STREAM ECOLOGICAL ASSESSMENT ON AN AEGEAN ISLAND: INSIGHTS FROM AN EXPLORATORY APPLICATION ON SAMOTHRAKI (GREECE)

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ABSTRACT

Island stream ecosystems, in contrast to continental lotic systems, have been poorly studied in the Mediterranean. Following the Water Framework Directive (2000/60/EC) process, we applied harmonized European methods for the ecological status assessment of the streams on Samothraki Island. Located in the northern Aegean Sea (Greece), Samothraki has a steep relief dominated by a high mountain massif and significant erosion. Stream corridors are characterized by a high degree of naturalness, waterfalls and remarkable rock-pools often buffered with ancient riparian woodlands. Benthic macroinvertebrates and environmental data were collected in 1999, 2002, 2011 and 2012 from four streams, while chemical quality analysis was conducted for cold and hot springs. The results of stream water analysis revealed that all sites exhibit good to high chemical-physicochemical quality. Overall, low stream water conductivities were recorded due to the siliceous substrate. Higher major ion, nitrate and nitrite levels during high flow periods were attributed to flashing processes, whereas higher ammonia and phosphate levels in summer were due to natural (organic matter mineralization in pools) and semi-natural pressures. Cold springs revealed good drinking water quality, while hot springs (used for curative drinking purposes) exceeded drinking water quality standards. Regarding bioassessment, stream sites varied from good to high quality, apart from one that varied from good to moderate. The unique physical character of Samothraki with perennial and intermittent running waters along with rather homogenous alternating mesohabitats (i.e. riffles, rock-pools, bedrock) requires the development of a specific methodological approach for ecological status assessment.

KEYWORDS:
Ecological quality, island streams, springs, Samothraki

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1. INTRODUCTION

The European Water Framework Directive (WFD) requires establishing type-specific references conditions and monitoring using biological quality elements. Many biological indices which have been developed using macroinvertebrates have focused on continental temperate surface waters, usually in large river basins. Freshwater systems of the Mediterranean islands present many differences in contrast to continental surface waters. Specifically, island streams are characterized by extreme seasonality, distinctive habitat types, and reduced abundances of macroinvertebrates [1, 2]. Thus, the existing assessment systems may not reflect the actual quality in these aquatic ecosystems [3]. Failure to adapt the existing indices is probably due to the absence of some high scoring families and the reduced abundance [4, 5]. Therefore, island streams may require the development of indices that satisfy these distinctive Mediterranean insular conditions [6, 7]. Samothraki is a unique island in the northeastern Aegean Sea, with seemingly pristine natural valley features and numerous perennial streams flowing through deep ravines with impressive waterfalls and pools bordered by remarkable riparian woodlands. Few islands in the Mediterranean provide near-natural conditions with extensive lotic ecosystems for study; insular Mediterranean systems, are generally poorly studied. Samothraki has attracted our scientific interest and its water resources have received periodic research visits for more than a decade.

Herein, we analyze all available data and critically present results related to ecological quality assessment according to the demands of the WFD 2000/60/EC.

2. MATERIAL AND METHODS

2.1 Study area

Samothraki Island is located in the northeastern Aegean Sea (Thraki, Greece), 45 km south of the Greek coastal city of Alexandroupolis (Fig. 1). It covers an area of 178 km^2 and has a high-gradient relief and an ellipsoid shape. The name of the island (Samo-Thraki) means "high" Thraki (i.e. Thrace). The highest point on the island is Mt. Saos peaking at 1611 m a.s.l.; this is one of the highest peaks in the insular Aegean, after the much larger islands of Crete and Euboea. The island presents very steep slopes, ranging between 15^o and 30^o, with high denudation rates and linear, deep erosion, whereas the morphology of stream terraces reveal the continuing tectonic rise of Mt. Saos [8, 9]. Samothraki has a high biodiversity value with 1534 plant species, among them 15 endemic and range-restricted ones [10]. 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. Regarding its general morphology, the island may be divided into two regions (a northeastern and a southwestern region). The first one consists of humid climatic conditions, steep slopes, extensive woodlands and dense shrublands. The second has drier climatic conditions, extensive rocky slopes, and substantial agricultural lands, mainly olive groves [9]. In addition, there are several extensive highland areas with sparse or nearly no vegetation (bare soil and rock), and these bare areas dominate the mountain peaks and the drier eroded valleys of the southwest. The existence of these areas is due to high rates of erosion that is enhanced by anthropogenic deforestation from woodcutting, wild fires, and livestock overgrazing. The island's small streams flow usually rather abruptly to the sea but in several lowland areas, wetland habitats are formed. Eleven very small wetlands, including four coastal lagoon systems are documented on the island's coasts [11], but this inventory is not a complete review of all wetland habitat sites on the island [10].

The climate of the island is of a Mediterranean type but strongly influenced by humid sub-mediterranean and continental winters due to the island's geographical position near the Thracian Landbridge between the Southeast Balkans and the Black Sea. Winters bring rain and snow, and summers are relatively hot and dry. The mean annual rainfall for the period 1986-2008 was 605 mm [12, 13]. The geology of the island is 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 units are locally un-conformably overlaid 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. The south-central part of Samothraki is covered by granite (26% of the island's area) that intruded into the Ophiolite complex during the Miocene. The youngest successions on the island 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 present, Samothraki Island constituted a high mountain of 1731 m connected to the mainland [14-16]. The island is rich in both springs and streams but an inventory of all stream reaches and springs has never been completed. Springs are fed by low potential aquifers that are developed within faults or weathering zones in volcanic rocks and in quaternary sediments [14]. As a result of the geological and tectonic settings of the island, hot springs with water temperatures of 35-58 ^{o}C occur in the island, particularly in the Therma area [17], within the Tsivdogiannis stream basin. The hydrographic network of the island is mainly developed on hard substrate (ophiolites and granites) and presents a radial form. Some of the larger river basins, such as Fonias, present a dendritic hydrographic network [8]. Only in the SW part of the island, streams flow through recent sedimentary series. The development of the network started in Miocene synchronously with the granite intrusion that upraised Mt. Saos [8]. Steep slopes and high runoff, in combination with tectonic uplift movements, have created ravines with impressive waterfalls, commonly followed by small plateaus with long pooling waters (locally known as "vathres" = deep pools). Highly eroding badland features are widespread but restricted in extent. During the winter, streams flow rapidly, transporting large quantities of mainly coarse sediments. In summer, the flow is reduced and most of the streams, such as Xiropotamos and Gria Vathra, do not flow to the sea thus having an intermittent flow pattern in their lowermost reaches.

Samothraki has a low human population density and few anthropogenic alterations in the uplands. The island sustains 16 small settlements with 2,840 residents; most settlements are below 150m elevation. Human pressures, such as domestic solid and liquid waste discharge, land-use change and livestock farming, have only local impacts, primarily at low elevations. Nutrients derived from agricultural crops are restricted, due to the limited extent of agricultural areas. Hence, the most widespread pressure in Samothraki is livestock grazing, mostly represented by free grazing goats. Water abstraction for small scale irrigation, livestock production, urban use and tourism locally affect stream hydrological regimes.

Four small stream basins were investigated in this study; Gria Vathra (basin area: 5.3 km^2), Fonias (9.5 km^2) and Agkistros (6.9 km^2), in the northeastern part of the island; and Xiropotamos (16.1 km^2) in the southwest. Apart from Fonias basin, small settlements are found in Xiropotamos (50 residents, 115 m a.s.l.), Gria Vathra (73 residents, 50 m a.s.l.) and Agkistros (52 residents 100 m a.s.l.) basins. The largest percentage of land-use in Agkistros (94.3%), Xiropotamos (79.8%), Fonias (70.2%) and Gria Vathra (54.2%) basins is occupied by grazed scrubland (termed "grasslands" in Corine Landcover). Regarding geology, Xiropotamos and Gria Vathra basins are dominated by ophiolites (56.8% and 70.1% of the basin area, respectively), Fonias basin mainly consists of granites (81.7%), while Quaternary sediments (36.2%) predominate in Agkistros stream basin. Two sampling sites were selected along Xiropotamos (X1 and X2), Gria

Vathra (GV1 and GV2) and Fonias (F1 and F2), and one along Agkistros (AG) streams (Fig. 1). Also, samples from four cold springs, Palaeopolis (PAL), Kariotes (K), Paraga (P), Agios Georgios (A.G.), and two hot springs at Therma, i.e. T(A) and T(B), were examined (Fig. 1). Field campaigns were carried out during summers and winters of 1999, 2002, 2011 and 2012.

2.2 Environmental and Biological Data

A preliminary assessment of the ecological quality of the sites examined was carried out based on chemical-physicochemical quality elements and macroinvertebrate fauna. Benthic macroinvertebrate samples were collected from all stream sites. The collection of macroinvertebrates was performed by 3-min kick and sweep [18] plus one min of scanning the riparian vegetation where it existed [19, 20], and with the STAR-AQEM methodology. A hand net with mesh size of 0.09 cm, which follows ISO 7828:1985, renamed EN 27828 1994 [21], was used. Macroinvertebrate identification to the lowest possible taxonomic level was conducted using a stereoscope (Novex Holland Model 65.560 RZT-SF) and various identification keys [22-25].

Environmental variables, such as altitude, width and depth of the stream, current velocity, riparian vegetation and stream's substrate composition for each site, were also recorded. Water samples for major ions and nutrient laboratory analyses were collected, along with *in situ* measurements of physicochemical 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) [26] and M.D. 4813/98 (Irrigation Standards) [27].

2.3 Data analysis

Biotic indices, i.e. BMWP, IBMWP, ASPT, STAR_ICMi, EQR_STAR_ICMi and HES, were applied in order to assess the biological quality of each sampling site. To classify the chemical-physicochemical quality of the sites, the Nutrient Classification System (NCS) was applied for nutrients, which has been developed for Greek streams [28], and the Norwegian system regarding dissolved oxygen [29]. 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 1-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 [30]. R is close to zero, if the null hypothesis is proven 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.

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

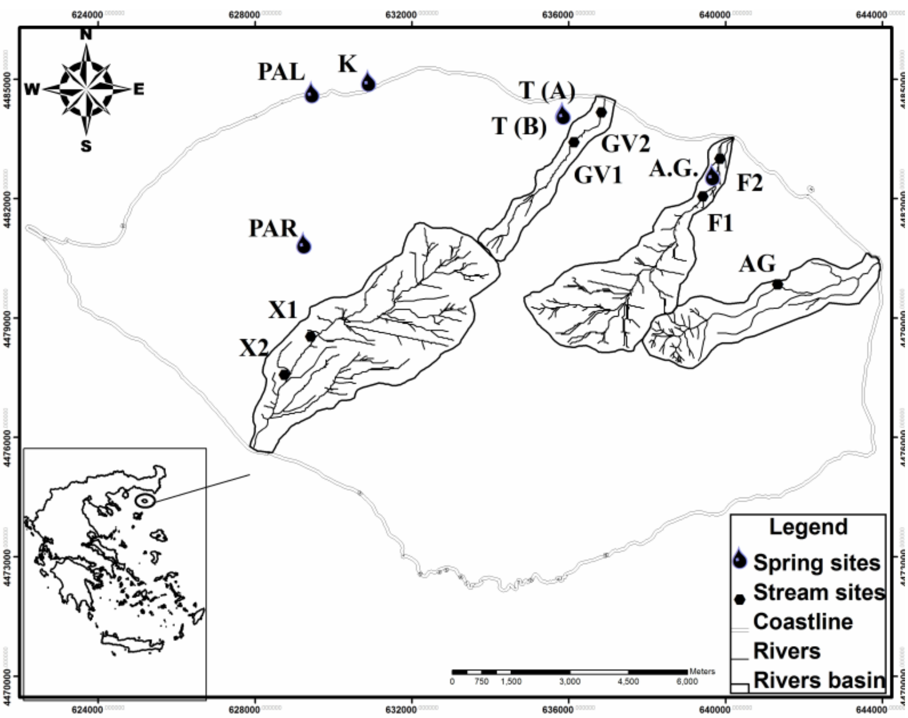

FIGURE 1 - Map of study area that presents the stream basin with the hydrographic network of each stream and the selected sampling sites.
Stream basins: Gria Vathra (GV):, Fonias (F), Agkistros (AG) and Xiropotamos (X), Cold springs: Palaeopolis (PAL), Kariotes (K), Paraga (P) and Agios Georgios (A.G.), Hot springs: Therma (T)

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 [31]. 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 [32]. After the analysis application, the significance of environmental variables is checked based on the Monte Carlo test (variables have P-values < 0.05). Then, more variables are selected provided that the inflation factor is less than 20.

3. RESULTS

3.1 Chemical-physicochemical assessment of stream sites

The values of the physicochemical and chemical parameters of the stream sites are presented in Table 1. The levels of the examined parameters were below the drinking and irrigation water standards. The chemical-physicochemical quality, carried out by averaging the quality of individual parameters (according to the levels of nutrient and dissolved oxygen (DO) and using the aforementioned classification systems) ranged between high and good (Table 2).

TABLE 1 - Values of physicochemical and chemical parameters of the sampling sites along with Drinking Water and Irrigation Standards. (1: summer, 2: winter).

Sampling Site			DO (mg/L)	BOD_5 (mg/L)	pH	T (°C)	Cond (μS/cm)	TDS (mg/L)	$N\text{-}NO_2$ (mg/L)	$N\text{-}NO_3$ (mg/L)	$N\text{-}NH_4$ (mg/L)	$P\text{-}PO_4$ (mg/L)	TN (mg/L)	TP (mg/L)	Discharge (m^3/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
DWS[a]					6.5-9.5		<2500		0.152	11.29	0.389	0.306			
IWS[b]				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, for the abbreviations of the sampling sites see legend in /Fig.1.

TABLE 2 - Chemical-physicochemical assessment classification of each sampling site using dissolved oxygen and nutrient standards (H: High, G: Good, M: Moderate, P: Poor, B: Bad).

		Sampling Site	DO	$N\text{-}NO_2$	$N\text{-}NO_3$	$N\text{-}NH_4$	$P\text{-}PO_4$	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	EQR_ STAR_ ICMi	STAR_ ICMi	Class	HES	Class
1999	Summer	F2	159	H	175	H	6.481	1.012	0.993	H	4	G
		GV1	130	H	125	H	6.579	0.936	0.918	G	3.5	G
	Winter	F2	61	G	61	G	6.1	0.826	0.810	G	3	M
		GV1	46	M	39	M	5.571	0.650	0.638	M	2.5	M
2011	Summer	X1	99	G	98	G	6.533	1.078	1.057	H	3.5	G
		X2	109	H	108	H	6.353	1.122	1.101	H	3.5	G
		F1	138	H	133	H	6.65	0.942	0.924	G	3.5	G
		F2	145	H	149	H	6.478	0.820	0.804	G	4	G
		GV1	94	G	90	G	6.429	0.936	0.918	G	3.5	G
		GV2	68	G	65	G	5.417	0.754	0.739	G	2.5	M
	Late Summer	X1	32	P	32	P	5.333	0.434	0.426	P	2	P
		F1	98	G	101	H	6.733	0.911	0.894	G	4	G
		F2	106	H	97	G	6.467	0.860	0.843	G	3.5	G
		GV1	48	M	48	M	6.636	0.506	0.496	M	3.5	G
2012	Winter	F1	139	H	141	H	6.714	1.074	1.054	H	4	G
		F2	150	H	152	H	6.909	1.103	1.082	H	5	H
		GV1	86	G	73	G	6	0.753	0.739	G	4	G
		AG	138	H	131	H	6.55	1.116	1.095	H	5	H

TABLE 4 – Provisional ecological quality of each sampling site according to biotic indices and nutrient classification. (H: High, G: Good, M: Moderate, P: Poor, B: Bad).

			Ecological status			
Sampling Site			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

3.2 Biological assessment of stream sites

According to the applied indices, the biological quality of the sites did not differ significantly (Table 3). 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.

3.3 Ecological quality of stream sites

The provisional ecological quality of each sampling site (Table 4) was assessed taking into account its available biological and chemical-physicochemical quality (according to the one out all out principle). Most of the sites showed good ecological status. The ecological quality 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 due to their degraded biological quality.

3.4 Interpretation of macroinvertebrate assemblages using 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 streams and sites. However, according to the ANOSIM test, there were no significant seasonal and yearly differences among species composition 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 parameters, i.e. sampling sites were grouped according to either the sampling period or the year of sampling. Particularly, during summer 2011, biocommunities seemed 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 (SIMPER) showed that group a and group c presented average dissimilarity of 68.54%. The average dissimilarities between group a and groups b, d and e were 61.73, 64.36 and 67.37%, respectively. This dissimilarity was due to the low species richness and abundance of the group a sites.

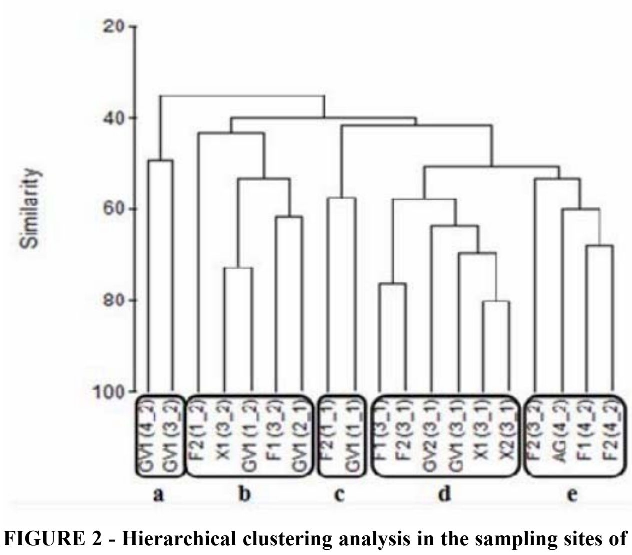

FIGURE 2 - Hierarchical clustering analysis in the sampling sites of Xiropotamos (X), Gria Vathra (GV), Agkistros (AG) and Fonias (F) stream basin. The first number in the site name refers to the year of sampling (1: 1999, 2:2002, 3:2011, 4:2012), and the second one to the sampling period (1: summer,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

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 , best explained macroinvertebrate variation. The first two axes explained 50.1% of species-environmental relation. The canonical weighted correlation of environmental variables with CCA axes indicated that the first ordination axis (horizontal axis) was mostly related to grasslands (-0.911) and the second axis (vertical axis) with conductivity (0.4493), P-PO_4 (0.3773) and DO (-0.3609) (Fig. 3). Sites of Fonias stream in 2011 and their taxa were positively correlated with grassland (except for F1(3_2). Generally, there was a clear separation among the streams. Sites of Fonias stream were distributed on the negative side of the first axis. The rest of the sites were distributed at the right side of the first axis but Gria Vathra was mostly related to, conductivity, P-PO_4 and DO.

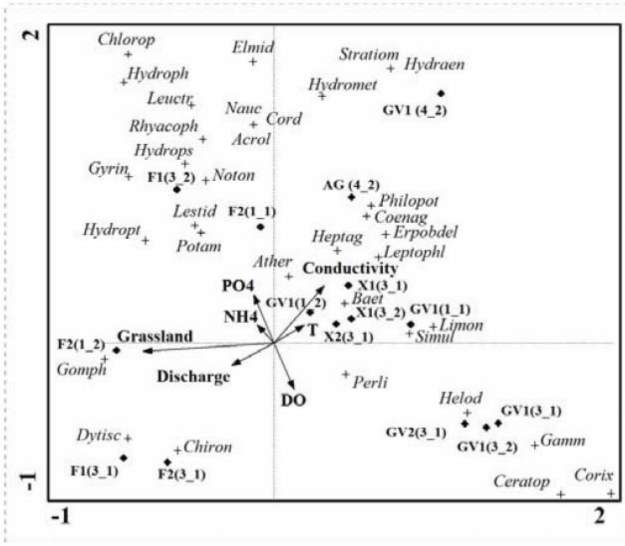

FIGURE 3 - Correlation plot of sampling sites (•) and macroinvertebrate families (+) with significant environmental variables. The first number in the site name refers to the year of sampling (1: 1999, 2:2002, 3:2011, 4:2012) and the second one to the sampling period (1: summer, 2: winter).

3.3 Cold and hot springs

The levels of the physicochemical parameters of the cold and hot springs are presented in Table 5. Overall, cold springs had good water quality, according to drinking water standards, and were classified as medium hard according to Hem [33] with low mineralization [28]. All cold springs are of a calcium bicarbonate type, except from one (Palaeopolis spring) that belongs to Na-Cl type, probably due to sea water influence (the spring is very close to the shore). Hot springs are of the Na-Cl type with very high conductivity and total dissolved solid (TDS) values, and are rich in major ions and trace elements. A number of parameters (conductivity, Na, Cl, NH_4, Mn) in these springs exceeded the drinking water quality standards.

4. DISCUSSION

Samothraki Island is rich in cold and hot springs and perennially flowing surface waters. Numerous small mountainous springs, fed by snowmelt and precipitation, are developed within fault-line ravines or weathering

TABLE 5 - Physicochemical parameters of cold and hot springs.

	T (°C)	pH	C (µs/cm)	DO (mg/l)	TDS (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	HCO_3 (meq/l)	CO_3 (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		6.5-9.5[a]	2500[a]					200[a]			

	SO_4 (mg/l)	Cl (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)	NH_4 (mg/l)	PO_4 (mg/l)	TN (mg/l)	TP (mg/l)	SiO_2 (mg/l)	Total Hardeness (mg/l $CaCO_3$)
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]	0.05[b]	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	50[c]	300[d]	20[c]	20[a]	20[c]	500[c]	1[c]	50[d]	-

C: conductivity, DWS: Drinking Water Standards, a: COUNCIL DIRECTIVE 98/83/EC, c, d: category A1, b: guide, c: mandatory, COUNCIL DIRECTIVE 75/440/EEC [35], T(A), T(B): thermal springs. PAL: Palaiopolis, K: Kariotes, P: Paraga, A.G.: Agios Georgios cold springs.

zones in igneous rocks creating a high number of streams with substantial flow considering the dimension of the island. In this work, the preliminary ecological assessment of seven stream sites in four stream basins was evaluated. Of the four investigated streams, only the Fonias Stream currently flows into the sea throughout the year, exhibiting a substantial area of perennial flow. Most of the other streams, at their lower reaches, are dominated by intermittent or ephemeral flow. There is evidence that water abstraction at Gria Vathra, Agkistros and Xiropotamos created periodic desiccation in the stream's lower reaches; but this needs further investigation. Overall, the ecological quality of the running waters of Samothraki is good where the most significant pressure is considered to be water abstraction, as is most evident in Xiropotamos stream valley. Any pollution sources existing in the basins (i.e. small-scale agro-industrial development, municipal wastes and localized tourism activities) seem to be balanced by high quantities of clean, turbulent waters resulting by extensive mountainous topography and steep slopes. More investigations near point-sources of pollution may reveal locally degraded conditions.

An increase of conductivity during the high flow period compared to the low flow period was evident, a phenomenon also observed in other Greek streams [35-37]. This seasonal trend of dissolved solid concentration is attributed to flushing of salts that accumulate in the soil during the dry period of the year [e.g. 37]. Nevertheless, the mean conductivity values were generally very low due to the presence of siliceous substrates [28, 38]. As 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. 39]. In contrast, ammonium and phosphorus concentrations were higher in the low flow period for all sites. This seasonal trend is normal for most Greek streams and is attributed to point sources of ammonia and phosphorous [e.g. 37]. However, since in the examined basins only minor point pollution sources exist, high values of these compounds may be also due to mineralization of natural organic matter that accumulates in standing waters occurring in several plateaus along the stream courses. In, fact, these pools are eutrophic as the existence of filamentous algae communities indicates [38]. An additional cause may be excrements of grazing goats that are gathering for shade and water. The stream-bed substrate at all sites consisted mainly of coarse material (cobbles and boulders). This substrate composition is typical for small mountainous stream basins with steep slopes [28].

Ephemeroptera, Diptera and Amphipoda were the most dominant macroinvertebrate families in all sites. No significant differences were observed among the indices used for the classification of the biological quality of the sites. The poor biological quality of site X1 in late summer 2011 was mostly attributed to the fact that macroinvertebrate sampling was performed shortly after flow had been restored; thus, the benthic fauna had not fully recolonized the site. Cluster analysis revealed overall a similar macroinvertebrate community composition indicating the predominance of seasonal attributes (i.e. flow and discharge) over spatial differences.

Based on the results of this study, we speculate that the chemical-physicochemical and biological assessment of the stream sites was lower than anticipated due to the application of unsuitable indices and metrics. The rather homogenous and naturally poor microhabitat structure and the flashy stream dynamics may have resulted in a natural biocommunity perceived as poor from metrics, developed specifically for continental stream ecosystems and not Mediterranean island ones. In addition, mineralization processes taking place in pools may increase nutrient concentrations in stream water and may affect zoobenthos assemblages. However, these hypotheses need further investigation since the local biogeographical and cultural landscape impacts have not been researched. 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 the drinking water quality standards.

6. CONCLUSIONS

Samothraki Island sustains remarkable lotic environments and a high degree of naturalness, primarily due to its unique geological and morphological conditions that favor the occurrence of substantial surface runoff and hinder any intense human activities above about 200 m asl. However, the island has been poorly studied by aquatic scientists. Baseline natural history description of the island's waters, lotic and lentic habitats and associated riparian zones, particularly, their biological attributes, have not been adequately documented or inventoried. Specific stream typologies and reference conditions for the island's stream lotic features have not been developed. Our exploratory survey has helped to 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 quality of the streams as perceived by our research team's expert opinion. The same may be valid for nutrients. We expected lower nutrient levels [39] matching with the nearly "pristine" conditions of the island's mountainous part. Hence, we presume that in the case of Samothraki Island, type-specific reference conditions include higher nutrient concentrations than in other Greek regions, since N and P compounds may also originate through natural processes occurring in stream widespread bedrock pools or during flash events (natural enrichment). Therefore, due to the peculiar nature of Samothraki's streams presenting extensive standing waters and flashy dynamics, a special approach for the assessment of their ecological quality may be needed. This may also be valid for other Mediterranean island streams exhibiting similar natural features in fragmented "cultural landscapes". A comprehensive aquatic, wetland and riparian research survey is required, including hydromorphological and additional biological quality elements, to provide a clearer impression of the island's freshwater resources and conditions, and assist in better adapting assessment techniques to Mediterranean island stream conditions.

Samothraki's lotic waters are one of the island's most precious environments for biodiversity and local society. This is especially important since few islands in the Aegean have so much perennially flowing water. The island provides an outstanding research and conservation opportunity since the small river basins could be holistically studied, and particular proposals could assist water resources and landscape management prescriptions. The main part of the island has already been designated under the Natura 2000 conservation area and an updated UNESCO man and biosphere reserve (MAB) proposal has been promoted [40]. Strategically coordinated river basin research could assist efforts to integrate and promote both water management and nature conservation initiatives.

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