EU limits								
	SK	Max.	11.7 (SK4)	8.19 (SK4)	6.8 (SK1)	523 (SK4)	0.205 (SK1)	637.8 (SK4)
		Min.	10.0 (SK1)	7.77 (SK1)	6.8 (SK4)	510 (SK1)	0.107 (SK4)	116.2 (SK1)
Sites exceeding the EU limits						SK1 and SK4		
June	OL	Max.	9.1 (OL1)	8.71 (OL4)	22.5 (OL4)	394 (OL4)	0.154 (OL4)	232.0 (OL4)
		Min.	8.9 (OL4)	8.39 (OL1)	14.4 (OL1)	387 (OL1)	0.076 (OL1)	141.1 (OL1)
Sites exceeding the EU limits				OL4				
	SK	Max.	9.3 (SK4)	8.37 (SK4)	17.1 (SK4)	502 (SK4)	0.053 (SK4)	445.3 (SK4)
		Min.	9.0 (SK1)	8.03 (SK1)	13.7 (SK1)	476 (SK1)	0.043 (SK1)	116.4 (SK1)
Sites exceeding the EU limits						SK1 and SK4		
August	OL	Max.	10.7 (OL1)	8.20(OL1)	26.2 (OL4)	374 (OL4)	0.07 (OL1)	86.2 (OL1)
		Min.	10.3 (OL4)	8.22 (OL4)	16.3 (OL1)	371 (OL1)	0.03 (OL4)	9.6 (OL4)
Sites exceeding the EU limits					OL4			
	SK	Max.	10.2 (SK4)	8.90 (SK1)	20.5 (SK4)	626 (SK1)	0.12 (SK1)	304.8 (SK4)
		Min.	7.8 (SK1)	8.25 (SK4)	17.4 (SK1)	600 (SK4)	0.05 (SK4)	30.4 (SK1)
Sites exceeding the EU limits				SK1		SK1 and SK4		

* OL1 + OL2 from Kipouristra creek.
* SK1 = Piavitsa and SK2 = Asprolakka creek.

Discussion

Concerning the studied sites, the results suggest that the substrate and TSS were found to be the most important in the studied sites in determining community structure. Conductivity, slope and temperature were also found to be highly influential factors. The influence of substrate on macroinvertebrate communities, found as a differentiating factor by MDA, has long been known as such (Hynes 1970). In Greek rivers, discharge is much higher during winter and the beginning of spring whereas conductivity declines. The latter increases in summer, mainly in June, causing a deterioration of biocommunities in summer (June–August). The results of this study vary from others in the strength of chemical parameters as influencing factors on community structure. Wright (1995) found alkalinity to be the most important factor by MDA, whilst Marchant et al. (1994) found a strong pH and conductivity gradient. Such strong gradients are not apparent in this study apart from conductivity. This is likely to be because such parameters are of more use in detecting differences between, rather than along rivers. Wright's (1995) and Marchant's et al. (1994) studies investigated 41 and 9 rivers respectively, whilst this study investigates only 4 systems (Olympias, Skouries, Aliakmon and Moglenitsas). Therefore factors relating to differences between rivers were of less importance in this study.

Concerning the distribution of various taxa along the environmental gradients it is clear that Trichoptera largely show a preference for more diverse, coarser substrates,

Table 8. Nutrients at Axios and Aliakmon river (ND: not detectable).

Date	Stations		N-NO_3 mg l^{-1}	N-NO_2 mg l^{-1}	N-NH_4 mg l^{-1}	P-PO_4 mg l^{-1}
EU permitted values			50	0.1	0. 50	
EU suggested values			25		0. 06	
November	Axios	Max.	0.83 (E)	0.070 (A)	0.003 (E)	0.349 (A)
		Min.	0.42 (A)	ND (E)	ND (A)	0.281(E)
Sites exceeding the EU limits						
	Aliakmon	Max.	0.84 (1N)	0.015 (N)	0.018 (N)	0.032 (N)
		Min.	0.67 (G)	0.006 (G)	ND (G)	0.016 (G)
Sites exceeding the EU limits				Niseli		
January	Axios	Max.	1.34 (E)	0.070 (A)	0.060 (A)	0.700 (E)
		Min.	0.76 (A)	0.050 (E)	0.020 (E)	0.420 (A)
Sites exceeding the EU limits						
	Aliakmon	Max.	1.64 (N)	0.028 (N)	0.088 (N)	0.106 (N)
		Min.	1.60 (G)	0.009 (G)	ND (G)	0.026 (G)
Sites exceeding the EU limits						
March	Axios	Max.	1.24 (E)	0.020 (A)	0.020 (A)	0.129 (E)
		Min.	1.18 (A)	0.010 (E)	ND(E)	0.123 (A)
Sites exceeding the EU limits						
	Aliakmon	Max.	0.97 (N)	0.050 (N)	0.137 (N)	0.160 (N)
		Min.	0.92 (G)	0.006 (G)	ND (G)	0.032 (G)
Sites exceeding the EU limits						
June	Axios	Max.	0.97 (E)	ND (E)	ND (E)	1.661 (E)
		Min.	0.84 (A)	ND (A)	ND (A)	ND (A)
Sites exceeding the EU limits						
	Aliakmon	Max.	0.75 (N)	0.096 (N)	0.015 (N)	0.049 (N)
		Min.	0.65 (G)	0.004 (G)	ND (G)	0.022 (G)
Sites exceeding the EU limits						
August	Axios	Max.	0.89 (E)	0.130 (E)	0.004 (E)	0.616 (A)
		Min.	0.87 (A)	0.100 (A)	ND (A)	0.290 (E)
Sites exceeding the EU limits				Evazoni and Anatoliko		
	Aliakmon	Max.	1.02 (G)	0.008 (G)	ND (G)	0.048 (G)
		Min.	0.04 (N)	0.003	ND (N)	0.019 (N)
Sites exseeding the EU limits						

rather than depositional ones. The Ephemeroptera show a more general distribution, with different taxa showing preferences for both streams and larger river sites. The Potamanthidae were found only in the larger Aliakmon sites, where they live on the sand and gravel. The prosobranch families (especially the Hydrobiidae) were largely confined to turbulent stream sites due to their higher dissolved oxygen requirements (e.g. Skouries and Olympias). Conversely, the pulmonates (Physidae) were found to flourish mainly in the Aliakmon and less in the Axios sites, due to their ability to exploit less turbulent microhabitats.

Concerning seasonality, the study of the two representative sites in each Greek lotic system showed that streams and creeks must be regarded separately from large and long rivers according to the MDA analysis, because these systems differ mainly in their physical characteristics and less on the strength of their chemical characteristics. This can perhaps be explained by the fact that the studied small rivers, here in Greece, run mainly in woody areas and their physical characteristics do not change much along them, so biocommunities do not have to accomodate to striking differences. Whereas in the plain parts of long rivers, as is the case for Axios river, different land uses along them cause differences in the physicochemical parameters. So, the different benthic macroinvertebrate groups flourish at different times of the year, taking advantage of the most favourable conditions for them to fulfill their cycles. Consequently, the evolution of the biocommunity structure in

Table 9. Nutrients at Olympias and Skouries areas (bold values: values exceeding the EU limits).

Date	Station		N-NO_3 mg l^{-1}	N-NO_2 mg l^{-1}	N-NH_4 mg l^{-1}	P-PO_4 mg l^{-1}
EU permitted value			50	0.1	0.50	–
EU suggested value			25	–	0.05	–
November	Olympias	Max.	0.35 (OL4)	0.007 (OL1)	0.002 (OL1)	0.517 (OL4)
		Min.	0.29 (OL1)	0.006 (OL4)	0.001 (OL4)	0.002 (OL1)
Sites exceeding the EU limits						
	Skouries	Max.	0.59 (SK1)	0.001 (SK4)	0.003 (SK4)	0.085 (SK1)
		Min.	0.47 (SK4)	0.000 (SK1)	0.002 (SK1)	0.082 (SK4)
Sites exceeding the EU limits						
January	Olympias	Max.	0.44 (OL4)	0.003 (OL4)	**0.073** (OL4)	0.051 (OL1)
		Min.	0.31 (OL1)	0.002 (OL1)	0.011 (OL1)	0.045 (OL4)
Sites exceeding the EU limits					OL4	
	Skouries	Max.	0.36 (SK4)	0.002 (SK1)	0.010 (SK1)	0.059 (SK1)
		Min.	0.21 (SK1)	0.002 (SK4)	0.001 (SK4)	0.055 (SK4)
Sites exceeding the EU limits						
March	Olympias	Max.	0.41 (OL1)	0.003 (OL1)	0.002 (OL1)	0.095 (OL1)
		Min.	0.25 (OL4)	0.003 (OL4)	0.002 (OL4)	0.048 (OL4)
Sites exceeding the EU limits						
	Skouries	Max.	0.32 (SK1)	0.004 (SK1)	0.008 (SK1)	0.109 (SK1)
		Min.	0.03 (SK4)	0.004 (SK4)	0.002 (SK4)	0.079 (SK4)
Sites exceeding the EU limits						
June	Olympias	Max.	0.31 (OL4)	0.004 (OL1)	0.017 (OL1)	0.198 (OL4)
		Min.	0.25 (OL1)	0.003 (OL4)	0.016 (OL4)	0.164 (OL1)
Sites exceeding the EU limits						
	Skouries	Max.	0.30 (SK4)	0.004 (SK1)	0.016 (SK1)	0.212 (SK4)
		Min	0.21 (SK1)	0.004 (SK4)	0.013 (SK4)	0.132 (SK1)
Sites exceeding the EU limits						
August	Olympias	Max.	0.59 (OL4)	0.000 (OL1)	**0.090** (OL4)	0.200 (OL4)
		Min.	0.50 (OL1)	0.000 (OL4)	**0.057** (OL1)	0.100 (OL1)
Sites exceeding the EU limits					OL1 and OL4	
	Skouries	Max.	0.88 (SK4)	0.000 (SK1)	**0.054** (SK1)	0.100 (SK1)
		Min.	0.33 (SK1)	0.000 (SK4)	**0.054** (SK4)	0.100 (SK4)
Sites exceeding the EU limits					SK1 and SK4	

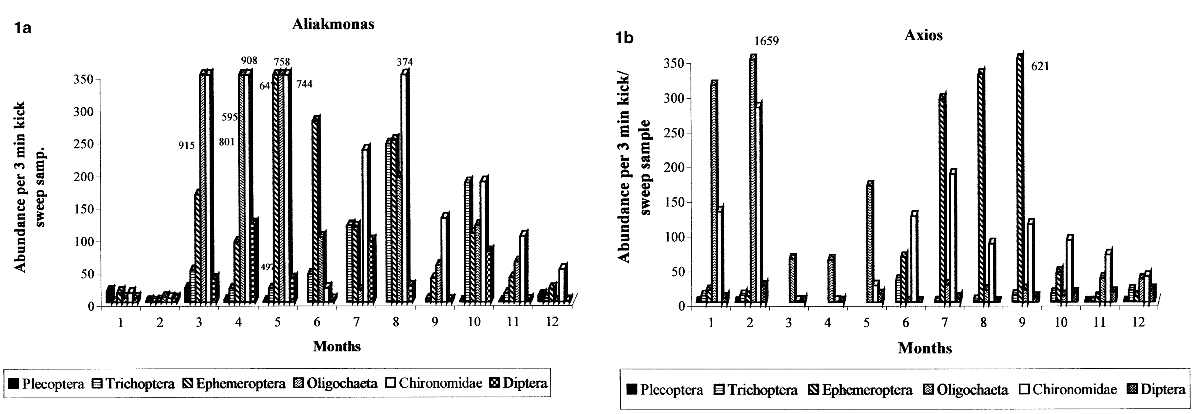

Fig. 1. Monthly fluctuations of the abundance of the benthic macroinvertebrate groups in two sites in Aliakmon (a) and Axios (b) river.

Table 10. Percentages of the taxa at Aliakmon River (Grevena + Niseli) (A), Axios river (B), Olympias area (C), Skouries area (D). Other taxa may be Odonata, Coleoptera, Hemiptera, Hirudinea, Amphipoda, Isopoda or/and Crustacea. (A: number of families, B: number of genera, C: dominant taxa).

A: Aliakmon river (Grevena + Niseli).

Main groups	January			March		
	A	B	C	A	B	C
Ephemeroptera	6	6	*Potamanthus* sp. 8.5% *Baetis* sp. 2.85% *Ecdyonurus* sp. 2.13%	7	9	*Baetis* sp. 4.88%
Plecoptera	2	3	*Rhabdiopteryx* sp. 13.52% *Taeniopteryx* sp. 3.91%	2	3	*Rhabdiopteryx* sp. 0.96%.
Trichoptera	1	1	*Hydroptila* sp. 1.09%.	4	5	*Hydropsyche* sp. 1.53%
Diptera	7		Rhagionidae 1.78% Dolichopodidae 1.78%	8		Simuliidae 0.83% Ceratopogonidae 0.71%
Chironomidae			14.95%			40%
Oligochaeta			7.1%			45.07%
Gastropoda (Pulmonata)	1	1	*Lymnaea* sp. 7.83%	1	1	*Physa* sp. 0.33%
Gastropoda (Prosobranchia)						
Other taxa	5	5	Elminthidae 24.55%	5	5	Coenagriidae 0.067%
Total	22			27		

	June			August		
	A	B	C	A	B	C
Ephemeroptera	5	7	*Baetis* sp. 43.9% *Ephemerella* sp. 6.08% *Ecdyonurus* sp. 4.21%	7	10	*Ecdyonurus* sp. 8.92% *Baetis* sp 5.46% *Caenis* sp 3.64%
Plecoptera				2	2	*Leuctra* sp. 0.34%
Trichoptera	7	8	*Psychomyia* sp 6.9%.	4	5	*Cheum/psyche* sp 13.05% *Hydropsyche* sp. 3.03% *Psychomyia* sp. 3.11%.
Diptera	3		Tipulidae 0.41% Simuliidae 0.28%	5		Tabanidae 0.71% Athericidae 0.76%
Chironomidae			4.35%			29.59%
Oligochaeta			20.73%			15.19%
Gastropoda (Pulmonata)	1	1	*Physa* sp. 4.59%	1	1	*Physa* sp. 0.029%
Gastropoda (Prosobranchia)						
Other taxa	4	5	Haliplidae 3.25% Corixidae 1.52%	4	5	Elminthidae 13.4%
Total	20			23		

	November		
	A	B	C
Ephemeroptera	5	5	*Caenis* sp. 2.71% *Potamanthus* sp. 6.22%
Plecoptera	2	2	*Taeniopteryx* sp. 0.87% *Leuctra* sp. 0.87%
Trichoptera	4	4	*Psychomyia* sp. 2.1%
Diptera	3		Ceratopogonidae 0.26% Tabanidae 0.26% Tipulidae 0.087%
Chironomidae			26.62%
Oligochaeta			16.11%
Gastropoda (Pulmonata)			
Gastropoda (Prosobranchia)			
Other taxa	5	5	*Asellus* sp. 41.33%
Total	19		

Table 10. Continued.

B: Axios river (Evzoni site + Anatoliko site).

Main groups	January A	B	C	March A	B	C
Ephemeroptera	3	3	*Caenis* sp. 3.35%			
Plecoptera	1	1	*Rhabdiopteryx* sp. 0.03%			
Trichoptera	2	2	*Hydropsyche* sp. 1.71%			
Diptera	6		Simuliidae 0.91%	1		Dolichopodidae 0.4%
Chironomidae			26.38%			2.03%
Oligochaeta			63.04%			74.8%
Gastropoda (Pulmonata)	1	1	*Physa* sp. 0.87%	2	2	*Physa* sp. 2.44%
Gastropoda (Prosobranchia)	1	1	Hydrobiidae 0.07%	1	1	Hydrobiidae 15.45%
Other taxa	3	3	*Gammarus* sp. 3.42%	1	1	*Gammarus* sp. 4.06%
Total	17			5		

	June A	B	C	August A	B	C
Ephemeroptera	4	5	*Canis* sp. 24.26%	3	5	*Caenis* sp. 68.86%
Plecoptera						
Trichoptera	1	1	*Hydropsyche* sp. 14.11%	2	2	*Hydroptila* sp. 0.37%
Diptera				1		Scatopsidae 0.07%
Chironomidae			54.70%			18.89%
Oligochaeta			0.3%			3.88%
Gastropoda (Pulmonata)			–	1	1	*Physa* sp. 0.15%
Gastropoda (Prosobranchia)			–			
Other taxa	3	3	Gomphidae 0.59% Mysidacea 0.59%	3	4	Gomphidae 0.15%
Total	8			10		

	November A	B	C
Ephemeroptera	2	2	*Caenis* sp. 19.11%
Plecoptera			
Trichoptera	2	2	*Hydropsyche* sp 20.94%.
Diptera	3		Tipulidae 3.67%
Chironomidae			31.34%
Oligochaeta			15.9%
Gastropoda (Pulmonata)	1	1	*Physa* sp. 0.15%
Gastropoda (Prosobranchia)			
Other taxa	3	3	Gomphidae 0.46%
Total	11		

Table 10. Continued.

C: Olympiada Stream (OL1 + OL4).

Main groups	January A	January B	January C	March A	March B	March C	June A	June B	June C	August A	August B	August C
Ephemeroptera	5	9	*Caenis* sp. 16.37% *Ephemera* sp. 8.44% *Batis* sp. 5.65% *Ecdyonurus* sp. 2.81% *Heptagenia* sp. 1.54%	6	10	*Baetis* sp. 12.59% *Caenis* sp. 8.99% *Ephemera* sp. 4.02% *Ecdyonurus* sp. 1.98% *Paraleptophlebia* sp. 0.75%	6	8	*Ephemera* sp. 13.58% *Caenis* sp. 9.12% *Ecdyonurus* sp. 3.99% *Ephemerella* sp. 3.69% *Habrophlebia* sp. 2.07%	5	8	*Caenis* sp. 22.83% *Heptagenia* sp. 2.94% *Ephemera* sp. 2.42% *Ecdyonurus* sp. 1.33% *Baetis* sp. 3.23%
Plecoptera	3	5	*Leuctra* sp. 3.01% *Brachyptera* sp. 3.52% *Protonemura* sp. 1.28% *Amphinemura* sp. 1.28%	4	5	*Amphinemura* sp. 1.43% *Protonemura* sp. 1.07% *Brachyptera* sp. 0.99 %	1		*Leuctra* sp. 6.62%	2	3	*Leuctria* sp. 10.15%
Trichoptera	10	11	*Hydropsyche* sp. 2.09% Limnephilida 0.59% *Sericostoma* sp. 0.6%	10	12	*Hydropsyche* sp. 2.43% *Sericostoma* sp. 0.55%	8		*Hydropsyche* sp. 1.65%	7	8	*Hydropsyche* sp. 0.81%
Diptera	10		Athericidae 2.75% Simuliidae 13.91%	9		Simuliidae 6.83% Ceratopogonidae 1.91% Athericidae 1.01%	6		Simuliidae 3.66%	9		Athericidae 4.44% Simuliidae 3.57%
Chironomidae			22 %			42.20%			34.55%			9.46%
Oligochaeta			5.75%			1.03%			3.03%			1.85%
Gastropoda (Pulmonata)	2	2	Ancylidae 0.13%				1	1	*Lymnaea* sp. 0.127%	1	1	*Lymnaea* sp. 0.17%
Gastropoda (Prosobranchia)	1	1	Hydrobiidae 0.04%			Hydrobiidae 0.18%			Hydrobiidae 0.81			Hydrobiidae 1.09%
Other taxa	4	4	Elminthidae 1.92%			Elminthidae 1.75%	4	5	Elminthidae 4.84% *Gammarus* sp. 3.27%	5	5	*Gammarus* sp. 4.44% Gomphidae 1.15%
Total	33			29			26			29		

	November A	November B	November C
Ephemeroptera	5	8	*Caenis* sp. 38.28%, *Ephemera* sp. 4.02%, *Baetis* sp .2.46%
Plecoptera	2	3	*Leuctra* sp. 7.74%
Trichoptera	7	9	*Sericostoma* sp. 0.62%, *Psychomyia* sp. 0.59%
Diptera	9		Ceratopogonidae 10.84%, Athericidae 2.64%
Chironomidae			13.6%
Oligochaeta			7.67%
Gastropoda (Pulmonata)	1	1	*Lymnaea* sp. 0.07%
Gastropoda (Prosobranchia)	1	1	Hydrobiidae 0.44%
Other taxa	4	4	Elminthidae 7.69%
Total	29		

Table 10. Continued.

D: Skouries stream (SK1 + SK4).

Main groups	January A	January B	January C	March A	March B	March C	June A	June B	June C	August A	August B	August C
Ephemeroptera	5	9	*Caenis* sp. 15.77% *Baetis* sp. 7.94% *Ecdyonurus* sp. 7.83% *Ephemera* sp. 7.19%	5	10	*Baetis* sp. 7.96% *Caenis* sp. 5.56% *Ecdyonurus* sp. 5.35% *Ephemera* sp. 1.3% *Heptagenia* sp. 1.21%	6	10	*Baetis* sp. 10.35% *Caenis* sp. 7.89% *Ephemerella* sp. 6.59% *Ecdyonurus* sp. 4.66% *Ephemera* sp. 2.28%	5	10	*Caenis* sp. 1.94%
Plecoptera	3	4	*Leuctra* sp. 10.58%	7	9	*Protonemura* sp. 3.19%	3	3	*Leuctra* sp. 1.93%	3	3	*Leuctra* sp. 8.1%
Trichoptera	7	9	Limnephilidae 1.55% *Hydropsyche* sp. 2.01% *Sericostoma* sp. 1.16%	11	14	*Hydropsyche* sp. 2.52% Limnephilidae 0.82% *Agapetus* sp. 1.3%	7	8	*Hydropsyche* sp. 2.02%	8	11	*Hydropsyche* sp. 3.66%
Diptera	9		Athericidae 1.37%	7		Empididae 2.16% Simuliidae 1.43%	7		Simuliidae 2.73% Athericidae 2.02%	5		Athericidae 3.67%
Chironomidae			14.49%			22.67%			5.83%			20.95%
Oligochaeta			0.56%			0.76%			0.58%			2.78%
Gastropoda (Pulmonata)							1	1	*Ancyllus* sp. 0.13%	1	1	*Ancyllus* sp. 0.06%
Gastropoda (Prosobranchia)	1	1	Hydrobiidae 0.21%			Hydrobiidae 0.03%						
Other taxa	5	6	*Gammarus* sp. 13.97%	4	6	*Gammarus* sp. 29.15% Elminthidae 3.13%	5	5	*Gammarus* sp. 44.33%			*Gammarus* sp. 37.92% Elminthidae 4.02%
Total	30			34			29			22		

	November A	November B	November C
Ephemeroptera	5	9	*Caenis* sp. 36.65% *Ephemera* sp. 4.11%
Plecoptera	2	5	*Leuctra* sp. 6.089%
Trichoptera	9	12	*Hydropsyche* sp. 4.73%
Diptera	8		Athericidae 3.82%
Chironomidae			7.8%
Oligochaeta			5.59%
Gastropoda (Pulmonata)			
Gastropoda (Prosobranchia)	1	1	Hydrobiidae 0.2%
Other taxa	5	6	*Gammarus* sp. 8.76%, Elmintyhidae 9.5%, Gomphidae 8.12%
Total	30		

the small rivers, streams or creeks is free of distinct seasonality in phenology for 50% of dominant benthic macroinvertebrate groups. In the plain parts of large rivers, however, seasonality characterizes all the groups as happens with other animal groups in the Mediterranean region (Argyropoulou et al. 1993, 1994, Stamou et al. 1993). Accordingly, in Axios Ephemeroptera and Chironomidae peak at the same time (June–November) whereas Oligochaeta, that occupy almost the same habitat with Chironomidae, peak from November to June when water quality is poor mainly due to TSS.

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