Ecological quality of the River Axios (N. Greece) during spring and summer, 1997

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ABSTRACT. This study examines the applicability of five European biotic indices combined with the measurements of physicochemical parameters in order to determine the water quality at ten sites along the Greek part of the river Axios during the high flow (spring) and low flow season (summer) in 1997. The river Axios is situated in northern Greece, west of the city of Thessaloniki. Its source is located in the Former Yugoslavian Republic of Macedonia close to the city of Skopia. The Greek part of the river Axios receives mainly agricultural runoff but also urban sewage and industrial wastes. The following physicochemical parameters were measured in situ : substrate, flow, water temperature, pH, concentration and percentage saturation of dissolved oxygen, BOD_5, conductivity and total dissolved solids. Total suspended solids, orthophosphates, nitrate, nitrite and ammonia were measured in vitro. The benthic macroinvertebrates, sampled with the 3 min kick/sweep method, were identified to the lowest possible taxonomic level. Three British and two Iberian biotic indices were applied. The data were analyzed with Twinspan, Fuzzy, Canonical Correspondence Analysis and Discriminant Analysis. The faunal composition was typical of a lowland river, i.e. the zoobenthos was not very diverse. The quality of the water was influenced by human activities during both seasons. The deterioration in water quality during spring was due to excess suspended solids of diffuse agricultural origin, and during summer was due to organic pollution. Lower discharge and impoundment accentuated this deterioration. Overall, changes in physicochemical parameters were in agreement with the results of the biological data, despite their instant nature. However, some problems arose with regard to the applicability of the European biotic indices, thus emphasizing the need to develop a Greek Biotic Index.

KEY WORDS : biomonitoring, macroinvertebrates, Axios.

INTRODUCTION

The European Union has obliged member states to establish national freshwater monitoring networks [EU Proposal Directives C184/20/17.6.97 and COM(98)76 final (17.02.1998)]. In Greece there is as yet no such national or regional monitoring network. The combination of chemical and biological methods constitutes the best approach for an integrated assessment of freshwater quality. Benthic macroinvertebrates are considered the best biological indicators of water quality in EU countries (METCALFE, 1989), including Greece (ANAGNOSTOPOULOU et al., 1994) and their responses to organic pollutants have been used to develop contemporary biotic indices (METCALFE, 1989).

The river Axios originates in the Former Yugoslavian Republic of Macedonia (FYROM). It discharges into the Thermaikos Gulf in northern Greece. Only the last 80km of its total 320km are within Greek territory (ARGIROPOULOS, 1991). At 49 km from the border, there is an irrigation dam (Fragma Ellis), which remains closed from May to September. Due to the closure of the dam, discharge falls to 1 m^3/s during the dry season (ARGIROPOULOS, 1991). Catchment land use is predominantly agricultural. Urban and industrial effluents are discharged into the river mainly in the vicinity of Axioupoli-Polykastro and Koufalia. It should also be kept in mind that there is an unknown pollution load coming in from FYROM. Additionally, significant sand extraction is carried out at several points. An integrated water quality assessment of the Axios was carried out at 4 sites in February, April and May 1997 (LANGRICK et al., 1998) and at 10 sites during the low flow season in 1998 (DROUIN et al., 1999).

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This paper examines the relationship between the physicochemical characteristics, water quality and macroinvertebrate benthos of the river Axios during high and low flow conditions (May and July 1997). The use of the biota to predict Axios water quality is also evaluated.

MATERIAL AND METHODS

Ten sampling sites along the Greek part of the river course were chosen for their proximity to known sources of pollution (Fig.1). In July, sites Gorgopis and Anthofito were dry and, therefore, were not sampled. Three samples of benthic macroinvertebrates were taken at each site with the 3-min kick-sweep method (ARMITAGE & HOGGER, 1994). Substrate type and 13 physicochemical parameters were measured; five European biotic indices and four methods of statistical analyses were applied. For details of the materials and methods used in this study, see LAZARIDOU-DIMITRIADOU et al. (2000). In addition to the statistical methods CANOCO and FUZZY applied as described in LAZARIDOU-DIMITRIADOU et al. (2000), Twinspan and Discriminant Analysis were used. Twinspan classification arranges site groups into a hierarchy on the basis of their taxonomic composition (MASON, 1991). Discriminant analysis was used to identify the discriminating environmental variables among the given Fuzzy groups and to state whether the actual groups coincide with the predicted ones.

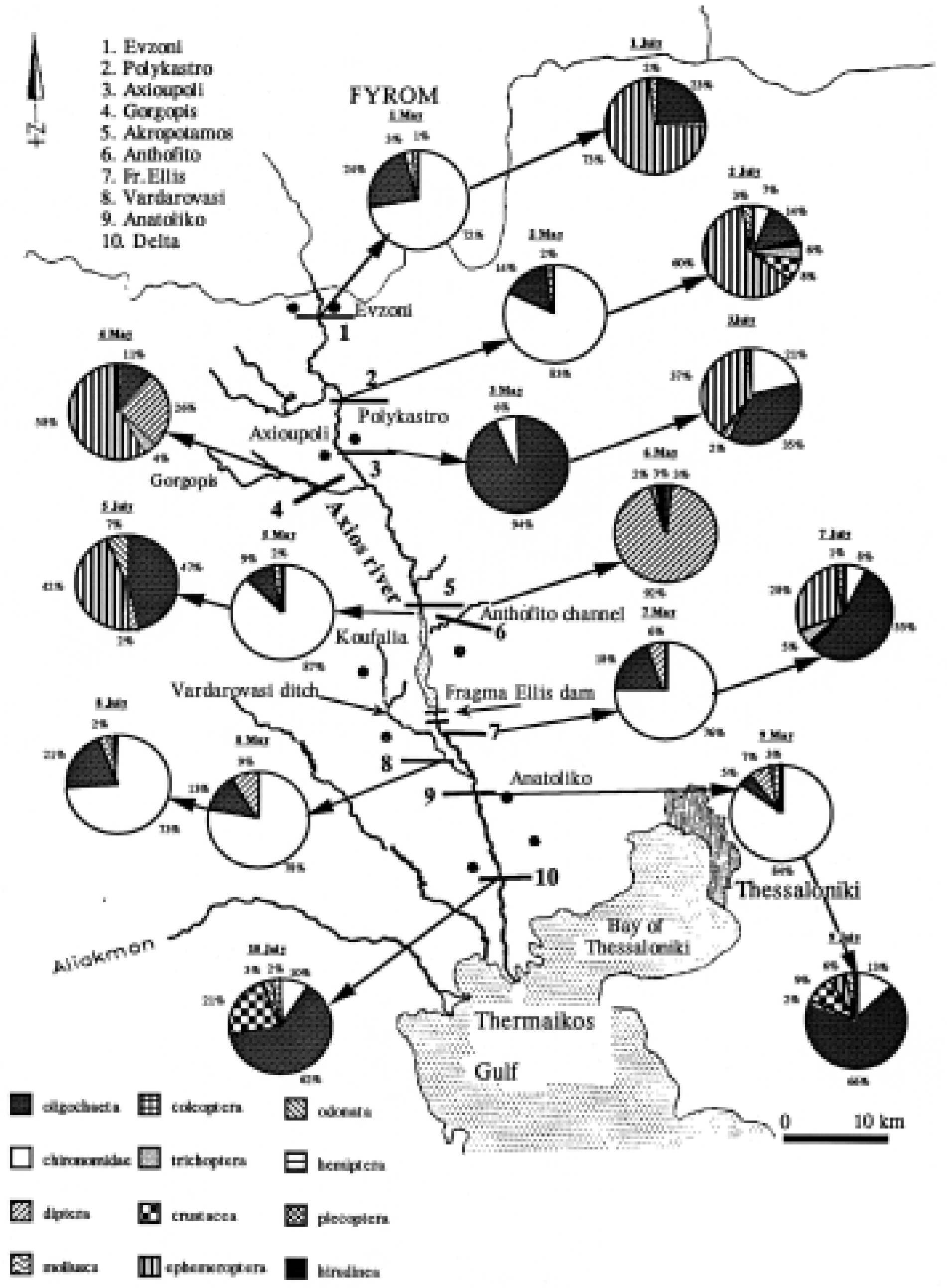

Fig 1. – Study area, sampling sites along the Axios river and their benthic macrofauna in May and July 1997.

RESULTS

Physicochemical parameters

In May, all sites except for Gorgopis and Anthofito were characterized by silty substrate. In July, the substrate was more differentiated than in May. Physicochemical data are presented in Table 1. Flow velocity appeared lower in May than in July because, during the flood, flow was measured, at most sites, close to the bank side as the middle of the river was not easily accessible. Temperature was higher in July and increased downstream on each sampling occasion, reflecting diurnal fluctuations. pH was quite alkaline and in July exceeded the E.U. suggested values for drinking water (80/778/EU) at many sites. BOD_5 was very elevated at all sites in May and mainly at three sites (Fragma Ellis, Anatoliko and Delta) in July. Dissolved oxygen values were slightly higher in July than in May. On both sampling occasions, dissolved oxygen was significantly lower at site Vardarovasi. Conductivity values exceeded the E.U. suggested value (80/778/EU) at Anthofito in May and at all sites in July. Total suspended solids were significantly higher in May while in July they were elevated only at site Fragma Ellis because of sand extraction carried out upstream of the site. All nutrients appeared quite elevated in July compared to May values. Nitrites were present in high concentrations in July at Vardarovasi and Anatoliko and nitrates at Axioupoli, Anatoliko and Delta. Ammonia exceeded the E.U. permitted value (80/778/EU) at Vardarovasi during both seasons. In comparison with the results of this study, the concentrations of nutrients were lower in July 1998 (Drouin et al., 1999).

TABLE 1

Physicochemical parameters at ten sites on the river Axios in May and July 1997. Where: DO= dissolved oxygen, TDS= total dissolved solids, TSS= total suspended solids, ND= not detectable

Sites	BOD_5 mg/l	DO %sat	DO mg/l	Flow m/s	T °C	pH	Cond. µS	TDS mg/l	TSS mg/l	$N\text{-}NO_3$ mg/l	$N\text{-}NO_2$ mg/l	$N\text{-}NH_3$ mg/l	$P\text{-}PO_4$ mg/l
1 May	6,12	99	10,4	0,172	13	8,05	287	143	166,3	0,79	0,01	ND	0,047
2 May	4,51	91	9,3	0,126	14	8,07	292	146	194,1	0,34	ND	ND	ND
3 May	5,94	103	10,5	0,299	14	8,01	290	145	186,9	0,76	0,02	0,01	0,05
4 May	3,36	93	8,6	0,541	19	8,36	338	169	6,93	0,49	ND	ND	ND
5 May	7,67	79	7,9	0,133	15	8,07	298	149	189,7	0,71	ND	ND	0,3
6 May	4,54	90	8,2	0,352	20	8,51	914	458	3,67	0,1	ND	ND	ND
7 May	3,62	73	7,1	0,21	15	8,12	299	150	53,07	0,77	0,01	0,01	0,039
8 May	15,4	5	0,1	0	17	7,7	2,56	1,26	193,8	ND	ND	1,73	0,19
9 May	3,62	103	9,6	0,082	16	8,09	303	152	70,17	0,75	0,01	0,02	0,048
10 May	4,68	92	9,6	0,167	16	8,27	308	154	102,3	1,45	ND	ND	ND
1 July	1,7	107	9,7	0,667	20	8,57	543	272	19,33	2,61	ND	ND	0,57
2 July	2,6	124	10,8	0,635	21	8,82	598	298	21,33	2,84	ND	ND	0,7
3 July	1,75	120	10,3	0,383	22	8,95	610	306	21,66	3,78	0,03	ND	0,01
5 July	2,7	133	11,4	0,515	23	9	597	297	43,9	2,54	0,03	ND	0,011
7 July	3,3	139	12,1	0,58	22	9,16	616	289	125,1	1,46	0,04	ND	1,01
8 July	2,77	82	7	0,216	24	7,81	820	410	13,17	2,26	0,14	1,28	0,02
9 July	6,25	148	12,1	0,355	24	9,6	563	284	52,63	5,58	0,15	ND	0,94
10 July	6,27	154	12,5	0,344	25	9,65	783	394	64,9	5,98	0,04	ND	0,56

Biotic Indices and scores

Biotic scores and indices are presented in Table 2. Water quality was characterized as better in July than in May by all scoring systems. In May, Gorgopis was notable for its high score and characterized as of "excellent" water quality by the LQI (Class I in the Iberian system). All remaining sites in May had "very poor" to "moderate" water quality (Class IV and V). Sites in July were of "moderate/good" water quality (class II, III, IV and V) while site Fragma Ellis had "excellent" water quality (Class II).

Benthic macroinvertebrates

Over 11500 individuals were sampled at the ten sites. In May, the benthic community consisted mostly of Oligochaeta, the dipteran family Chironomidae, while other families of Diptera, Coleoptera, Odonata and Hemiptera were present in smaller numbers (Fig. 1). No pollution-sensitive taxa (BMWP score 7-10) were collected. The benthic community at Gorgopis consisted of 3290 individuals belonging mainly to the Ephemeroptera (58%) and consisting mostly of *Ephemerella* sp. and *Baetis* sp., Diptera (26%) and Trichoptera. Gorgopis was the only site where Plecoptera were collected. At Anthofito the percentage occurrence of Diptera (Simuliidae pupae) was very high (92%). In July, the benthic community was more diverse than in May and mainly consisted of Ephemeroptera (*Baetis* sp. and *Caenis* sp.), Chironomidae, Trichoptera (mainly *Hydropsyche* sp. and *Ceraclea* sp.), Odonata and Amphipoda. The dipteran family Chironomidae and the order Mysidacea constituted

TABLE 2

Biotic scores and indices at 10 sites on the river Axios in May and July 1997 sites

Sites	Abund	High-score	Low-score	BMWP	ASPT	Lincoln Quality Index			IBMWP	Class	IASPT
						O.Q.I.		Inter-pretation			
1 May	231	0	2	18	3,6	3	E	Moderate	16	IV-V	3,2
2 May	102	0	2	14	3,5	2,5	F	Poor	12	IV-V	3
3 May	242	0	2	8	2,66	1,5	H	Very poor	10	IV-V	2,5
4 May	3290	6	3	109	5,7	5,5	A+	Excellent	125	I	5
5 May	116	0	2	19	3,8	3	E	Moderate	21	IV-V	3,5
6 May	105	0	2	10	3,33	2,5	F	Poor	10	IV-V	3,33
7 May	33	0	2	8	2,66	1,5	H	Very poor	8	V	2,66
8 May	763	0	2	3	1,5	1	I	Very poor	11	IV-V	2,75
9 May	395	0	2	23	3,83	3	E	Moderate	21	IV-V	3
1 July	1176	3	2	46	5,11	4	C	Good	41	III	4,55
2 July	1184	4	5	91	5	4,5	B	Good	90	II	4,74
3 July	182	2	3	44	4,4	4	C	Good	47	III	3,92
5 July	45	2	1	26	5,2	3,5	D	Moderate	27	IV	4,5
7 July	275	5	5	92	5,41	5	A	Excellent	82	II	4,82
8 July	2502	0	5	31	3,44	3	E	Moderate	33	III-IV	3
9 July	429	2	2	43	4,77	4,5	B	Good	42	III	3,82
10 July	441	1	2	38	4,75	4,5	B	Good	36	III-IV	4,5

a significant part of the benthic community at the Delta site and Anatoliko. In general, more pollution-sensitive taxa were present at the upstream sites, whereas at the downstream sites (6-10) tolerant taxa were dominant, similarly to the study in the summer of 1998 (Drouin et al., 1999). Vardarovasi contained a quite different macroinvertebrate benthic community, consisting mainly of Oligochaeta, Chironomidae, *Cloeon dipterum* (Ephemeroptera), that prefers eutrophic waters (Elliot et al., 1988), plus a few Gastropoda, Coleoptera and Diptera. At site Delta in May, no benthic macroinvertebrates were sampled.

Statistical analyses

Fuzzy analysis produced three clusters on the basis of the benthic community (Fig. 2). These clusters separate July sites and Gorgopis of 'good'/'excellent' water quality from May sites of 'poor'/'very poor' water quality. Site Anthofito in May constituted a cluster on its own. Twinspan classification of the sites was, in general, in agreement to Fuzzy clustering. According to CANOCO, July sites and high-scoring taxa were placed on the left side of the diagram correlated to flow and pH, which characterized the first axis (Fig. 3). May sites and low-scoring

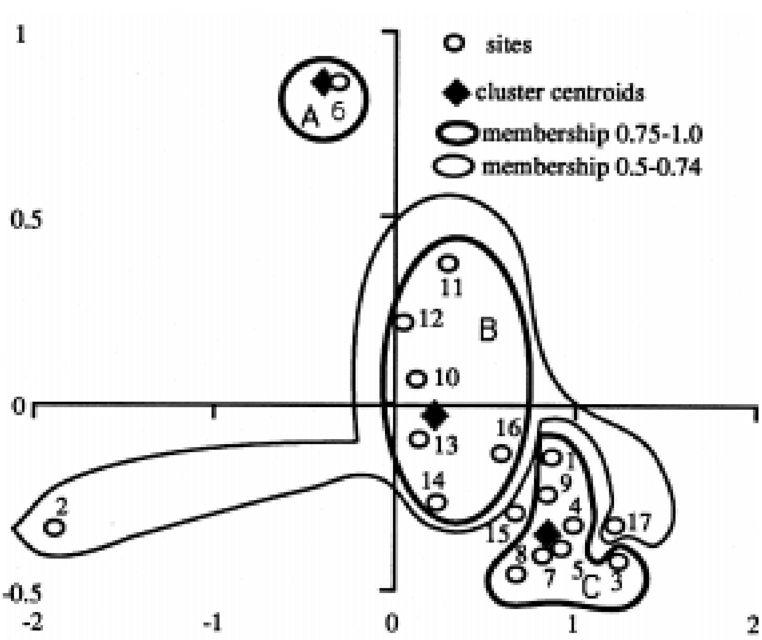

Fig 2. – Clustering of sites along the Axios in May and July 1997 according to Fuzzy analysis.

The characteristics of the analysis are:

partition coefficient	.6999
membership sum of squares:	
between	.00196/within 1.17198
eigenvalues	.451/.456/.391/.289
no.of sites	17
no.of taxa	67
no.of clusters	3
tranformation	ln(x+1)
axes	c-means(5)
norm	diagonal
convergence criterium	.00010000

Where: 1. Evzoni May, 2. Gorgopis May, 3. Axioupoli May, 4. Polykastro May, 5. Akropotamos May, 6. Anthofito May, 7. Fr. Ellis May, 8. Vardarovasi May, 9. Anatoliko May, 10. Evzoni July, 11. Axioupoli July, 12. Polykastro July, 13. Akropotamos July, 14. Fr. Ellis July, 15. Vardarovasi July, 16. Anatoliko July, 17. Delta July.

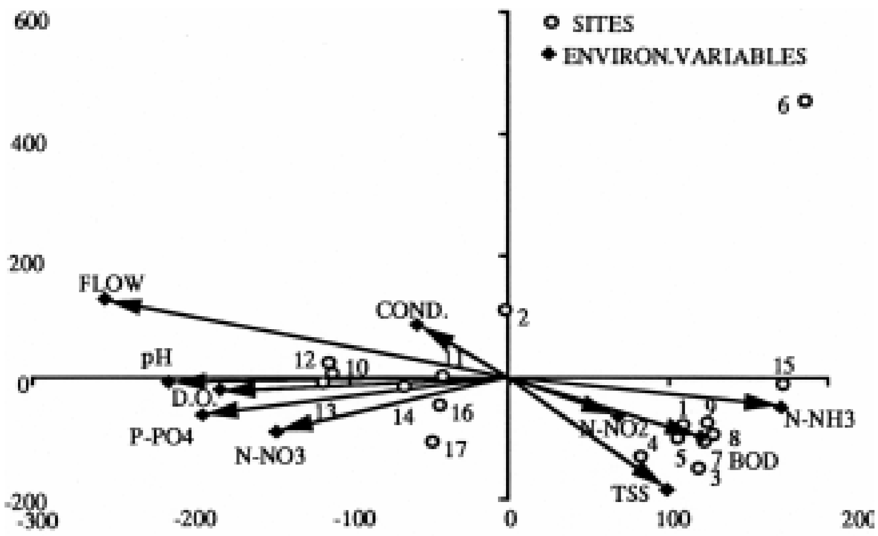

Fig. 3. – Ordination of sampling sites and environmental variables along the river Axios in May and July 1997 according to CANOCO. The characteristics of the analysis are:

axes	1	2
eigenvalues	.357	.330
species-environ.correlation	.988	.965
cumulative percentage:		
variance of species data	19.0	36.6
of species-environ.relation	23.3	44.9

The Interset correlations of the environmental variables with axes are:

axes	1	2
BOD	.3975	-.3227
DO	-.5968	-.0719
pH	-.7053	-.0323
conduct.	-.1896	.2668
tss	.3287	-.5953
flow	-.8354	.4063
N-NO3	-.4817	-.2930
N-NO2	.2275	-.2103
N-NH3	.5644	-.1618
P-PO4	-.6326	-.2016

taxa were placed on the right side of the diagram correlated to TSS and BOD_5, which characterized the second axis. Vardarovasi in both seasons was correlated to ammonia. Discriminant analysis confirmed the Fuzzy clustering, but the unusually high value of the discriminant coefficient (100%) may be due to the small sample of sites processed. According to the pooled within-groups correlations, site Anthofito constituted a separate group because of its high conductivity. Vardarovasi in July was outgrouped mainly because of its low flow and pH. Finally, July and May sites were separated due to differences in TSS and temperature values.

DISCUSSION

The macroinvertebrate benthos in the 10 stations along Axios during the high and low flow season of 1997 was, in general, not very diverse due partly to the typically lowland character of the river stretch, but also resulting from anthopogenic effects. Physicochemical characteristics, biotic indices and statistical analyses indicated poor water quality in spring and moderate to good quality in summer. In the high flow season, lower quality was due to diffuse pollution in the form of suspended solids along the main river course, concentrations of which were well above current E.U. guidelines for waters capable of supporting cyprinids (78/659/EU). The same kind of pollution was detected along the main course of the Axios in April and May 1997 during a study of monthly water quality assessment of only four stations (Langrick et al., 1998). Heavy rainfall and the lack of aquatic and bankside vegetation led to excessive flooding of the river and to the transport of suspended solids into the Axios, which were consequently deposited as silt. The main sources of suspended solids were nearby fields that were recently ploughed in preparation for the spring sowing. Organic pollution load was significant in the tributaries Vardarovasi and Anthofito, because of better self-purification capacity of the river during the high flow season. The high BOD_5 values were most probably related to the diffuse organic matter accompanying the suspended solids and not to point source organic pollution. In May, sampling took place at silt-substrata at the edges of the riverbed, and some of the sites were perhaps just recently covered by water. The fauna consisted mainly of Chironomidae and Oligochaeta, which are taxa tolerant to suspended solids and silt-substrate habitats (Hynes, 1970). In sandy and silty areas, which have low resistance to high discharge because of lack of suitable refugees, only burrowing animals such as Oligochaeta and Chironomidae can survive without being swept down (Hynes, 1970). Furthermore, following a flood, the fauna of the recovering stages is dominated by Chironomidae that have short life cycles (Hynes, 1970). Very diverse fauna and excellent water quality, however, characterized the Gorgopis tributary. In the low flow season, nitrates and conductivity were high due to farming and the release of industrial and urban effluents, which is in accordance with previous measurements in the Axios (Vasilikiotis et al., 1991). High BOD_5 values at Anatoliko and the Delta were clearly due to organic pollution. The increased amounts of orthophosphate during summer were due to urban run-off and industrial effluents discharged in the river, as noted in a previous study (Moustaka et al., 1992). Lower discharge and the closing of the dam, both noted during this research and as described in Argiropoulos (1991), contributed to the accentuation of pollution and to the lower self-purification capacity of the river especially downstream of the dam. Additionally, Anatoliko and the Delta were burdened with organic load, nitrates and orthophosphates. The fauna in July was more diverse reflecting mainly the more diverse substrate.

Biotic indices functioned satisfactorily but, overall, the physicochemical and the benthic macroinvertebrate data were better explained by the statistical analyses. At Fragma Ellis in July, water quality was overestimated, as the use of the biotic indices do not take abundance into consideration. Therefore, it is suggested that the development of a Greek index should include both abundance and diversity. The performance of the Iberian system was more in agreement with the physicochemical status of the system. The British system (BMWP and ASPT scores and Lincoln Quality Index) seemed to overestimate water quality on some occasions, probably because it does not take into account several pollution-tolerant families (mainly Dipteran families) that are abundant in Greek systems. The statistical analyses functioned very well as they separated the two seasons because of differences in biotic and physicochemical parameters (mainly temperature and TSS). The clean site Gorgopis was grouped separately. Anthofito was not grouped with any of the other sites because of its high conductivity. Vardarovasi was correlated mainly to its high load of ammonia, low flow and low pH. Site Vardarovasi was still characterized by high levels of ammonia in the summer of 1998 (Drouin et al., 1999). Anatoliko and the Delta of lower water quality in July, were placed at a distance from the centroid of their group of clean sites. Low scoring taxa such as Oligochaeta, Chironomidae, *Physa* spp. and Diptera were correlated to TSS and BOD_5. High scoring taxa (Ephemeroptera, Plecoptera, Trichoptera, Odonata) were correlated to dissolved oxygen and flow.

This study indicates that it is essential that bankside vegetation is developed and not cut, and the irrigation system is improved in order to prevent excessive soil erosion and to reduce flooding. The anthopogenic regulation of the discharge of the Axios seems to be affecting the ecological status of the river and its self-purification capacity. Additionally, during summer, the amount of water taken up for irrigation needs to be controlled. This is necessary as the low discharge due to irrigation coincides with seasonal pollutant inputs from adjacent industries and urban centers resulting in organic pollution of the Axios.

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