A COMPARATIVE STUDY OF THE AQUATIC INSECTS' FAUNA OF FOUR RIVERS IN GREECE

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SUMMARY

The insect fauna of four Greek rivers (Kalamas and Acherontas in Ipeirus, Alfeios and Pineios in Peloponnisos) in relation to the ecological parameters of the sampling sites was studied seasonally over a period of three years. Eight orders and 44 insect families were identified in our samplings. Ephemeroptera consisting of the genera *Heptagenia, Ephemerella, Ephemera, Caenis, Habrophlebia, Siphlonurus, Baetis* and *Cloen* was the most abundant order, whilst Diptera was the order with the largest variety in families' taxa. Among the rivers, Kalamas was the "richest" in insect's fauna followed by Pineios, Acherontas and Alfeios.

KEYWORDS: Aquatic insects, Greek rivers, Epehemeroptera, Diptera, Plecoptera, Trichoptera.

INTRODUCTION

Many species of the diverse taxa of insecta live in freshwater environment playing a major ecological role in aquatic habitats [1]. They are the principle converters of the photosynthetic production of plants into food for fishes whilst many of them are food for fishes [2, 3]. On the other hand the importance of aquatic insects as biological indicators of freshwater pollution is marked out by many authors [4-7]. However in Greece, the aquatic insects' fauna has not been studied extensively. Only little work has been done, focusing in the insects related to the monitoring of freshwater pollution [8-10].

In this research, the insect fauna in relation to the ecological parameters of four Greek rivers (Kalamas and Acherontas in Ipeirus, Alfeios and Pineios in Peloponnisos) was studied for the first time in order to enrich the knowledge about the Greek fauna.

MATERIALS AND METHODS

For the study of the aquatic fauna, two samples were taken from each site seasonally starting in autumn '98 and finishing in the summer of 2001 using a Surber net (size 0.5 x 0.5 m, mesh size 900 μm), [11-13]. The organisms collected were sorted alive and preserved in 70% ethanol for further identification to the lowest possible taxonomic level with the use of an Italian identification key [14] which was considered to be more suitable since there have not been developed identification keys for the Greek region.

The rivers Kalamas and Acherontas are situated in Ipeirus (northwest Greece) (Fig. 1). Kalamas is the largest river in the prefecture of Ipeirus with a total length of 115 km [15]. Samples were taken from three sites: (1) springs, (2) Brosina 44 km downstream and (3) Neraida a further 12 km downstream. Acherontas is a smaller river with a length of 53 km. Samples were taken from two sites: (1) Gliki (springs) and (2) Kastrio which is 14 km downstream.

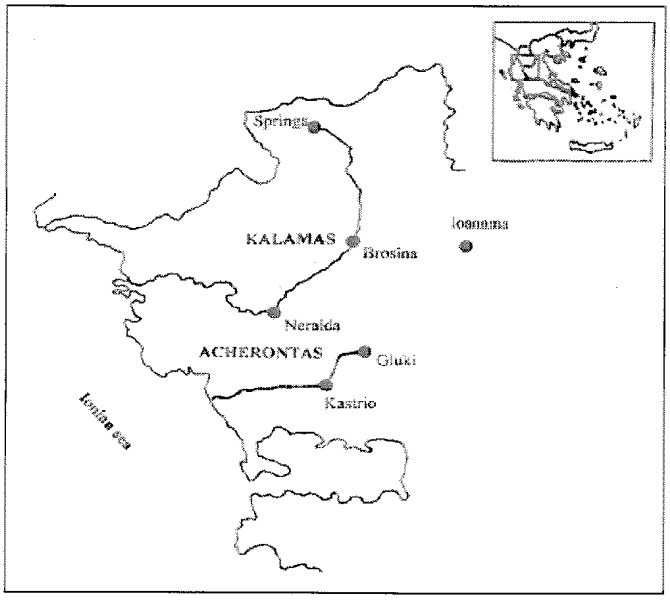


FIGURE 1 - Map of the rivers Kalamas and Acherontas showing the sampling sites.

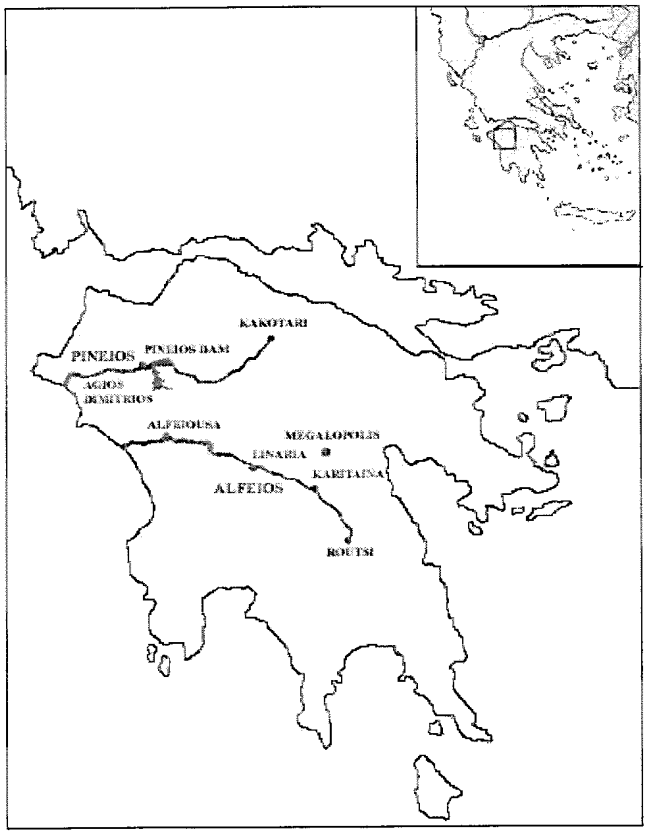


FIGURE 2 - Map of the rivers Alfeios and Pineios showing the sampling sites.

The Rivers Alfeios and Pineios are located in Peloponnisos (southwest of Greece) (Fig. 2). Alfeios is the largest river of Peloponnisos with a total length of 110 km [15]. Samples were taken from four sites: (1) Routsi (Springs), (2) Karitaina 35 km downstream, (3) Linaria, a further 45 km and (4) Alfeiousa, 15 km downstream. Pineios is the second most important river of Peloponnisos with a length of 80 km. Samples were taken from two sites: (1) Kakotari (Springs) and (2) Agios Dimitrios, 35 km downstream.

Seasonal samples were taken over a period of three years starting in autumn '98 and finishing in the summer of 2001. In some cases however, sampling was not possible due to high discharge conditions.

In each sampling period, dissolved oxygen and percentage saturation, water temperature, pH, total dissolved solids (TDS), conductivity, and flow velocity were measured in the field with portable equipment (JENWAY 9200, 3200, 4200) whilst water samples were collected for further chemical analysis in laboratory: phosphates, nitrates, nitrites, sulphates by the use of the HACH device, as well as BOD and COD. Samples were transported in a cold box (4 ^{0} C) and were analysed within 24 hours [16-18]. The substrate type was also analysed at each sampling site using appropriate sieves [19].

RESULTS

The mean values of the physicochemical parameters of the four rivers for every season are presented in Tables 1 - 6. High values of conductivity, TDS and sulfates were measured in all seasons in the sampling sites of Kalamas and Acherontas rivers. At Karitaina (Alfeios), high values of conductivity, sulfates BOD and COD were measured in all seasons. All other measurements were found to be normal.

At the springs the substrate type was sandy-mud, whilst at Brosina it was middle coarse sand and at Neraida poorly sorted gravel (Kalamas). At Gliki it was gravel and at Kastrio it was poorly sorted gravel (Acherontas). At Routsi, Karitaina and Alfeiousa it was poorly sorted gravel whilst at Linaria it was coarse sand (Alfeios). At the river Pineios it was sandy mud at Kakotari and poorly sorted gravel at Agios Dimitrios.

TABLE 1
Seasonal mean values of the physicochemical parameters of the river Acherontas.

RIVER	ACHERONTAS							
SITE	GLIKI				KASTRIO			
SEASON	AUTUMN	WINTER	SPRING	SUMMER	AUTUMN	WINTER	SPRING	SUMMER
TEMPERATURE (^{0}C)	13.1	12.7	14.8	14.4	15.3	12.5	18.2	17.5
DO_2 (mg l^{-1})	10.8	10.3	9.76	10.6	11.2	10.5	9	10.2
pH	7.3	7.86	7.4	7.6	7.6	7.28	7.47	8.04
CONDUCTIVITY (mS cm^{-1})	1.01	0.833	0.944	1.014	0.866	1.72	0.887	0.985
TDS (mg l^{-1})	601	502	565	601	3500	1032	539	589
FLOW VELOCITY (m sec^{-1})	1.26	1.1	1.8	1	1.1	0.6	0.9	2.6
PO_4 (mg l^{-1})	0.17	0.6	0.1	0.2	0.2	0.14	0.1	0.1
NO_2 (mg l^{-1})	0.03	0.017	0.015	0.03	0.02	0.015	0.015	0.066
NO_3 (mg l^{-1})	2	1.3	1.2	3	1	0.75	0.5	4.4
SO_4 (mg l^{-1})	>100	>100	>100	>100	>100	>100	>100	>100
BOD_5 (mg l^{-1})	2.8	0	3.5	0	4.9	5		
COD (mg l^{-1})	4	0	5	0	7	7.3		

TABLE 2
Seasonal mean values of the physicochemical parameters of the river Kalamas (Springs and Brosina).

RIVER	KALAMAS							
SITE	SPRINGS				BROSINA			
SEASON	AUTUMN	WINTER	SPRING	SUMMER	AUTUMN	WINTER	SPRING	SUMMER
TEMPERATURE (^{0}C)	12.2	12.3	13.1	13.5	15.8	12.1	16.4	17.5
DO_2 (mg l^{-1})	10.6	10.8	10.1	10.8	10.7	30.8	9.6	9.5
pH	7.4	7.63	7.46	7.43	7.83	7.92	7.5	7.95
CONDUCTIVITY (mS cm^{-1})	1.8	1.76	1.67	1.63	0.86	0.528	0.742	0.686
TDS (mg l^{-1})	1097	1065	1018	1006	515	319	445	408
FLOW VELOCITY (m sec^{-1})	0.8	0.7	0.95	0.8	1.9	1.3	1.9	1.3
PO_4 (mg l^{-1})	0.7	0.12	0.27	0.1	0.25	0.27	0.25	0.3
NO_2 (mg l^{-1})	0.017	0.01	0.02	0.03	0.03	0.025	0.03	0.04
NO_3 (mg l^{-1})	1.67	1.2	1.7	3.9	2	1.5	2.7	2.84
SO_4 (mg l^{-1})	>100	>100	>100	>100	>100	>100	>100	>100
BOD_5 (mg l^{-1})	11.2	0	7	7	3.5	0	4.2	14
COD (mg l^{-1})	16	0	10	10	5	0	6	20

TABLE 3
Seasonal mean values of the physicochemical parameters of the rivers Kalamas (Neraida) and Alfeios (Routsi).

RIVER	KALAMAS				ALFEIOS			
SITE	NERAIDA				ROUTSI			
SEASON	AUTUMN	WINTER	SPRING	SUMMER	AUTUMN	WINTER	SPRING	SUMMER
TEMPERATURE (^{0}C)	12.8	12.7	17	17.7	11.2	9.3	14	16.6
DO_2 (mg l^{-1})	11.2	10.47	9.46	9.9	11.1	11.1	9.46	10.17
pH	7.9	7.9	7.3	7.9	7.43	7.6	7.64	7.78
CONDUCTIVITY (mS cm^{-1})	0.685	0.58	0.588	0.706	0.462	0.462	0.490	0.444
TDS (mg l^{-1})	410	344	357	419	276	260	292	260
FLOW VELOCITY (m sec^{-1})	2.1	1.4	1.8	1.2	0.68	0.51	0.3	0.3
PO_4 (mg l^{-1})	0.8	0.27	0.2	0.2	0.47	0.9	0.17	0.3
NO_2 (mg l^{-1})	0.027	0.02	0.025	0.054	0.017	0.012	0.02	0.036
NO_3 (mg l^{-1})	1.3	3	3	3.37	1.2	1.6	1	8.47
SO_4 (mg l^{-1})	>100	>100	>100	>100	34.7	23	18	17
BOD_5 (mg l^{-1})	5.6	0	7	14	12	0	11	
COD (mg l^{-1})	8	0	10	20	17	0	15	

TABLE 4
Seasonal mean values of the physicochemical parameters of the river Alfeios (Karitaina and Linaria).

RIVER	ALFEIOS							
SITE	KARITAINA				LINARIA			
SEASON	AUTUMN	WINTER	SPRING	SUMMER	AUTUMN	WINTER	SPRING	SUMMER
TEMPERATURE (^{0}C)	12.9	10.6	21.4	22.5	16.5	12.5	20.4	21.3
DO_2 (mg l^{-1})	1	10.4	8.57	9.14	10.4	10	7.5	8.98
pH	7.64	7.96	7.65	7.8	7.67	7.7	7.37	
CONDUCTIVITY (mS cm^{-1})	1.043	0.8	0.691	0.795	0.460	0.438	0.436	0.453
TDS (mg l^{-1})	621	472	415	480	275	262	263	272
FLOW VELOCITY (m sec^{-1})	0.9	0.8	0.5	1	1.58	0.9		0.72
PO_4 (mg l^{-1})	0.3	0.21	0.1	0.1	0.1	0.08	0.1	0.1
NO_2 (mg l^{-1})	>0.2	0.16	0.03	0.09	0.08	0.024	0.02	0.066
NO_3 (mg l^{-1})	13	4.5	4	15	0.75	1	2	30.8
SO_4 (mg l^{-1})	>100	>100	>100	>100	50	30	30	45
BOD_5 (mg l^{-1})	24.1	13	14	12	5.6	0		
COD (mg l^{-1})	35	19	20	17	8	0		

TABLE 5
Seasonal mean values of the physicochemical parameters of the river Alfeios (Alfeiousa).

RIVER	ALFEIOS			
SITE	ALFEIOUSA			
SEASON	AUTUMN	WINTER	SPRING	SUMMER
TEMPERATURE (^{0}C)	17.3	14.3	22.6	24.5
DO_2 (mg l^{-1})	9.7	9.8	9.1	9.65
pH	7.45	7.65	7.45	
CONDUCTIVITY (mS cm^{-1})	0.480	0.453	0.453	0.44
TDS (mg l^{-1})	287	270	272	264
FLOW VELOCITY (m sec^{-1})	1.7	1.2		0.6
PO_4 (mg l^{-1})	0.5	0.2	0.3	0.2
NO_2 (mg l^{-1})	0.04	0.005	0.02	0.132
NO_3 (mg l^{-1})	5	0	3.5	13.2
SO_4 (mg l^{-1})	52	30	35	60
BOD_5 (mg l^{-1})	20	0		
COD (mg l^{-1})	32	0		

TABLE 6
Seasonal mean values of the physicochemical parameters of the rivers Pineios (Kakotari and Agios Dimitrios).

RIVER	PINEIOS							
SITE	KAKOTARI				AGIOS DIMITRIOS			
SEASON	AUTUMN	WINTER	SPRING	SUMMER	AUTUMN	WINTER	SPRING	SUMMER
TEMPERATURE (^{0}C)	12.6	10.9	13.3	13.9	16.5	9.8	25.9	25.5
DO_2 (mg l^{-1})	11.1	10.8	9.5	9.2	9.87	10.4	9.49	9
pH	7.72	7.63	7.5	7.46	7.17	7.77	7.25	7.63
CONDUCTIVITY (mS cm^{-1})	0.301	0.329	0.298	0.33	0.52	0.504	0.605	0.573
TDS (mg l^{-1})	190	197	180	203	313	301	363	345
FLOW VELOCITY (m sec^{-1})	0.6	0.6	1.2	0.6	0.3	0.3	0.3	1.2
PO_4 (mg l^{-1})	0.2	0.1	0.13	0.1	0.3	0.2	0.1	0.2
NO_2 (mg l^{-1})	0.02	0.02	0.017	0.025	0.03	0.018	0.03	0.06
NO_3 (mg l^{-1})	1.8	1.5	1.3	7.6	3.1	3.5	3	12
SO_4 (mg l^{-1})	12	10	12	11	48	30	45	42
BOD_5 (mg l^{-1})	0.8	0	1.4		21	0		22
COD (mg l^{-1})	12	0	2		30	0		31

TABLE 7
Insect families collected at the rivers Kalamas, Acherontas, Alfeios and Pineios.

ORDERS	TAXA				
Ephemeroptera	Ephemerellidae: *Ephemerella*	Baetidae: *Baetis, Cloeon*	Heptageniidae: *Heptagenia*	Caenidae: *Caenis*	Siphlonuridae: *Siphlonurus lacustris*
	Leptophlebiidae: *Habrophlebia*	Ephemeridae: *Ephemera danica*			
Plecoptera	Perlodidae: *Perlodes, Isoperla*	Perlidae: *Perla bipunctata, Perla marginata, Dinocras cephalotes*	Taeniopterygidae: *Taeniopteryx*	Leuctridae: *Leuctra*	Capniidae: *Capnia*
Trichoptera	Hydropsychidae: *Hydropsyche instabilis, Hydropsyche angustipennis*	Rhyacophilidae: *Hyperhyacophila occidentalis*	Glossosomatidae	Polycentropodidae	Sericostomatidae: *Sericostoma*
	Hydroptilidae	Lepidostomatidae			
Coleoptera	Elminthidae: *Elmis, Stenelmis*	Hydraenidae	Dytiscidae	Haliplidae	Gyrinidae
Diptera	Stratiomyidae	Anthomyidae	Ephyridridae	Chironomidae	Limoniidae: *Hexatoma*
	Tipulidae: *Tipula, Prionocera*	Tabanidae: *Haematopota italica*	Rhagionidae	Syrphidae	Dixidae
	Ceratopogonidae	Athericidae: *Atherix ibis*	Blephariceridae		
Odonata	Platycnemidae: *Platycnemis*	Cordulegasteridae: *Cordulegaster*	Gomphidae: *Onychogomphus*	Calopterygidae: *Calopteryx virgo*	
Hemiptera	Gerridae	Mesoveliidae			
Megaloptera	Sialidae: *Sialis lutaria*				

Eight orders and 44 insect families were identified in our samplings (Table 7). Diptera was the order with the largest variety of taxa consisting of the families Stratiomyidae, Anthomyidae, Ephyridridae, Chironomidae, Limoniidae, Tipulidae, Tabanidae, Rhagionidae, Syrphidae, Dixidae, Ceratopogonidae, Athericidae and Blephariceridae.

Insects total percentage distribution is presented at Figure 3: Ephemeroptera was the most abundant order with 37%, followed by Diptera (20%), Plecoptera (17%) and Trichoptera (16%). Each site's total percentage distribution is presented in Figure 4(a – c): At the springs of Kalamas Ephemeroptera dominated, followed by Plecoptera whilst at Brosina and Neraida Ephemeroptera were more abundant followed by Trichoptera (Figure 4a). At the river Acherontas, at Gliki Ephemeroptera were more abundant followed by Plecoptera whilst at Kastrio Diptera dominated (Figure 4b). At Routsi (Alfeios), Diptera were in higher proportions followed by Ephemeroptera whilst at Karitaina Ephemeroptra were the most abundant taxa, followed by Diptera (Figure 4b). At Linaria Diptera dominated followed by Trichoptera whilst at Alfeiousa the most abundant taxa were Ephemeroptera and Diptera (Figure 4b). At the river Pineios at Kakotari Epehmeroptera dominated, followed by Plecoptera whilst at Agios Dimitrios, Diptera were by far the most abundant taxa (Figure 4c).

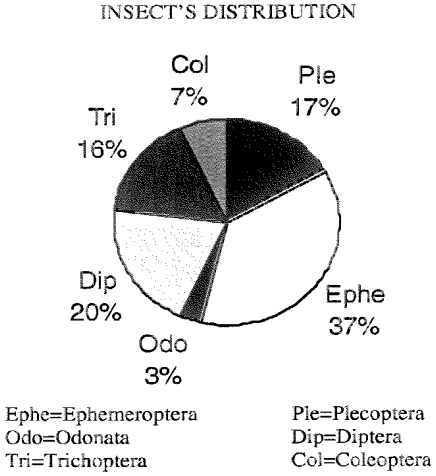
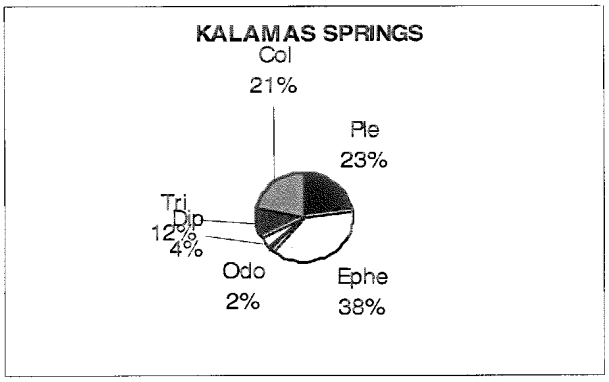
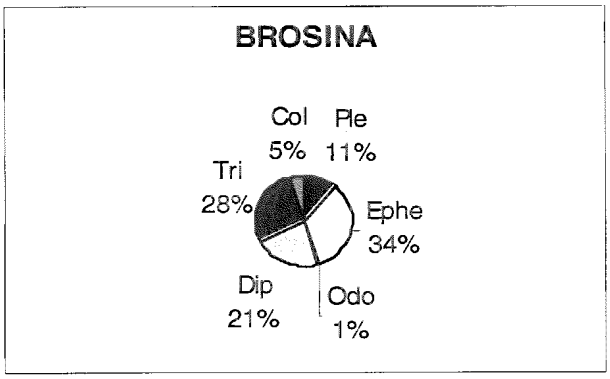


FIGURE 3
Insect's total percentage distribution.





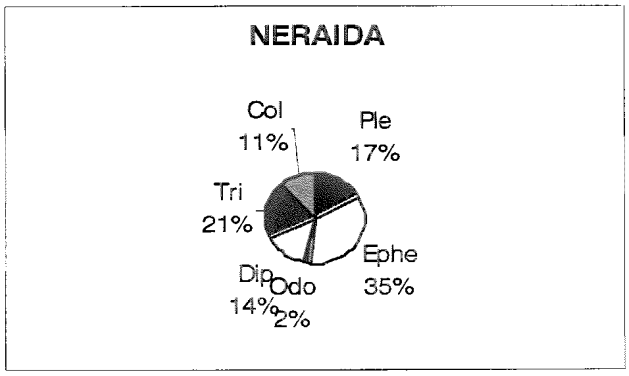


FIGURE 4a
Insect's percentage distribution at each site.

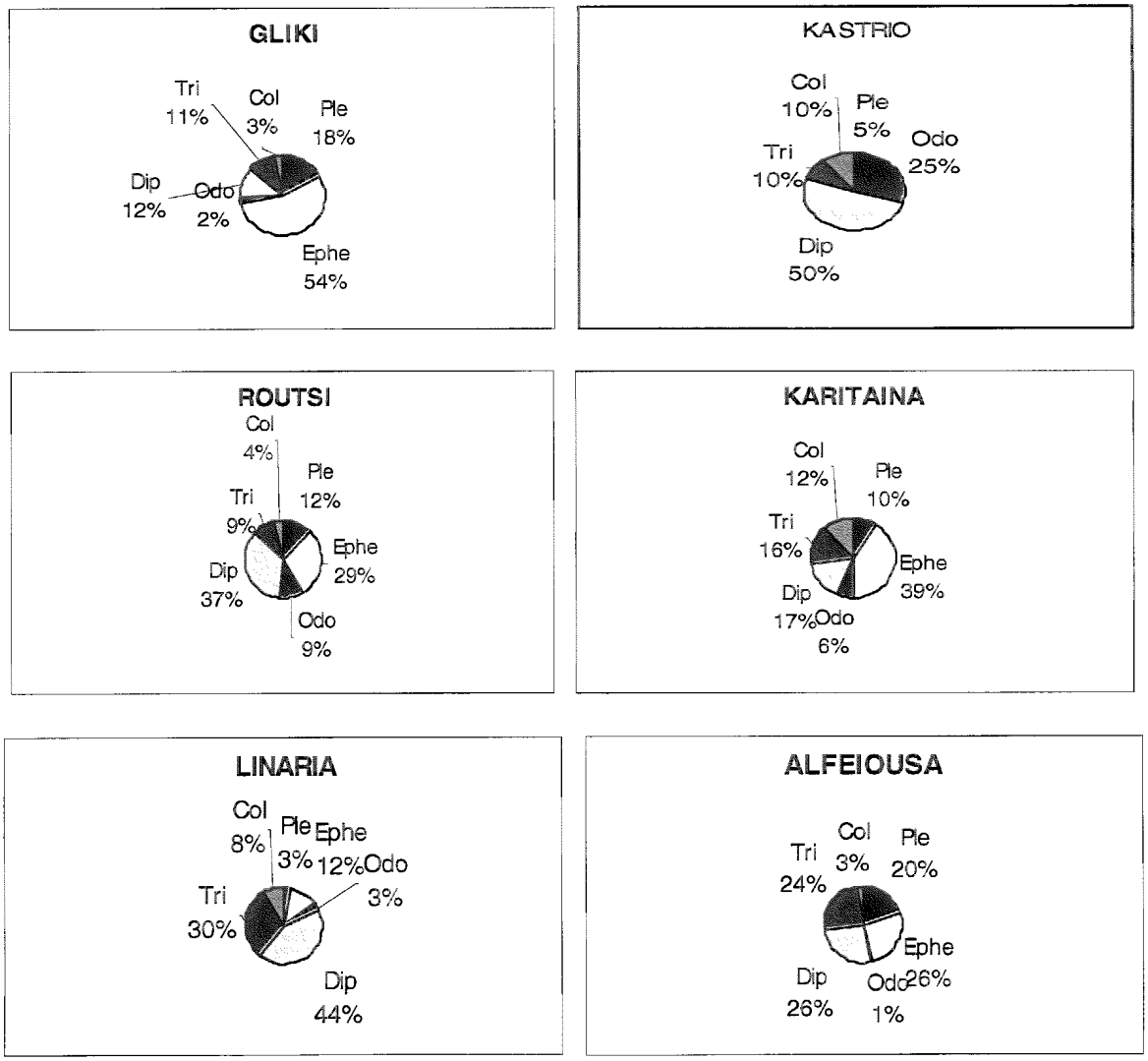


FIGURE 4b
Insect's percentage distribution at each site.

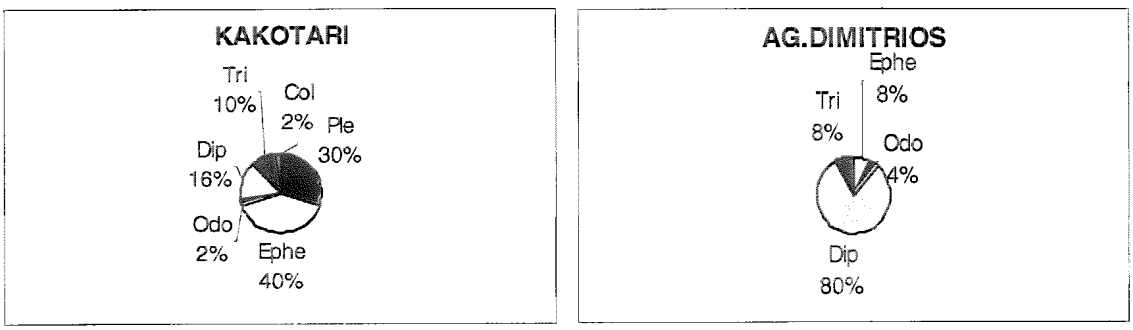


FIGURE 4c
Insect's percentage distribution at each site.

DISCUSSION AND CONCLUSION

According to our research Ephemeroptera, Diptera and Plecoptera were the most abundant orders at the Greek rivers. At the springs of Kalamas where the substrate type was sandy mud, Ephemeroptera were more abundant with representatives of the genera *Heptagenia, Ephemerella, Ephemera, Caenis, Habrophlebia, Siphlonurus, Baetis* and *Cloen* although they are usually found on rocks [20].

Ephemeroptera were followed by Plecoptera with the species *Perla bipunctata, Perla marginata* and *Dinocras cephalotes* and the genera *Perlodes, Isoperla, Leuctra, Capnia* and *Taeniopteryx*. The high values of conductivity did not seem to affect the presence of aquatic insects at this site whose fauna was the richest amongst the sites examined with many genera, belonging to the orders of Odonata, Trichoptera, Coleoptera and Diptera. At Brosina, where the substrate type was middle coarse sand and Neraida, where it was poorly sorted gravel, Ephemeroptera were still the most abundant order with representatives of the genera *Heptagenia, Ephemerella, Ephemera, Caenis* and *Baetis*. At these sites Trichoptera was the second most abundant order with the species *Hydropsyche instabilis* and *Hydropsyche angustipensis* and the genera *Rhyacophila* and *Sericostoma*. The high values of sulfates (>100 mg l^{-1}) at Kalamas did not prevent it from having a rich and diverse insect fauna. The richness of this river fauna can be attributed to its geomorphology and the presence of nutrients, which favored the growth of many diverse taxa. Especially for the site of the springs of Kalamas, the large daily and seasonal temperature range created optimum or favorable thermal conditions for a larger number of species than in the other sites where thermal variation is minimum [21, 22].

At Gliki (Acherontas), where the substrate type was gravel, Ephemeroptera dominated, followed by Plecoptera, Diptera and Trichoptera but with fewer taxa than those found at Kalamas. This can be attributed to the less thermal variation of Gliki and to the different geomorphology of this river. At Kastrio Diptera was by far the most dominant order. Sand and gravel gathering affected this site, preventing the growth of other taxa and favoring the presence of the Dipteran family Chironomidae that can be found in almost every imaginable habitat [20].

At Routsi (Alfeios), although the substrate type was poorly sorted gravel Diptera dominated, followed by Ephemeroptera whilst in Karitaina (with the same subtrate type) Ephemeroptera were more abundant, followed by Diptera. At Karitaina despite the high values of conductivity and sulfates intolerant taxa like Ephemeroptera, Plecoptera and Trichoptera occurred. The higher flow velocity in combination with the presence of big rocks at the river bed, which increases water oxygenation, favored the presence of these taxa. At Alfeiousa the substrate type of poorly sorted gravel favored the abundance of Ephemeroptera and Diptera whilst at Linaria with substrate type of coarse sand Diptera were the most abundant.

At Kakotari (Pineios), with the substrate type of sandy mud, Ephemeroptera dominated, followed by Plecoptera. This site's fauna was one of the richest amongst those studied. This can be attributed to the greater range of temperature than other sites, at the moderate flow velocity and at the geomorphology of this site. At Agios Dimitrios, where the substrate type was poorly sorted gravel, Diptera were by far the most abundant taxa. This site was characterized by having the "poorest" insect fauna. This is attributed to the fact that it was affected by the overflowing of a dam existing very close to this site as well as by the intense sand and gravel gathering that prevented many taxa (with the exception of Diptera, especially Chironomidae) to grow.

In conclusion, the insect fauna of the Greek rivers studied was "rich" consisting of many diverse taxa. Epehemeroptera was the most abundant order found in every substrate type and in every site followed by Diptera, Plecoptera and Trichoptera. Kalamas was the richest river, followed by Pineios, Acherontas and Alfeios. The springs of Kalamas was the "richest" site containing many families of Ephemeroptera, Plecoptera, Trichoptera, Diptera, Odonata and Coleoptera. The site Kakotari (Pineios) was the second "richest" site. The richness of these two sites (which are the springs of Kalamas and Pineios, respectively) can be attributed to: a) the substrate type of sandy mud, that favored the presence of a diverse insect fauna, b) the moderate flow velocity and c) the large daily and seasonal temperature range of these sites, which creates favorable conditions for a larger number of species.

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