Inland Waters of Samothraki Island (Greece): Exploratory Ecological Assessment

N. SKOULIKIDIS - A. LAMPOU - I. KARAOUZAS - S. ZOGARIS - K. GRITZALIS

Hellenic Centre for Marine Research, Institute of Marine Biological Resources & Inland Waters, 46.7 km Athens-Sounion Ave., Anavyssos 19013, Attika, Greece.
**E-mail: nskoul@hcmr.gr*

Abstract

Samothraki is a northern Aegean island with poorly studied inland waters. River features show a high degree of naturalness; lotic, lentic and riparian conditions exhibit significant perennial flows with waterfalls, pools and ancient riparian woodlands. In this study, we document surface and ground water quality status based on recent field observations, data collection and analyses. The island has a steep relief with high elevation (1.611 m. asl.) and significant erosion. Basalts and granites are frequently encountered and the dominating impermeable substrates produce many springs and surface waters, including 23 river sub-basins. The results regarding water chemistry showed low stream water conductivities due to the siliceous substrate. Cold springs revealed a good drinking water quality, while hot springs that are commonly used for curative drinking purposes exceeded drinking water quality standards. Overall, levels of major ions, nitrate and nitrite in rivers increase during high flow periods due to flashing processes, whereas ammonia and phosphate are higher in summer, mainly as a result of natural (organic matter mineralization in pools) and semi-natural (free grazing goats) pressures. However, all stream sites examined exhibit a good to high chemical-physicochemical status. Regarding biological status assessment, stream sites vary from good to high status, except from Tsivdogianni which varies from good to moderate status. Macroinvertebrate fauna was mainly represented by the orders Ephemeroptera, Diptera and Amphipoda. No freshwater fish were recorded in river reaches that are not adjacent to the sea. The existence of steep slopes with rapidly running waters and extreme flood events are most likely responsible for the inability of the system to support fish fauna. It is hypothesized that poor in-stream natural habitat structure and flashy stream dynamics along the river courses throughout the year cause naturally poor biocommunities. In addition, mineralization processes taking place in stream pools increase nutrient concentrations. The unique character of the running waters of Samothraki Island requires the development of a specific methodological approach for ecological status assessment.
Keywords: Ecological quality, island streams, springs, Samothraki.

Introduction

Samothraki is a unique island in the northern Aegean Sea with nearly pristine natural features and numerous permanent streams flowing through deep ravines with impressive waterfalls, commonly followed by small plateaus with long pooling waters, all surrounded by remarkable riparian forests. The island had attracted our scientific interest and its water resources have become subject of research more than a decade. Here we present results related with aquatic quality and the assessment of the ecological status of streams according to the demands of the WFD 2000/60/EC.

Material and methods

Study area

Samothraki Island is located in the northeastern Aegean Sea (Thrace, Greece), 45 km south of the Greek coastal city of Alexandroupolis. It covers an area of 178 km2 and has a rough relief and an ellipsoid shape. The name of the island (Samo-Thraki) means “high” Thraki (i.e. Thrace). The largest area of the island is covered by Mt. Saos peaking at 1611 m a.s.l., the second highest island peak after the Cretan island. The island presents very steep slopes, ranging between 15 and 30o, with high denudation rates and linear, deep erosion, whereas the morphology of river terraces reveal the rise of Mt. Saos (Vouvalidis et al., 2005; Syridis et al., 2005). Depending on its morphology, the island may be divided into two regions (a northeastern and a southwestern region). The first one consists of steep slopes, forests and densely shrublands while the second one is hilly (Syridis et al., 2005) with agricultural lands and olive groves. However, there are several extensive areas with sparse or nearly no vegetation (bare soil and rock). The existence of these areas is due to anthropogenic deforestation from woodcutting, wild fires, and overgrazing, all resulting to high rates of soil erosion. In contrast, the island’s ravines have impressive riparian woodlands, particularly dominated by Oriental Plane (Platanus orientalis), with many “ancient trees” many of which are centuries old. The existence of steep slopes, that cause extreme flood events are likely responsible for the inability of the system to support fish fauna as it was concluded during different sampling periods (Gritzalis, 2006; Lampou, 2012). However, estuaries or other coastal habitats that may support eels have not been sampled exhaustively. Eleven very small wetlands, including a unique lagoon system are found on the island’s coasts (Catsadorakis & Paragamian, 2007). The climate of the island is of a Mediterranean type. Winters bring rain and snow, and summers are hot and dry. The mean annual rainfall for the period 1986-2008 is 605 mm (Lampou, 2012; Romaidis et al., 2010). The geology of the island is mainly composed of a Jurassic – Upper Cretaceous basement unit (3% of the island’s area) consisting of low grade metamorphosed sedimentary and volcanic rocks, and a Cretaceous ’ophiolitic complex’ (31% of the island’s area), partially intrusive into the ’basement unit’, both locally unconformably overlain by unmetamorphosed Tertiary sedimentary and volcanic rocks (Upper Eocene-Lower Miocene) (8% of the island’s area) that can mainly be found in the western and eastern part of the island. In Miocene, a granite (26% of the island’s area) intruded into the Ophiolite complex in south-central Samothraki. The youngest successions on Samothraki are marine sediments of Pliocene age and Quaternary deposits (32% of the island’s area), which occur around the peripheral parts of the island. At the last glacial maximum (21,500 years BP), when the sea level was 120 m lower than today, Samothraki Island constituted a high mountain of 1731 m connected to the mainland (Vergis, 1984; Seymour et al., 2006; Koglin et al., 2009). The island is rich in both spring and surface waters. Streams are fed by precipitation, snowmelt and springs. Within faults or weathering zones in volcanic rocks, as well as within quaternary sediments, low potential aquifers are developed that feed small springs (Vergis, 1984). As a result of the geological and tectonic settings of the island, hot springs with water temperatures of 35-58 oC occur in the island especially in the Therma area (Kolios et al., 2007), within the Tsivdogianni river basin. The hydrographic network of the island is mainly developed on hard substrate (ophiolites and granites) and presents a radial form, except of Fonias River that presents a dendritic hydrographic network (Vouvalidis et al., 2005). Only in the SW part of the island, rivers flow through recent sedimentary series. The development of the network started in Miocene synchronously with the granite intrusion that upraised Mt. Saos (Vouvalidis et al., 2005). Steep slopes and high runoff in combination with uplift movements have created ravines with impressive waterfalls, commonly followed by small plateaus with long pooling waters (locally known as “vathres”=deep ponds)|. For example, Xiropotamos River is characterized by five terraces (Vouvalidis et al., 2005). During the winter, rivers flow rapidly, transporting large quantities of mainly coarse sediments. In summer the flow is reduced and most of the rivers such as Xiropotamos and Tsivdogiannis do not outflow in the sea thus having an intermittent flow pattern. The island sustains 16 small settlements with 2,840 residents. Human pressures such as domestic solid wastes, domestic wastewaters (served by septic tanks), land use change and livestock farming have only local impacts. Nutrients derived from agricultural crops are restricted, due to the limited extent of agricultural areas. Hence, the most important pressure in Samothraki is livestock farming, mostly represented by free grazing goats.

Four small river basins were investigated in this study; Tsivdogiannis (area: 5.3 km2), Fonias (9.5 km2) and Agkistro (6.9 km2), which are located in the northeastern part of the island, and Xiropotamos (16.1 km2) situated in the southwest. Apart from Fonias basin, small settlements are found in Xiropotamos (50 residents), in Tsivdogiannis (73 residents) and Agkistro (52 residents) basins. The largest percentage of land use in Agkistro (94.3%), Xiropotamos (79.8%), Fonias (70.2%) and Tsivdogiannis (54.2%) river basins is occupied by grasslands. Regarding geology, Xiropotamos and Tsivdogiannis basins are dominated by ophiolites (56.8% and 70.1% of the basin area, respectively). The Fonias river basin mainly consists of granites (81.7%), while in Agkistro river basin occur primarily Quaternary rocks (36.2%). Two sampling sites were selected along Xiropotamos (X1 and X2), Tsivdogiannis (GV1 and GV2) and Fonias (F1 and F2) rivers and one along Agkistro (AG) river (Fig. 1). Also, samples from four cold springs, i.e. Palaiopolis (PAL), Kariotes (K), Paraga (P), Agios Georgios (A.G.), and two hot springs at Therma, i.e. T(A) and T(B), were taken (Fig. 1). Sampling campaigns were carried out primarily during summer and winter.

Environmental and Biological Data

Data used in this study were collected within the AQEM and STAR EU R&D programs, from a Master Thesis (Lampou, 2012) and from field sampling carried out during the winter of 2012. Macroinvertebrate samples were collected from all streams sites. The collection of benthic macroinvertebrates was performed by 3-minute kick and sweep (Armitage & Hogger, 1994) plus one minute of scanning the riparian vegetation where it was existed (Wright, 2000; Kemitzoglou, 2004) and with the STAR-AQEM methodology. Hand net with mesh size of 0.09 cm, which follows ISO 7828:1985 (renamed EN 27828 1994, Davies 2001), was used. Macroinvertebrate identification to the lowest possible taxa level was conducted using a stereoscope (Novex Holland Model 65.560 RZT-SF) and various identification keys (Campaioli et al., 1994; Tachet et al., 2000; Orive & Rallo, 2002; Patsia, 2009).

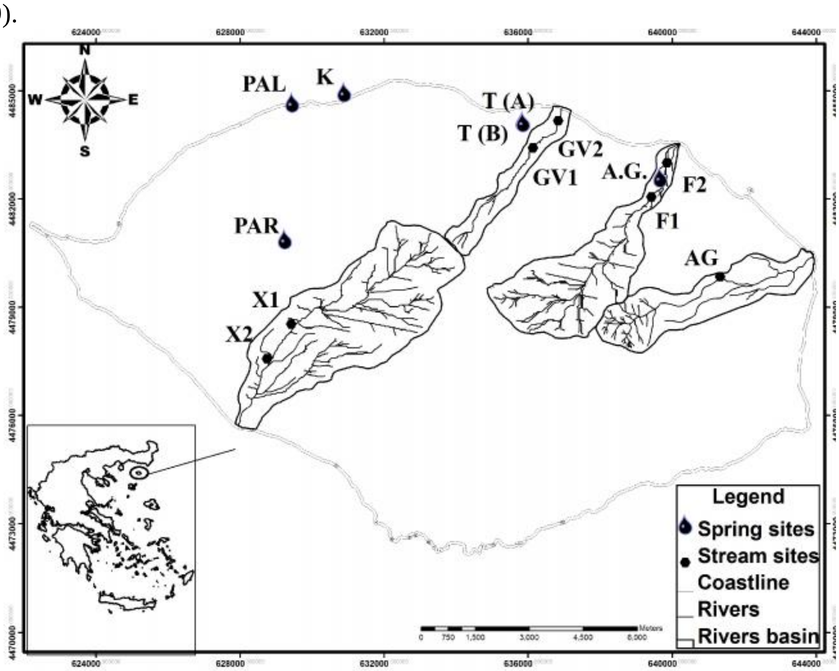

Fig. 1. Map of study area that presents the river basin with the hydrographic network of each river and the selected sampling sites.

Environmental variables such as altitude, width and depth of the river, current velocity, riparian vegetation and river's substrate for each site were also recorded. Water samples for laboratory analyses of major ions and nutrients were collected, along with in situ measurements of physical-chemical parameters (water temperature, dissolved oxygen, pH and conductivity) for both stream and spring (cold and hot) sites. Finally, heavy metal analysis was performed for the thermal springs. Some of the values were compared with the thresholds according to Y2/2600/2001 (Drinking Water Standards) and M.D. 4813/98 (Irrigation Standards).

Data analysis

Biotic and diversity indices were applied in order to assess the biological status of each sampling site, including BMWP, IBMWP, BBI, IBE, ASPT, STAR_ICMi, EQR_STAR_ICMi, HES, and several diversity indices. To classify the chemical-physicochemical status of the sites, the Nutrient Classification System (NCS) was applied for nutrients, which was developed for Greek rivers and streams (Skoulikidis et al., 2006), and the Norwegian system for dissolved oxygen (Cadorso et al., 2001). Hierarchical clustering was applied in order to identify the similarities in macroinvertebrate assemblages among seasons and years. To identify if there are differences in the macroinvertebrate community structure among seasons and years, a one-way ANOSIM test was applied. The results are expressed with a value of R which ranges usually between 0 and 1, indicating a differentiation degree between the sites (Clarke & Gorley, 2001). R is close to zero, if the null hypothesis is true, when there are no differences between different groups. R is 1 when all repetitions in the sites of a group are so similar to each other than with the other sites. It is unlikely, the value of R will be less than 0 (indicates an error in the data).

To examine the association of macroinvertebrate assemblages with environmental variables an indirect gradient analysis was performed. Initially, Detrended Canonical Correspondence Analysis (DDCA) was applied. This analysis aims to check if biological data respond linearly in the theoretical environmental variables which are manufactured by this process (ordination axes) or if they have a better response around of the values of these theoretical variables (Ter Braak 1986). When the length of gradient of the first ordination axis is >2 SD (standard deviation) a Canonical Correspondence Analysis (CCA) is performed. If the length of gradient is < 2 SD, then the benthic macroinvertebrates respond more linearly in the theoretical variables and a Redundancy Analysis (RDA) is applied (Ter Braak & Prentice 1998). After the analysis application, the significance of environmental variables is checked based on the Monte Carlo test (that is variables have P-value < 0.05). Then, more variables are selected provided that the inflation factor is less than 20.

Results

Chemical-physicochemical status of stream sites

The values of the physical – chemical parameters of the river sites are presented in Table 1. The levels of the examined parameters were below the drinking and irrigation water standards. The chemical-physicochemical status (carried out by averaging the status of individual parameters according to NCS and the DO levels) ranged between high and good (Table 2).

Biological status of stream sites

For the assessment of the biological status, six metrics were selected (Table 3). No significant differences between the metrics of macroinvertebrates were found. If we consider the average of the metrics applied, most of the sites score over the good/moderate boundary. Only site GV1 scored moderate in winter 1999 and late summer 2011 and site X1 scored poor in late summer 2011.

Table 1. Concentrations of physicochemical and chemical parameters of the sampling sites along with the Drinking water and the Irrigation standards. (1: summer, 2: winter).

Year	Season	Sampling Site	DO (mg/l)	BOD5 (mg/l)	pH	T (°C)	Cond (μS/cm)	TDS (mg/l)	N-NO2 (mg/l)	N-NO3 (mg/l)	N-NH4 (mg/l)	P-PO4 (mg/l)	TN (mg/l)	TP (mg/l)	Discharge (m3/sec)
1999	1	F2	9.1	-	7.45	20.3	69	-	0.0024	0.78	0.016	0.222	-	0.283	0.092
		GV1	8.02	-	8.58	21	112	-	0.0018	0.12	0.008	0.130	-	0.155	0.019
	2	F2	12.0	-	7.5	9.4	71	-	0.0036	0.89	0.012	0.036	-	0.041	0.224
		GV1	12.0	-	7.29	9.8	97	-	0.0018	0.86	0.008	0.023	-	0.042	0.05
2011	1	X1	9.5	7.3	8.3	18.2	219	-	<0.005	0.532	0.009	0.009	-	-	0.093
		X2	10.0	7	8.3	19.1	239	-	<0.005	0.632	0.01	0.01	-	-	0.045
		F1	9.4	5.2	7.9	17.1	66	-	<0.005	0.378	0.018	0.018	-	-	0.082
		F2	9.2	7.1	7.9	17.8	66	-	<0.005	0.358	0.017	0.017	-	-	0.169
		GV1	9.9	8.5	8	15.8	93	-	<0.005	0.325	0.011	0.011	-	-	0.081
		GV2	9.8	8.1	8.1	16.5	92	-	<0.005	0.282	0.014	0.014	-	-	0.010
	2	X1	11.3	9.4	7.7	8.3	199	-	<0.005	0.329	0.068	0.013	-	-	0.046
		F1	13.5	9.6	-	4.8	53	-	<0.005	0.116	0.065	0.015	-	-	0.009
		F2	12.5	9.2	-	6.5	62	-	<0.005	0.148	0.059	0.013	-	-	0.016
		GV1	11.1	9	-	8.3	89	-	<0.005	0.134	0.048	0.013	-	-	0.034
2012	2	F1	10.12	-	8.78	11.1	67	36	<0.005	1.51	0.023	0.013	1.7	<0.026	0.121
		F2	7.7	-	8.8	16.8	91	47	<0.005	0.63	0.020	0.013	<1	<0.026	0.066
		GV1	9.14	-	8.75	14.3	127	-	<0.005	0.77	0.026	0.013	1.5	<0.026	0.035
		AG	7.7	-	9.16	13.9	116	61	<0.005	1.40	0.021	0.013	<1	<0.026	0.073
DWSa					6.5-9.5		<2500		0.152	11.29	0.389	0.306			
IWSb			25							11.29	0.778	2.183			

DWS: Drinking Water Standards, a: COUNCIL DIRECTIVE 98/83/EC, IWS: Irrigation Water Standards, b: MD 4813/98

Table 2. Classification of each sampling site according to its physico-chemical status using dissolved oxygen and nutrient standards. (H: High, G: Good, M: Moderate, P: Poor, B: Bad).

Year	Season	Sampling Site	DO	N-NO2	N-NO3	N-NH4	P-PO4	Total P	Classification
1999	Summer	F2	H	H	M	H	P	P	G
		GV1	G	H	H	H	M	G	G
	Winter	F2	H	G	M	H	H	H	G
		GV1	H	H	M	H	H	H	G
2011	Summer	X1	H	H	G	H	H	-	H
		X2	H	H	M	H	H	-	H
		F1	H	H	G	G	H	-	H
		F2	H	H	G	G	H	-	H
		GV1	H	H	G	H	H	-	H
		GV2	H	H	G	H	H	-	H
	Late Summer	X1	H	H	G	M	H	-	G
		F1	H	H	H	M	H	-	G
		F2	H	H	H	G	H	-	H
		GV1	H	H	H	G	H	-	H
2012	Winter	F1	H	G	P	H	H	H	G
		F2	G	G	M	H	H	H	G
		GV1	H	G	M	H	H	H	G
		AG	G	G	P	H	H	H	G

Table 3. Calculated scores of the indices IBMWP, BMWP, ASPT, STAR_ICMi, EQR_STAR_ICMi, HES and quality classification of each site. (H: High, G: Good, M: Moderate, P: Poor, B: Bad).

			Metric scores									
Sampling Site			IBMWP	Class	BMWP	Class	ASPT	STAR_ICMi	Class	EQR_STAR_ICMi	HES	Class
1999	Summer	F2	159	H	175	H	6.481	0.993	H	1.012	4	G
		GV1	130	H	125	H	6.579	0.918	G	0.936	3.5	G
	Winter	F2	61	G	61	G	6.1	0.810	G	0.826	3	M
		GV1	46	M	39	M	5.571	0.638	M	0.650	2.5	M
2011	Summer	X1	99	G	98	G	6.533	1.057	H	1.078	3.5	G
		X2	109	H	108	H	6.353	1.101	H	1.122	3.5	G
		F1	138	H	133	H	6.65	0.924	G	0.942	3.5	G
		F2	145	H	149	H	6.478	0.804	G	0.820	4	G
		GV1	94	G	90	G	6.429	0.918	G	0.936	3.5	G
		GV2	68	G	65	G	5.417	0.739	G	0.754	2.5	M
	Late Summer	X1	32	P	32	P	5.333	0.426	P	0.434	2	P
		F1	98	G	101	H	6.733	0.894	G	0.911	4	G
		F2	106	H	97	G	6.467	0.843	G	0.860	3.5	G
		GV1	48	M	48	M	6.636	0.496	M	0.506	3.5	G
2012	Winter	F1	139	H	141	H	6.714	1.054	H	1.074	4	G
		F2	150	H	152	H	6.909	1.082	H	1.103	5	H
		GV1	86	G	73	G	6	0.739	G	0.753	4	G
		AG	138	H	131	H	6.55	1.095	H	1.116	5	H

Ecological status of stream sites

The ecological status of each sampling site (Table 4) was assessed taking into account its biological and physico-chemical status (according to the one out all out principle). Most of the sites showed a good ecological status. The ecological status of site X1 in late summer 2011 was classified as poor and site GV1 during summer 1999 and late summer 2011 was classified as moderate.

Macroinvertebrate assemblages & Multivariate analysis

A total of 7.252 individuals, which belong to 60 macroinvertebrate families, were collected and identified from all sampling sites. The most dominant taxa were the species of the Baetidae and Chironomidae families, which comprised 24.6% and 22.1% of the total abundance, respectively. Gammaridae, the next most abundant family accounted for 10.7%, followed by Heptageniidae (7.2%), Hydropsychidae (5.4%), Simuliidae and Caenidae (5%). Baetidae, Chironomidae and Hydropsychidae were the families that were found in all sampling seasons during the years. The abundance of benthic macroinvertebrates was different during the high and low flow period for all rivers and sites. However, according to the ANOSIM test, the null hypothesis applies. That means there were no significant seasonal and yearly differences among macroinvertebrates communities in sampling sites (R = 0.181 and R= 0.196, respectively). The hierarchical clustering analysis, categorized the macroinvertebrate communities of the sampling sites into five groups, based on the Bray-Curtis similarity index (Fig. 2). Overall, stream sites were grouped according to temporal issues, i.e. sampling sites were grouped according to either the sampling period or the year of sampling. Particularly during summer 2011, biocommunities seem to be very similar among the examined streams (group d). In some cases, the grouping was based on both of these parameters. An exception was site GV1 during the high flow period in 2011 and 2012, which presented a separate group (a). Another group was composed by sites F2 and GV1 for the low flow period in 1999 (group c). Similarity Percentages Analysis showed that group a and group c presented average dissimilarity 68.54%. The average dissimilarity between the group a and the groups b, d and e was 61.73%, 64.36% and 67.37%, respectively. This dissimilarity was due to the low species richness and abundance of group a sites.

Table 4. Ecological status of each sampling sites according biotic indices and nutrient classification. (H: High, G: Good, M: Moderate, P: Poor, B: Bad).

Sampling Site			Ecological status			
			IBMWP& NCS	BMWP & NCS	STAR_ICMi & NCS	HES & NCS
1999	Summer	F2	G	G	G	G
		GV1	G	G	G	G
	Winter	F2	G	G	G	M
		GV1	M	M	M	M
2011	Summer	X1	G	G	H	G
		X2	H	H	H	G
		F1	H	H	G	G
		F2	H	H	G	G
		GV1	G	G	G	G
		GV2	G	G	G	M
	Late Summer	X1	P	P	P	P
		F1	G	G	G	G
		F2	H	G	G	G
		GV1	M	M	M	G
2012	Winter	F1	G	G	G	G
		F2	G	G	G	G
		GV1	G	G	G	G
		AG	G	G	G	G

As mentioned before, the Detrended Canonical Correspondence Analysis (DDCA) was initially applied. The length of gradient of the first DDCA axis was 2.128, thus the most suitable direct gradient analysis was CCA. Seven of the 28 environmental variables which were used in CCA analysis, explained in the best possible way macroinvertebrate variation and ordination. The first two axes explained 30.6% and 50.1% of species variation according their relation with environmental variables, respectively. The Monte Carlo test showed that Grasslands (%, p=0.002), Dissolved Oxygen (DO, mg / l, p=0.006), Conductivity (C, μS/cm, p=0.016) and Water Discharge (m3/sec, p=0.038) were the most significant environmental variables, followed by Temperature (T, oC), ammonium concentration (N-NH4, mg/l), and phosphorus concentration (P-PO4, mg/l), according to inflation factor. The correlation of environmental variables with CCA axes indicated that the first ordination axis (horizontal axis) was mostly related to grasslands and water discharge and the second axis (vertical axis) was associated with conductivity, temperature, DO, P-PO4 and N-NH4 (Fig. 3). Sites of Fonias River in 2011 samplings were positively correlated with discharge and consisted of the left bottom quadrant. Taxa which were distributed on the left upper and bottom quadrants are affected by grasslands. Generally, there was an obvious separation between the rivers. Sites of Fonias River were on the left upper and bottom quadrants and were related to grasslands, discharge, P-PO4 and N-NH4. Sites of Tsivdogiannis River were on the right upper and bottom quadrants and were associated with DO, conductivity and temperature. Finally, sites of Xiropotamos River were distributed on the upper right quadrant and were related to conductivity and water temperature.

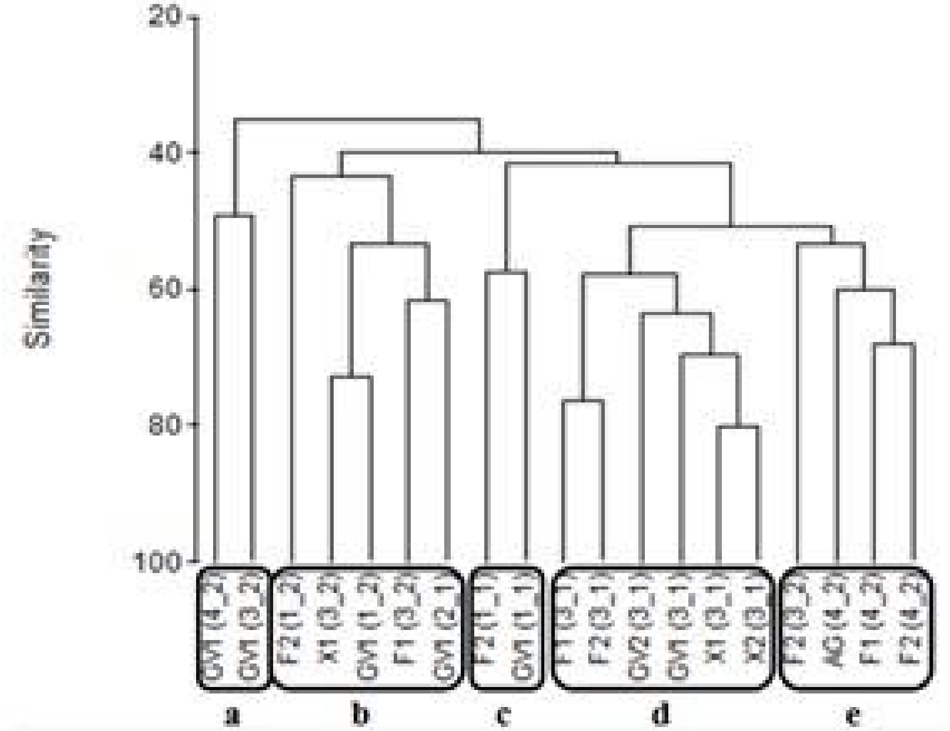

Fig. 2. Hierarchical clustering analysis in the sampling sites of Xiropotamos (X), Tsivdogiannis (GV), Agkistro (AG) and Fonias (F) river basin. The first number in the site name refers to the year of sampling (1: 1999, 2:2002, 3:2011, 4:2012) and the second one to the sampling period (1: summer, 2: winter).

Cold and hot springs

The values of the physicochemical parameters of the cold and hot springs are shown in Table 5. Overall, cold springs presented, according to drinking water standards, good quality, and were classified, as medium hard waters according to Hem (1985) and presented low mineralization (Skoulikidis et al., 2006). They are all of a calcium bicarbonate type, except from one spring (Palaeopolis spring) that belongs to a Na-Cl type, probably due to sea water influence (the spring is very close to the shore). The thermal waters are of the Na-Cl type with very high conductivity and total dissolved solids (TDS) values and are rich in major ions and trace elements. A number of parameters [Conductivity, Na, Cl, NH4, Mn] in these springs exceeded the drinking water quality standards.

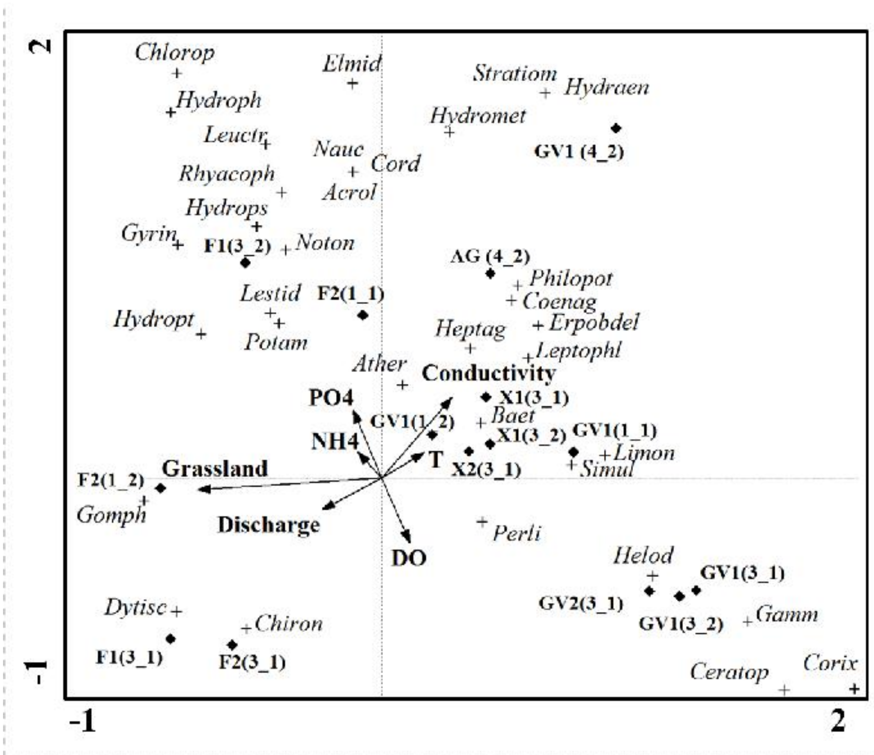

Fig. 3. Correlation plot of sampling sites (•) and macroinvertebrate families (+) with significant environmental variables. The first number in the site name refers to the year of sampling (1: 1999, 2:2002, 3:2011, 4:2012) and the second one to the sampling period (1: summer, 2: winter).

Discussion

Up to date, the running waters of Samothraki have not been studied for their ecological status. In this work the ecological status of seven stream sites in four river basins was evaluated. Of the four investigated rivers, only the Fonias River flows into the sea throughout the year, exhibiting perennial flow. Most of the other rivers at their lower reaches are dominated by intermittent and ephemeral flow. Overall, the ecological status of the running waters of Samothraki is good where the most significant pressure is water abstraction as is evident in Xiropotamos River. Low population density, tourism and agro-industrial development as well as the extensive mountainous topography provide high quantities of clean, turbulent waters. An increase of conductivity during the high flow period compared to the low flow period was evident, a phenomenon also observed in other Greek rivers (e.g. Lekka et al., 2004; Karaouzas et al., 2007; Skoulikidis, 2009). This seasonal trend of dissolved solid concentration is attributed to flashing of salts that accumulates in the soil during the dry period of the year (Skoulikidis 1993, Skoulikidis et al., 2006; Skoulikidis 2009). Nevertheless, the conductivity values were generally low. This was due to the presence of siliceous substrates (Gritzalis 2006, Skoulikidis et al., 2006). Similarly with conductivity, the concentrations of nitrate and nitrite were higher during the high flow period for all sites. This may be attributed to organic matter mineralization during soil leaching processes (e.g. Skoulikidis & Amaxidis, 2009). In contrast, ammonium and phosphorus concentrations were higher in the low flow period for all sites. This seasonal trend is normal for most Greek rivers and is attributed to point sources of ammonia and phosphorous (e.g. Skoulikidis 2009). Since in the examined basins only minor point pollution sources exist, high values of these compounds may be also due to mineralization of organic matter that accumulates in standing waters occurring in several plateaus along the river courses. These pools are eutrophic as the existence of filamentous algae communities indicates (Gritzalis, 2006). An additional cause may be excrements of free grazing goats that are gathering for shade and water. The river-bed substrate at all sites consisted mainly of coarse material (cobbles and boulders). This substrate composition is typical for small mountainous river basins with steep slopes (Skoulikidis et al., 2006).

Table 5. Physicochemical parameters of cold and hot springs.

	T (oC)	pH	C (μs/cm)	DO (mg/l)	TDS (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	HCO3 (meq/l)	CO3 (meq/l)
T(A)	41.8	6.63	19000	2.1	>2000	768.41	76.61	3538.2	478.3	6.696	0
T(B)	42.8	6.62	17000	4.9	>2000	645.96	37.25	4042.1	553	6.652	0
PAL	16.4	9.11	222	4.95		33.38	3.47	89.65	11.54	1.578	0
K	16.7	8.28	267	7.2	145	36.47	6.35	10.24	0.47	2.008	0
A.G.	15.5	8.44	262	8.24	140	44.29	3.29	8.28	0.42	2.214	0
PAR	16.8	9.04	136	9.32	73	19.75	2.22	6.39	0.38	1.015	0
DWS		6.5-9.5a	2500 a					200 a			

	SO4 (mg/l)	Cl (mg/l)	NO3 (mg/l)	NO2 (mg/l)	NH4 (mg/l)	PO4 (mg/l)	TN (mg/l)	TP (mg/l)	SiO2 (mg/l)	Total Hardeness (mg/l CaCO3)
T(A)	77.37	4384.9	0.2	0.008	10.34	0.09		0.032	74.4	2232.30
T(B)	23.87	4299.2	0.2	0.008	9.15	0.08		0.029	87.6	1764.89
PAL	15.96	140.66	7.41	0.008	0.016	0.09	1.7	0.038	11.23	97.56
K	15.12	14.6	5.35	0.008	0.028	0.04	1.3	0.013	15.12	117.11
A.G.	9.33	13.71	9.86	0.008	0.021	0.04	2.7	0.013	9.24	124.04
PAR	7.59	7.77	5.82	0.008	0.042	0.04	1.5	0.013	7.61	58.41
DWS	250 a	250 a	50 a	0.50 a	0.05b	0.27 b				

	Mn (μg/l)	Fe (μg/l)	Co (μg/l)	Ni (μg/l)	Cu (μg/l)	Zn (μg/l)	Cd (μg/l)	Pb (μg/l)	Sr (μg/l)
T (A)	346.3	94.7	0.771	1.515	2.086	2.148	0.032	0.347	13880
T (B)	312.3	159.5	0.651	1.345	1.642	6.424	0.028	0.289	12420
DWS	50c	300d	20 c	20a	20 c	500 c	1 c	50 d	-

C: conductivity, DWS: Drinking Water Standrads, a: COUNCIL DIRECTIVE 98/83/EC, c, d: category A1, b: guide, c: mandatory, COUNCIL DIRECTIVE 75/440/EEC.

Ephemeroptera, Diptera and Amphipoda were the most dominant macroinvertebrate families in all sites. No significant differences were observed between the indices used the classification of the biological status of the sites. The poor biological status of site X1 in late summer 2011 was mostly attributed to the fact that macroinvertebrate sampling was performed shortly after flow has been restored, thus the benthic fauna has not been fully recolonized. According to the cluster analysis, sampling sites of the three rivers (Xiropotamos, Tsivdogiannis and Fonias) revealed similar macroinvertebrate community composition structure. The chemical-physicochemical and biological status of the rivers was lower than expected. Poor in-stream natural habitat structure and flashy stream dynamics may result to naturally poor biocommunities. However, this hypothesis needs further examination. In addition, mineralization processes taking place in pools increase nutrient concentrations in stream water. Finally, the waters of the cold springs' were found to be suitable for drinking purposes. In contrast, hot springs that are commonly used for drinking, since it is believed that their effects are curative, exceeded drinking water quality standards.

Conclusions

Samothraki Island sustains interesting inland water environments and high degree of naturalness primarily due to its unique geomorphological conditions that hinder any intense human activities above 200 m asl; however it has been poorly studied by aquatic scientists. Baseline natural history description of the island's waters, lotic and lentic habitats, wetlands and associated riparian zones, particularly their biological attributes, have not been adequately studied. Specific stream typologies and reference conditions for the island's stream lotic features have not been developed. Our exploratory survey work has helped review the situation and provided initial inroads towards building knowledge by employing standardized approaches for ecological quality assessment. According to the present investigation, although existing biological indices showed no major differences among them, they do not seem to respond adequately to the actual status of the rivers as perceived by our research team's expert opinion. The same may be valid for nutrients. We have expected lower nutrient levels (see Skoulikidis & Amaxidis, 2009) matching with the nearly "pristine" conditions of the island's mountainous part. Hence, we presume that in the case of Samothraki, the existing Nutrient Classification System (NCS) may be not applicable, since N and P compounds may originate through natural processes occurring in stream pools or during flash events. Thus, because of the peculiar nature of Samothraki streams presenting standing waters and flashy dynamics there is a need to develop special indices for the assessment of their ecological status. This is valid also for Mediterranean streams exhibiting similar natural features in fragmented "cultural landscapes". A comprehensive aquatic, wetland and riparian research campaign is an immediate requirement, to provide a clearer impression of the island's inland waters resources and conditions.

Samothraki's waters are one of the island's most precious environments for biodiversity and local society. The island provides an outstanding research and conservation opportunity since the small stream environments could be holistically studied and particular management proposals could assist landscape management prescriptions. Large areas of the island have already been designated as conservation areas (Natura 2000 network) and a biosphere reserve proposal has recently been developed (Fischer-Kowalski et al. 2011). Well coordinated research could assist efforts to promote nature conservation initiatives.

References

Armitage P. D., Hogger J. (1994). Invertebrates Ecology and Methods of Survey. Sandy RSPB, Bedfordshire.

Cardoso A.C., Duchemin J., Magoarou P., Premazzi G. (2001). Criteria for the identification of freshwaters subject to eutrophication. EUR 19810 EN, EC Joint Research Centre, Ispra, Italy.

Campaioli S., Ghetti P.F., Minelli A. & Ruffo S. (1994). Manuale per il riconoscimento dei macroinvertebrati delle acque dolci italiane, Volume I, II, 484.

Catsadorakis G., Paragamian K. (2007). An inventory of the wetlands in the Aegean islands – Identity, ecological status and threats. WWF Greece, Athens, Greece.

Clarke K. R., Gorley R. N. (2001). Primer v5: User Manual/Tutorial. Plymouth Marine Laboratory: Plymouth.

Davies A. (2001). The use and limits of various methods of sampling and interpretation of benthic macroinvertebrates. Journal of Limnology, Volume 60 (1), 1-6.

Fischer-Kowalski M., Xenidis L., Jit Singh S., Pallua I. (2011). Transforming the Greek Island of Samothraki into a UNESCO Biosphere Reserve: An Experience in Transdisciplinarity, GAIA 20/3(2011), 81-190.

Gritzalis K. C. (2006). Biological Monitoring of Mediterranean Rivers with Special Reference to Greece. Biological Monitoring of Rivers, pp. 295 – 325.

Hem JD. (1985). Study and interpretation of the chemical characteristics of natural waters. US Geological survey Water Supply Paper 1473, 2nd ed., pp 363.

Karaouzas I., Gritzalis K. C., Skoulikidis N. (2007). Land use effects on macroinvertebrate assemblages and stream quality along an agricultural river basin. Fresenius Environmental Bulletin, Volume 16, 645-653.

Kemitzoglou D. (2004). Check of the effectiveness of the semi-quantitative method of benthic macroinvertebrate sampling. Master Dissertation Thesis, Aristotle University of Thessaloniki, Thessaloniki, 86.

Koglin N., Kostopoulos N., Reischmann T. (2009). Geochemistry, petrogenesis and tectonic setting of the Samothraki mafic suite, NE Greece: Trace-element, isotopic and zircon age constraints. Tectonophysics, Volume 473, 53–68.

Kolios N., Fytikas M., Arvanitis A., Andritsos N.& Koutsinos S. (2007). Prospective Medium Enthalpy Geothermal Resources in Sedimentary Basins of Northern Greece. Proceedings European Geothermal Congress 2007 Unterhaching, Germany, 30 May-1 June 2007.

Lampou A. (2012). Assessment of the ecological water quality, according to the Directive 2000/60/EC, in rivers of Samothraki island in 2011. Master Dissertation Thesis, Aristotle University of Thessaloniki, Thessaloniki, pp.158.

Lekka E., Kagalou I., Lazaridou – Dimitriadou M., Albanis T., Dakos V., Lambropoulou D., Sakkas V. (2004). Assessment of the Water and Habitat Quality of the Mediterranean River (Kalamas, Epirus, Hellas), in Accordance with the EU Water Framework Directive. Acta hydrochim. hydrobiol., Volume 32, 175 – 188.

M.D. 4813/98 (Gov. Gazette 575B/1161998) "Determination of the upper limit using surface water and special conditions of sewage disposal and industrial waste into natural receivers in the Prefecture of Trikala".

Ministerial Ordinance Y2/2600/2001 (Gov. Gazette 892B/1172001) "Water quality for human consumption", in compliance to the Directive 98/83 E.C. of the European Community Council on the "quality of water for human consumption", and the "Ministerial Ordinance G3a/761/6.3.68" (Gov. Gazette 189/volume II/1968).

Orive E., Rallo A. (2002). Rios de Bizkaia (Bizkaia rivers). Instituto de Estudios Territoriales de Bizkaia, pp. 258.

Patsia A. (2009). Photographic key characters of the Hellenic Evaluation System taxa of benthic macroinvertebrates. Case studies: Strymonas and Nestos rivers. Master Dissertation Thesis, Aristotle University of Thessaloniki, Thessaloniki, pp.255.

Romaidis I., Favas N., Katsanopoulos G. (2010). Project: Recording and valuation of the hydrogeological character of groundwater and aquifer systems of the country (7.3.2.1.). Subproject: Valuation of Thrace's water potential. IGME (Department of Water Resources and Environment, Department of Hydrogeology).

Seymour K. St., Tsikouras V., Kotopouli K., Hatzipanayiotou K., Pe-Piper G. (1996). A window to the operation of microplate tectonics in the Tethys Ocean: the geochemistry of the Samothrace granite, Aegean Sea. Mineralogy and Petrology, Volume 56, 251-272.

Skoulikidis N. (1993). Significance evaluation of factors controlling river water composition. Environmental Geology, Volume 22, 178-185.

Skoulikidis N., Amaxidis Y., Bertahas I., Laschou S., Gritzalis K. (2006). Analysis of factors driving stream water composition and synthesis of management tools – A case study on small/medium Greek catchments. The Science of the Total Environment,Volume362, 205-241.

Skoulikidis N. (2009). The environmental state of rivers in the Balkans - A review within the DPSIR framework. Science of the Total Environment, Volume 407, 2501–2516.

Skoulikidis N., Amaxidis Y. (2009). Origin and dynamics of dissolved and particulate nutrients in a minimally disturbed Mediterranean river with intermittent flow. Journal of Hydrology, Volume 37, 218–229.

Syridis G., Tsourlos P., Vouvalidis K., Albanakis K. (2005). Holocene stratigraphy and morphological evolution of the western low part of the Samothraki island. Bulletin of the Geological Society of Greek, Volume XXXVII (37), 38-50.

Tachet H., Richoux P., Bournaud M., Usseglio- Polatera P. (2000). Invertebres d'Eau Douce. Systematique, Biologie, Ecologie. (Editions) CNRS.

ter Braak C. J. F., Prentice C. (1998). A theory of gradient analysis. Advances in Ecological Research, Volume 18, 271-317.

ter Braak C.J.F. (1986). Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology, Volume 67, 1167-1179.

Vergis S. (1984). Hydrogeological research of Samothraki Island, Inst. of Geol. & Mineral. Research, Xanthi (in Greek), pp. 13.

Vouvalidis K., Syridis G., Albanakis K. (2005). Geomorphological surveys on Samothraki Island. The evolution of the hydrographic network. Bulletin of the Geological Society of Greek, Volume XXXVII (37), 29-37.

Wright J.F. (2000). An introduction to RIVPACS. In Wright J.F., Sutcliffe D.W., Furse M.T. (ed.), Assessing the Biological Quality of Fresh Waters. Freshwater Biological Association, pp. 1-24, Ambleside, UK.