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Environmental Parameters Affecting the Species Diversity Along the Aliakmon River, North Greece

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Abstract: The annual distribution of aquatic and coastal macrophytes in five selected sites along the Aliakmon River was studied from January 2005 to December 2005 in Northern Greece. Soil and water chemical parameters in these sites were also evaluated. A total of 75 taxa were recorded belonging to 37 families and 53 genera. The majority of the macrophytes belonged to coastal plants (76%), whereas the rest of the macrophytes belonged to aquatic plants (24%). Species of the family Asteraceae were dominant among coastal plants, whereas species of the family Potamogetonaceae were dominant among aquatic plants. Soil samples from the site of Dam of Veria had higher pH and electric conductivity (80-100 cm depth), whereas $CaCO_3$ contents were significantly higher in soil samples from the area of P. Prodromos (60-80 cm depth). Most physicochemical water parameters as well as selected soil nutrients and major ionic components showed an increase during the low charge period (fall) compared to with the high charge period (spring), especially in parameters associated with agricultural activity. Furthermore, there was an increase in most examined values moving towards the delta of the river.

Key words: Aliakmon river, aquatic plants, coastal plants, soil pH, electric conductivity, water physicochemical parameters

INTRODUCTION

The Aliakmon River is the longest river in Greece with a total length of about 310 km. It originates in Northwestern Macedonia, Greece and after traversing a basin of about 6500 km^2, which includes mountainous terrain, agricultural plains and urban areas, discharges into the Thermaikos Gulf, near Aiginio. The Aliakmon River collects water from two large watersheds:

- The upper flow watershed, which covers an area of 6100 km^2 and has an average elevation of 1000 m.
- The lower flow basin of Eastern Vermion consists of the Eastern slopes of mountain Vermion and the lowlands of the lower flow basin with a total area of 380 km^2. The basin receives an average precipitation 850 mm annually (Kounitzis *et al*., 1994; Sawidis *et al*., 1995).

The major sources which can affect the water quality of the Aliakmon River are the agricultural, cattle-raising, urban and industrial activities taking place in the area (Koumitzis *et al*., 1994; Vorloou, 2006). Two thermo electrical powers are located in the western region of this basin, while three hydroelectrical units and the corresponding artificial lakes interpose in the river flow between the mountains. The artificial lake of Polyfyto, with a length of 30 km and a maximum depth of 80 m receives the domestic effluents from many neighbouring settlements. The estimated organic load of the lake is about 2000 tons (BOD units) annually, from which approximately 80% is transferred to the lake by the Aliakmon River (Nikolaidis *et al*., 2006). The other two water reservoirs (lakes Sfikia and Asomaton) are smaller and practically unaffected by any pollution sources. The final part of the river flow is the wastewater receiver from a number of food industries, particularly fruit and juice canneries (Kounitzis *et al*., 1994; Sawidis *et al*., 1995).

Published data on annual distribution of the aquatic and coastal macrophytes along the Aliakmon River as well as in the other River of Greece are limited, while data related to the effect of water quality (water physicochemical parameters) and soil physicochemical characteristics on the species and their frequency along the Aliakmon River are not reported. This research presents the annual distribution of the aquatic and coastal macrophytes in five selected sites along the Aliakmon River as well as the mechanical analysis of soil (texture, pH, electric conductivity and $CaCO_3$ content), the water physicochemical parameters (pH, alkalinity, electric

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conductivity and hardness), the major ionic elements (Ca^{2+}, Mg^{2+}, Cl^{-}, Fe^{2+}, Mn^{2+}, SO_4^{2-}) and the nutrients (NO_2^{-}, NO_3^{-}, PO_4^{3-}) in these sites for a period of one year. The objectives of this study were to investigate: the annual distribution of the aquatic and coastal macrophytes, the mechanical analysis of soil (texture, pH, electric conductivity and $CaCO_3$ content), the water physicochemical parameters (pH, alkalinity, electric conductivity, hardness) and the major ionic species (Ca^{2+}, Mg^{2+}, Cl^{-}, Fe^{2+}, Mn^{2+}, SO_4^{2-}) and the nutrients (NO_2^{-}, NO_3^{-}, PO_4^{3-}) in selected sites along the river for a period of one year.

MATERIALS AND METHODS

Five sites were selected for sample collection and plant identification along the Aliakmon River between the city of Veria and the settlement of Kipseli during the period January 2005-December 2005 (Fig. 1). The length of the river at this point is approximately 33 km including the local irrigation channels. The aquatic and coastal flora of the five sites was identified using selected botanical keys and monographs (Kavadas, 1956-1964; Lavrindiadis, 1983; Tutin *et al*., 1964-1980).

Soil samples were collected from five of these sites, in four depths, 0-20, 20-40, 40-60 and 60-80 cm, with the exception of site 1, where the extra depth of 80-100 cm was included for sampling. The soil texture, pH, electric conductivity and $CaCO_3$ content were also determined. Water samples were collected from the sampling sites in two different periods-April 2005 and October 2005. These sampling periods were chosen because April is considered representative of winter and spring periods (high discharge period), whereas October is considered representative of summer and fall periods (low discharge period). The soil and water samples were analyzed by employing standard methods of analysis (APHA, AWWA, WPCF, 1985). Soil texture was determined using the Vougiouko method (Alexiadis, 1967) taking into account the USDA classification. The $CaCO_3$ content of the soil was determined using a Bernard calci-meter (Alexiadis, 1967).

In situ measurements of pH, water temperature, conductivity and total dissolved solids were carried out, while analysis of water nutrients was based on the methodology of the Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WPCF, 1985). The pH and electric conductivity were measured electrometrically, whereas total alkalinity, hardness and the concentration of chlorides were determined through titration. Sulphates, phosphates, ammonium and nitrites were determined using a spectrophotometer, while the nitrates were determined by the same method after reduction on a cadmium reduction column.

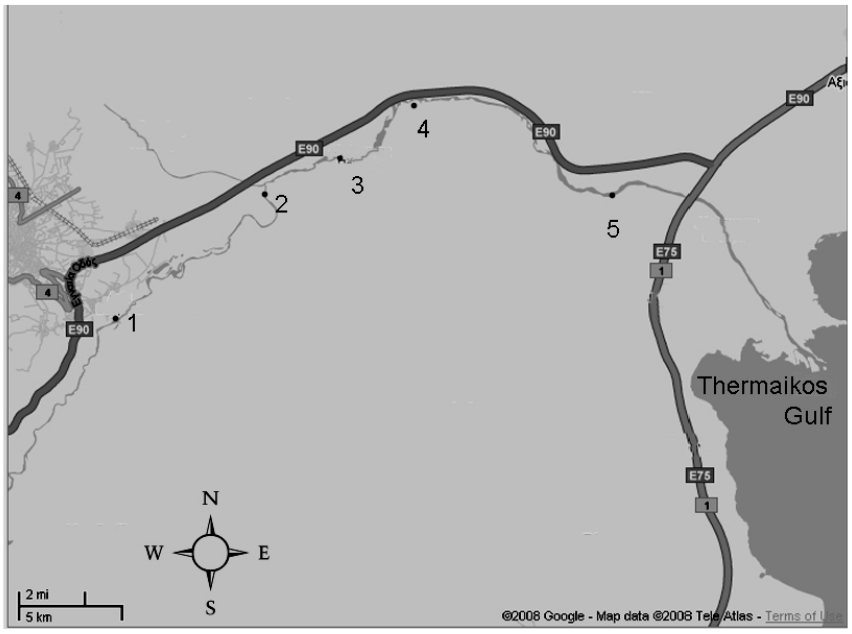

Fig. 1: Map of the study area showing the sampling sites and the river's watershed; 1: Dam of Veria, 2: Meliki, 3: P. Prodromos, 4: Agia Triada, 5: Kipseli

Statistical analysis: Data of water measurements were subjected to analysis of variance (ANOVA) using a two by five factorial approach (2 sampling dates × 5 sampling sites) with three replications for each combined treatment. Also, data of soil measurements were subjected to analysis of (ANOVA) using a four by five factorial approach (4 sampling depths × 5 sampling sites) with three replications for each combined treatment. Means were compared using LSD test at 5% level of significance.

RESULTS AND DISCUSSION

Species composition: A total of 75 taxa of macrophytes were identified from the five sites along Aliakmon River during the period studied. The species belong to 37 families and 53 genera. Eighteen aquatic plants were identified and belong to eight families and eight genera (Table 1). Potamogetonaceae comprised the highest number of species (27.8%) followed by Cyperaceae (16.7%), Ceratophyllaceae, Haloragaceae, Juncaceae and Polygonaceae (11.2%, respectively), Alismataceae and Plantaginaceae (5.6%), respectively. None of these species was found in any of the five sites, while Alisma plantago-aquatica (Alismataceae) was found only in four sites. Of the eighteen identified aquatic plants only four species (*C. demersum*, *M. spicatum*, *P. crispus* and *P. pectinatus*) had been previously identified by Sawidis *et al.* (1995). From the eight Families were collected from the studied area, the Potamogetonaceae, Ceratophellaceae and Cyperaceae Families were identified and characterized as dominant (Table 3).

Fifty seven coastal plants were identified belonging to 29 families and 45 genera (Table 2). Asteraceae comprised the highest number of species (17.5%) followed by Polygonaceae and Fabaceae (10.5%, respectively), Chenopodiaceae and Lamiaceae (5.3%, respectively) while the rest of the families ranged between 1.8-3.5%. *Platanos orientalis* and *Salix* sp. were found in all sites studied. Almost all of the remaining species were found in two or more sites except *Atriplex patula*, *Betula erecta*, *Erigeron* sp., *Polygonum aviculare*, *P. hydropiper*, *P. persicaria* and *Roriba thracica*, *Verbena officinalis*, which were found only in one site.

From 29 families were collected from the studied area, the Asteraceae, Fabaceae and polygonaceae families were identified and characterized as dominant (Table 4).

Soil analysis: The soil pH values did not show remarkable differences between sampling sites (Table 5). The sample analysis from various depths showed a normal slight increase of pH values with depth, which is attributed to the increased concentration of $CaCO_3$. Electric conductivity ranged between 36.8 μS cm^{-1} (Kipseli, depth 0-20 cm) and 182 μS cm^{-1} (Dam of Veria, depth 80-100 cm). These values are expected in such environments and are inside the permissible limits as well as content of $CaCO_3$. Soil $CaCO_3$ contents were significantly higher in the

Table 1: List of aquatic species at the five studied sites of Aliakmon River

Species	Dam of Veria	Meliki	P. Prodromos	Agia Triada	Kipseli
Alismataceae					
Alisma plantago-aguatica L.		+	+	+	
Ceratophyllaceae					
Ceratophyllum demersum L.		+	+		+
C. submersum L.		+	+		+
Cyperaceae					
Scirpus lacustris L.	+		+		
S. maritimus L.		+	+		
S. lacustus L. ssp. *tabernaemontani*	+	+	+		
Haloragaceae					
Myriophyllum spicatum L.	+	+			
M. verticillatum L.	+	+			
Juncaceae					
Juncus articulatus L.	+		+	+	
J. subulatus Forscal	+		+		
Plantaginaceae					
Plantago major L.			+	+	
Polygonaceae					
Rumex crispus L.		+	+		+
Rumex sp.		+	+		
Potamogetonaceae					
Potamogeton crispus L.		+	+		
P. fluitans L.		+	+		
P. gramineus L.		+	+		
P. natans L.		+			
P. pectinatus L.		+	+		

+: Species detected in the respective site

Table 2: List of coastal species at the five studied sites of Aliakmon River

Species	Dam of Veria	Meliki	P. Prodromos	Agia Triada	Kipseli
Amarantaceae					
Amaranthus retroflexus L.		+	+		
Amaranthus sp.		+	+		
Aristolochiaceae					
Aristolochia clematitis L.	+	+	+	+	
Asteraceae					
Achillea millefollium L.			+	+	+
Artemisia vulgaris L.		+		+	
Artemisia sp.	+				+
Bidens sp.		+	+		
Erigeron canadeusis L.			+		+
Erigeron sp.		+			
Inula sp.	+	+			
Pulicaria dysenterica L.		+	+		
Sonchus oleraceus L.		+		+	
Xanthium strumarium L.	+			+	
Betulaceae					
Alnus glntinosa (L.) Gaertner		+	+		
Betula erecta L.				+	
Brassicaceae					
Roripa thracica Griseb.	+				
R. palustris L.	+				+
Caprifoliaceae					
Sambucus nigra L.		+	+		
Caryophylaceae					
Stellaria media (L.) Vill.			+	+	
Chenopodiaceae					
Atriplex patula L.	+				
Chenopodium botrys L.		+	+	+	
Ch. murale L.		+	+	+	
Convolvulaceae					
Convolvulus arveusis L.			+		+
Euphorbiaceae					
Euphorbia peplus L.	+		+		
Fabaceae					
Astragalus sp.		+		+	
Melilotus indica All.		+	+	+	
M. officinalis (L.) Lam.	+		+	+	
Melilotus sp.			+		
Robinia pseudacacia L.		+	+		
Trifolium alpestre L.		+	+		+
Hypericaceae					
Hypericum perforatum L.		+	+	+	
Lamiaceae					
Lycopus europaeus L.		+		+	
Mentha aquatica L.	+		+		
M. pulegium L.	+		+		
Lythraceae					
Lythrum salicaria L.			+	+	
Malvaceae					
Althaea officinalis L.	+				+
Plantanaceae					
Platanus orientalis L.	+	+	+	+	+
Plantaginaceae					
Plantago lanceolata L.		+		+	
Poaceae					
Agropyron elongatum P. Beauv.		+	+		
Echinochloa crns-galli (L.) P. Beauv. Pal.Beauv BBeauv.		+		+	
Polygonaceae					
Polygonum aviculare L.					+
P. hydropiper L.					+
P. persicaria L.					+
P. mouspeliensis L.	+	+			
Polygonum sp.			+	+	
Rumex pulcher L.		+	+		+
Portulaceae					
Portulaca oleracea L.		+	+		

Table 2: Continued

Species	Dam of Veria	Meliki	P. Prodromos	Agia Triada	Kipseli
Ranunculaceae					
Clematis sp.	+			+	
Rosaceae					
Rubus sp.	+		+		
Rubiaceae					
Galium sp.			+	+	
Salicaceae					
Populus alba L.		+		+	
Salix alba L.		+	+	+	
Scrophulariaceae					
Veronica anagalis-aquetica L.		+	+		
Tamaricaceae					
Tamarix hampeana Bois.et Heldr.		+		+	
Urticaceae					
Parietaria sp.	+		+	+	
Ulmaceae					
Ulmus campestris L.		+	+		
Verbenaceae					
Verbena officinalis L.				+	

+: Species detected in the respective site

Table 3: Distribution of aquatic plants at the five studied sites of Aliakmon River

Family	Dam of Veria	Meliki	P. Prodromos	Agia Triada	Kipseli
Alismataceae		2*	1	1	
Ceratophyllaceae		2	3		2
Cyperaceae	2	2	2		
Haloragaceae	2	3			
Juncaceae	2		2	1	
Plantaginaceae			1	2	
Polygonaceae		2	2		1
Potamogetonaceae		6	5		

*: Number of species detected in the respective site, $LSD_{0.05} = 0.63$

Table 4: Distribution of coastal families at the five studied sites of Aliakmon River

Family	Dam of Veria	Meliki	P. Prodromos	Agia Triada	Kipseli
Amarantaceae		3*	2		
Aristolochiaceae	1	1	1	2	
Asteraceae	3	6	5	5	3
Betulaceae		1	1	2	
Brassicaceae	2				1
Caprifoliaceae		1	1		
Caryophylaceae			1	1	
Chenopodiaceae	1	2	3	2	
Convolvulaceae			1		1
Euphorbiaceae	1		1		
Fabaceae	2	4	5	3	1
Hypericaceae		1	1	1	
Lamiaceae	2	1	4	1	
Lythraceae			2	1	
Malvaceae	2				1
Plantanaceae	1	1	1	1	1
Plantaginaceae		1		1	
Poaceae		2	1	1	
Polygonaceae	1	2	3	1	4
Portulaceae		1	1		
Ranunculaceae	1			1	
Rosaceae	1		1		
Rubiaceae			1	1	
Salicaceae		2	1	2	
Scrophulariaceae		1	1	,	
Tamaricaceae		1		1	
Urticaceae	1		1	1	
Ulmaceae		1	1		
Verbenaceae				1	

*: Number of species detected in the respective site, $LSD_{0.05} = 0.54$

Table 5: Physicochemical parameters[a] of the soil in the five sampling sites along Aliakmon River

Sampling site	Depth (cm)	pH	Ec[b] (μS cm^{-1})	$CaCO_3$ (%)	Organic matter (%)	Soil texture (USDA)
Dam of Veria	0-20	7.99	154.0	8.756	0	SL
	20-40	8.06	160.0	9.68		
	40-60	8.09	165.0	11.032		
	60-80	8.25	178.0	11.66		
	80-100	8.29	182.0	14.96		
Meliki	0-20	8.09	56.6	4.40	0	SL
	20-40	8.11	60.0	9.24		
	40-60	8.16	63.0	9.68		
	60-80	8.21	67.0	10.12		
P. Prodromos	0-20	8.14	46.9	12.76	0	SL
	20-40	8.19	60.0	14.52		
	40-60	8.21	66.0	14.71		
	60-80	8.23	90.5	15.84		
Agia Triada	0-20	7.98	59.6	9.24	0	S
	20-40	8.05	71.0	6.68		
	40-60	8.10	77.7	11.44		
	60-80	8.15	88.8	13.64		
Kipseli	0-20	8.04	36.8	3.96	0	S
	20-40	8.10	37.5	6.60		
	40-60	8.19	43.0	9.24		
	60-80	8.26		14.08		
$LSD_{0.05}$	-	NS	13.3	1.43	-	-

[a]: Mean of 5 samplings, [b]: Electric conductivity

Table 6: Water analysis results[a] in the five sampling sites and for the two periods of sampling (April and October 2005)

	Sampling sites										
	Dam of Veria		Meliki		P. Prodromos		Agia Triada		Kipseli		
Parameters	April	October	April	October	April	October	April	October	April	October	LSD
LpH	8.10	8.21	8.15	8.33	7.81	8.23	7.73	7.96	8.06	8.32	0.65
LEc[b] (μS cm^{-1})	408.00	788.00	470.00	504.00	483.00	610.00	450.00	567.00	435.00	541.00	64.61
TDS[c] (mg L^{-1})	243.00	512.00	305.00	327.00	292.00	312.00	271.00	360.00	280.00	350.00	39.02
Total hardness (mg L^{-1})	180.00	198.00	230.00	253.00	196.00	208.00	165.00	156.00	240.00	230.00	21.31
Hardness Ca (mg L^{-1})	115.00	132.00	190.00	201.00	123.00	135.00	98.00	103.00	170.00	155.00	16.06
Hardness Mg (mg L^{-1})	65.00	66.00	40.00	52.00	73.00	73.00	67.00	53.00	70.00	75.00	7.31
Alkalinity P (meq L^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Alkalinity M (meq L^{-1})	133.00	150.00	195.00	200.00	138.00	142.00	124.00	109.00	168.00	182.00	14.61
Pt color	0.00	3.00	2.00	4.00	0.00	0.00	0.00	5.00	2.00	8.00	0.21
FTU[d]	0.00	5.00	3.00	5.00	0.00	0.00	0.00	8.00	5.00	7.00	0.17
Na^+ (ppm)	18.00	19.00	6.40	7.30	23.00	24.00	16.00	18.00	4.60	5.20	1.84
K^+ (ppm)	3.60	3.80	3.20	5.00	4.20	6.50	3.10	3.90	2.50	4.50	0.36
Ca^{2+} (ppm)	46.00	52.80	76.00	80.40	49.20	54.00	39.20	41.20	68.00	62.00	6.81
Mg^{2+} (ppm)	26.00	26.40	16.00	20.80	29.20	29.20	26.80	21.20	28.00	30.00	2.10
Fe^{2+} (ppm)	0.05	0.09	0.015	0.015	0.04	0.02	0.02	0.015	0.01	0.01	0.0020
Mn^{2+} (ppm)	0.01	0.02	0.00	0.00	0.01	0.01	0.01	0.00	0.02	0.02	0.0004
HCO_3^- (ppm)	133.00	150.00	195.00	200.00	138.00	142.00	124.00	109.00	168.00	182.00	21.56
PO_4^{3-} (ppm)	1.60	2.80	1.70	6.20	1.30	1.90	1.40	1.80	2.30	5.90	0.21
SO_4^{2-} (ppm)	25.00	54.00	65.00	82.00	31.00	43.00	22.00	32.00	25.00	38.00	3.14
NO_3^- (ppm)	7.00	11.00	5.10	6.30	6.00	17.00	8.00	32.00	8.00	35.00	2.17
NO_2^- (ppm)	0.07	0.10	0.01	0.02	0.05	0.14	0.02	0.03	0.02	0.02	0.0042
B^- (ppm)	0.04	0.04	0.02	0.02	0.04	0.02	0.03	0.03	0.03	0.03	0.0016
Cl^- (ppm)	34.00	37.00	29.00	34.00	32.00	35.00	28.00	30.00	38.00	42.00	3.99
F^- (ppm)	0.20	0.15	0.20	0.10	0.20	0.20	0.10	0.10	0.10	0.10	0.014

[a]: Mean of 5 samplings, [b]: Electric conductivity, [c]: Total dissolved solids, [d]: Turbidity

60-80 cm depth than in the 0-20 cm (Table 5). The soil textures varied from sandy to sandy loams, while certain horizons were found in oxidation-reduction (redox) conditions. This was due to the high water table as the sampling sites were next to the banks of Aliakmon River. There was no organic matter as the soils consist of leached sediments.

Water analysis: The two sampling periods represent two significant annual periods-the period of high discharge and the period of low discharge, with high temperatures and little or no rain. Therefore, each sampling period should be viewed separately (Table 6).

It is plainly evident that during the October sampling values were higher than those of the April period. This

was expected as spring and summer in Greece are seasons with high agricultural activity and limited water availability. It is also evident that there was a general increase in values moving towards the delta of the river. For example, the value of electric conductivity was 408 μS cm^{-1} in Dam of Veria for April and 470 μS cm^{-1} in Meliki. However, the same was not true for October. This difference could be attributed to the use of the river's water in agricultural activities (e.g., irrigation), a fact that affects both the quality and the quantity of the water.

Finally, another observation that can be easily made is that the greatest increase was in chemical parameters which are mostly associated with fertilizers, such as PO_4, SO_4 and NO_3. According to the values found for the two sampling periods (April and October 2005), Aliakmon River does not appear to be considerably loaded in spring. However, the effect of human activities becomes obvious in the samplings of October.

In general, the water quality of Aliakmon River was better in all sampling sites at the high charge period (spring) compared to that of the low charge period (fall), which agrees with the results of Lazaridou-Dimitriadou *et al.* (1997) as well as those of Koumitzis *et al.* (1994). It is obvious that the main tax accepted by Aliakmon River comes from urban sewages, industrial waste as well as from the rural activities which take place in the region. Further studies are needed, as Aliakmon River is one of the main surface water resources for drinking purposes for the city of Thessaloniki.

CONCLUSION

- This study describes the distribution of aquatic and coastal plant diversity in five selected areas of Aliakmon River (N. Greece) from January 2005 to December 2005.
- A total of 75 taxa were collected from the studied area, 18 aquatic and 57 coastal plants were identified and were characterized by the dominance of Potamogetonaceae and Asteraceae respectively.
- The soils are leached sediments that range from sandy to sandy loams with no organic matter.
- Water quality in Aliakmon River is affected by human activities in the region. Water quality is better in the high charge period (spring) than in the low charge period (fall).

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