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Ecological Water Quality and Management at a River Basin Level: A Case Study from River Basin Kosynthos in June 2011

Ch. Ntislidou, A. Basdeki, Ch. Papacharalampou,
K. Albanakis, M. Lazaridou and K. Voudouris*
Interdisciplinary Postgraduate Study Program
"Ecological Water Quality and Management at a River Basin Level"
Departments of Biology, Geology & Civil Engineering,
Aristotle University of Thessaloniki, Thessaloniki,
Greece

1. Introduction

The European Parliament and Council decided a policy on the protection, an appropriate treatment and management of water field leading on the Water Framework Directive 2000/60/EC (WFD, European Commission, 2000) in October 2000. The WFD obliges Member States to achieve the objective of at least a good ecological quality status before 2015 and requires them to assess it by using biological elements, supported by hydromorphological and physico-chemical ones. The assessment must be done at a basin level and authorities are obliged to follow efficient monitoring programs in order to design integraded basin management plans. Efforts are being made to adapt national programmes for the WFD requirements (Birk & Hering, 2006). In most European countries, river monitoring programmes are based on benthic macroinvertebrate communities (Sánchez-Montoya et al., 2010).

The WFD (EC, 2000) suggests a hierarchical approach to the identification of surface water bodies (Vincent et al., 2002) and the characterization of water body types is based on regionalization (Cohen et al., 1998). The directive proposes two systems, A and B, for characterizing water bodies according to the different variables considered (EC, 2000). The WFD allows the use of both systems, but considers system A as the reference system. If system B is used by Member States, it must achieve at least the same degree of differentiation. System A considers the following obligatory ranged descriptors: eco-region, altitude, geology and size, whereas system B considers five obligatory descriptors (altitude, latitude, longitude, geology and size) and fifteen optional ones.

A prerequisite for a successful implementation of the WFD in European waters is the intercalibration of the national methods for each biological quality element on which the

*Corresponding Author

classification of ecological status is based (Simboura and Reizopoulou, 2008). According to the Mediterranean intercalibration exercise (MED-GIG) (Casazza et al., 2003, 2004, five river types are proposed, based on the catchment area, the altitude, the geological background and the flow regime of the rivers. Greece participates in this exercise and belongs in the Mediterranean geographical intercalibration group (MED-GIG) (Casazza et al., 2003, 2004).

The pressures and impacts play a key role in the likelihood that a water body will fail to meet the set objectives. IMPRESS analysis (CIS Working Group 2.1: IMPRESS, 2003) assesses the impact and evaluates the likelihood of failing to meet the directive's environmental objectives. Additionally, the Driving force-Pressure-State-Impact-Response (DPSIR) framework represents the relations between socio-economic driving forces and impact on the natural environment (Kristensen, 2004) and the SWOT analysis helps the understanding of the Strength-Weakness-Opportunities-Threats.

This chapter deals with the ecological water quality of the Kosynthos river basin based on (a) the distinction of the water bodies by applying System B and taking into consideration the pressures, (b) the calculation of an approximate water balance according to the activities developed in the river basin, (c) the assessment of the ecological water quality, using benthic macroinvertebrates, (d) the implementation of Impress analysis DPSIR and SWOT analyses.

2. Study area

The Kosynthos River is located in the north-eastern part of Greece, flows through the prefectures of Xanthi and Rhodopi and discharges into the Vistonis lagoon (Figure 1) as a result of the diversion of its lowland part in 1958. Kosynthos' length is approximately 52 Km (Pisinaras et al., 2007). In the present study, 8 sites were selected in Kosynthos river basin (Figure 1) during the period June 2011, depending on the different pressures that presented in the area. Four sites belonged to the mountainous area and the rest sites to the low-land one. The Kosynthos river basin belongs to the water district of Thrace (12^{th} water district), covering an area of 460 Km^2. The region consists of forest and semi-natural areas (69.6%), rural areas (27.7%), artificial surfaces (2.5%) and wetlands (0.3%) (Corine Land Cover 2000). It is considered to be a mountainous basin (Gikas et al, 2006) of steep slopes and its average elevation is about 702 m. In total, the 7.3% of the basin is protected by the Ramsar Convention or belongs to the EU Natura 2000 sites.

Geologically speaking, the study area belongs entirely to Rhodope massif (Figure 2) consisting of old metamorphic rocks (gneisses, marbles, schists), observed mainly in the northern part of the basin. Moreover, igneous rocks (granites, granodiorites) have intruded the Rhodope massif through magmatic events during Tertiary and outcrop in the central part of the basin. Because of the granite intrusion in the calcareous rocks and the contact metamorphosis, a sulfur deposit is created, consisting mainly of pyrites. Quaternary and Pleistocene mixed sediments cover the south-eastern part of the catchment. The boundary between the highland area and the lowland is characterized by a sharp change of slope.

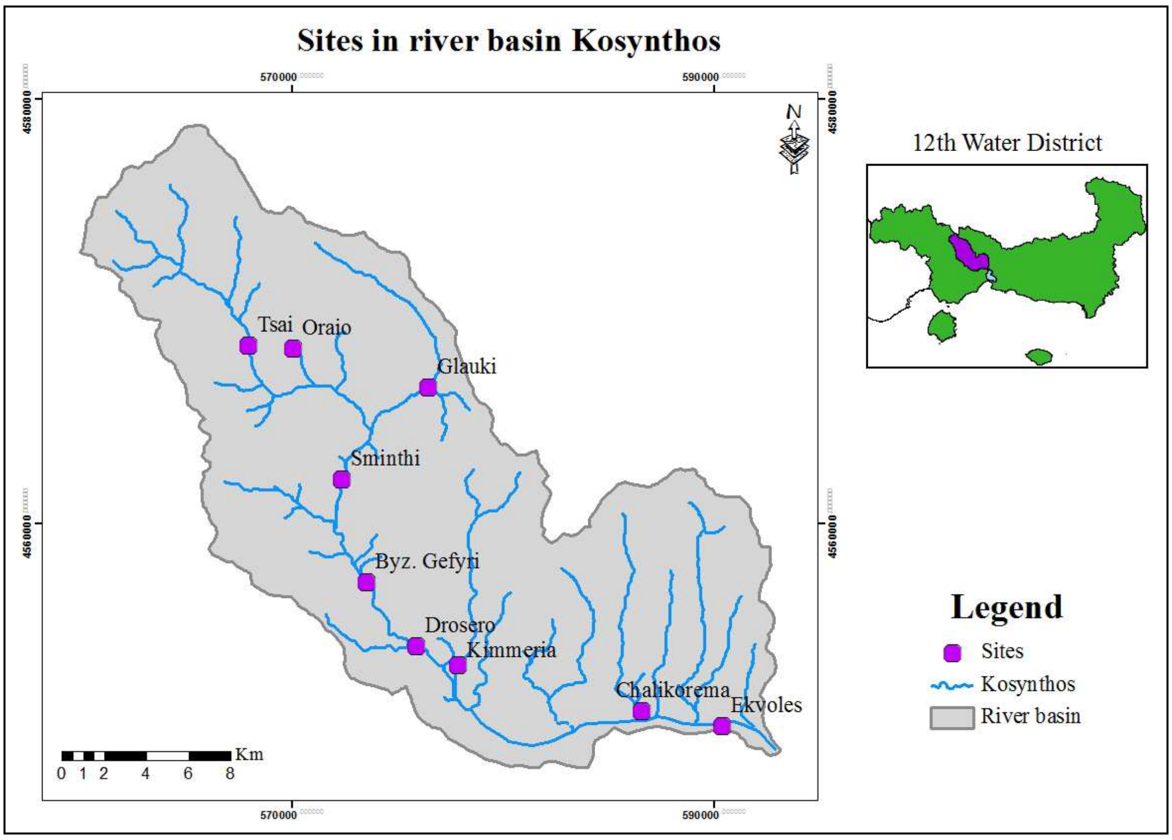


Fig. 1. Map of Kosynthos river basin showing the sampling sites.

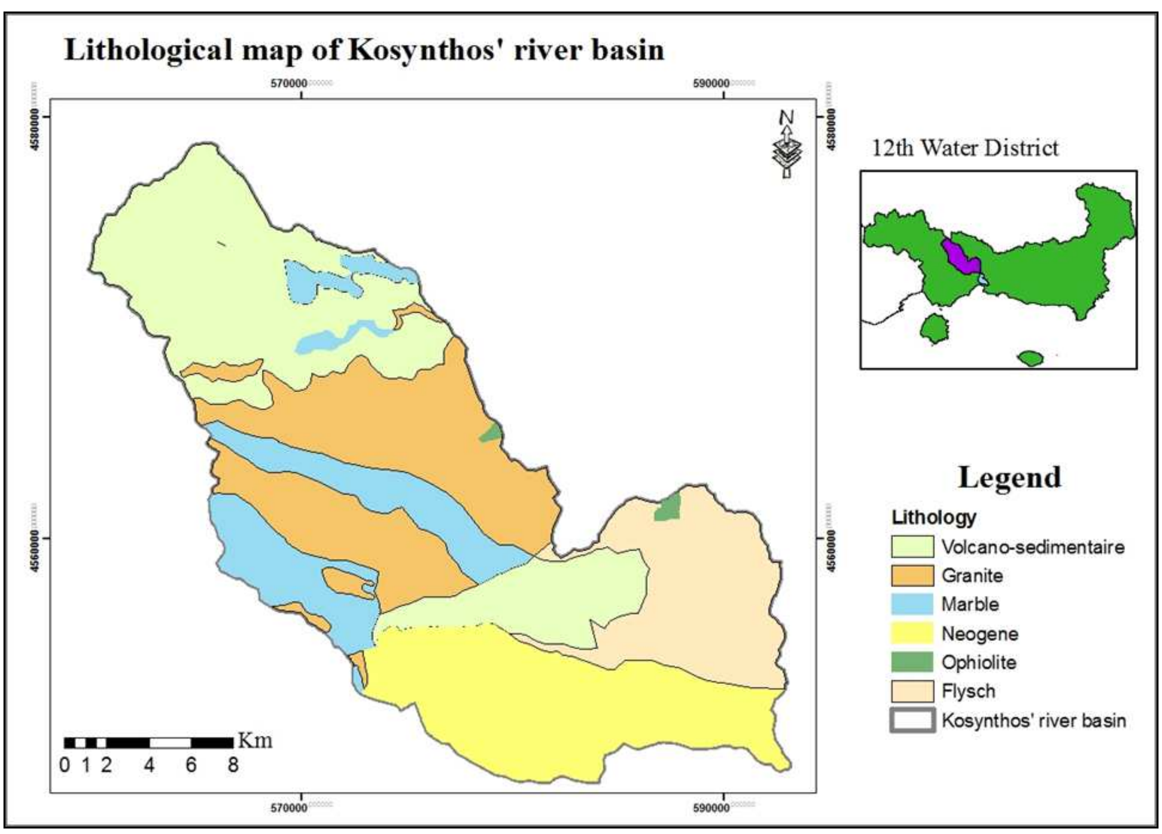


Fig. 2. Lithological map of Kosynthos' river basin.

From a hydrogeological point of view, two main aquifers are developed within the aforementioned geological formations: 1) an unconfined aquifer in the Quaternary deposits of lowlands and 2) a karst aquifer in marbles of the northern part of the basin (Diamantis, 1985). Karst aquifer system often discharges groundwater through springs in the hilly part of the basin, where permeable marbles are in contact with impermeable basement rocks. Previous studies (Hrissanthou et al., 2010; Gikas et al., 2006) show significant sediment transportation to Vistonis lagoon from Kosynthos river because of intense erosion. However, no deltaic deposits are observed in the outfall of Kosynthos, while an inner delta is created right before the stream's diversion (Figure 3). The steep topography combined with the inclination of the diverted section prevents the transportation of coarse sediments, allowing only fine-grained fractions to Vistonis lagoon.

Fig. 3. The inner delta of Kosynthos River, right before the diverted part (Google Earth).

3. Material and methods

3.1 Typology

In this study system B was selected because the basin of Axios River (a transboundary Greek-FYROM river) belongs to two different ecoregions according to System A. In order to distinguish the water bodies of the Kosynthos river basin, apart from the obligatory descriptors the slope, from the optional ones, was selected and a new category in the basin descriptor was added (0-10 Km^2). The rivers were characterized according to the MED-GIG intercalibration exercise (Van de Bund et al, 2009).

3.2 Approximate water balance

The estimation of the approximate water balance of Kosynthos catchment is based on monthly rainfall and temperature data of 7 weather stations (Genisea, Iasmos, Xanthi, Semeli, Gerakas, Thermes, Dimario) distributed equally across and beyond the basin, for the period 1964-1999 and GIS technique (Voudouris, 2007). As part of the estimation process, components of the hydrological cycle (precipitation *P*, actual evapotranspiration *E*, infiltration *I* and surface runoff *R*), instream flow, available water capacity and water needs (demand for urban, farming, irrigation and industrial water) of the river basin are calculated.

3.3 Quality elements

Dissolved oxygen (DO mg/l), water temperature (WTemp, ^oC), pH and conductivity (μS/cm) were measured in situ with probes (EOT 200 W.T.W./Oxygen Electrode, pH-220, CD-4302, respectively). TSS (mg/l), nutrients ($N\text{-}NH_4$ and $P\text{-}PO_4$, mg/l) and oxygen demand (BOD_5, mg/l) were estimated following A.P.H.A. (1985). Flow was quantified with a flow meter (type FP101) and stream discharge (m^3/s) was calculated for each site. The percentage composition of the substrate was visually estimated according to Wentworth (1922) scale. The Habitat Modification Scores (HMS) was calculated to assess the extent of human alterations at each site (Raven et al., 1998).

Benthic macroinvertebrates were collected using a standard pond net (ISO 7828:1985, EN27828:1994) with the semi-quantitative 3-minute kick and sweep method according to Armitage et al (1983) and Wright (2000) proportionally to the approximate coverage of the occurring habitats (Chatzinikolaou et al., 2006). The animals were preserved in 4% formaldehyde.

In the laboratory, they were sorted and identified to family level. To assess the ecological quality of each site the Hellenic Evaluation System (HES) (Artemiadou & Lazaridou, 2005) and the European polymetric index STAR ICMi (European Commission 2008/915/EC) were applied to the benthic macroinvertebrate samples.

3.4 Statistical analysis

For the statistical analyses all data were log (x+1) transformed except for pH and temperature which were standardized. Parameter expressed as percentages (substrate) was arcsine transformed (Zar, 1996). The hierarchical clustering analysis, based on Bray-Curtis index (Clarke and Warwick, 1994) was applied to the samples of benthic macroinvertebrates for grouping them.

Similarity percentages analysis (SIMPER analysis) (Clarke & Warwick, 1994) was used to distinguish the macroinvertebrate taxa contributing to similarity and dissimilarity between the groups. Redundancy Analysis (RDA) was performed in order to detect covariance between environmental variables and abundances of taxa (Ter Braak, 1988). Correlated variables were excluded with the use of the inflation factor (<20) and the Monte Carlo permutations test ($p<0.05$).

3.5 Impress analysis/DPSIR and SWOT analysis

Impress analysis estimates the impacts taking into account the morphological alterations and the pollution pressures. The morphological alterations estimated through the calculation of a Habitat Modification Score (HMS) (Raven et al., 1998) which is based on the artificial modifications. The pollution pressures are treated differently for point and non point sources. As point sources of pollution are considered the urban wastewater and septic tanks, producing BOD, N and P combinations, which are calculated according to the emission factors (Fribourg-Blanc and Courbet, 2004) whereas livestock according to Ioannou et al., (2009) and Andreadakis et al., (2007) calculated the pollutants.

The human population and the species numbers of breeding animals derived from the Greek National Statistical Service. Industries data, the point sources of pollution, are not available from National Services. Non point sources of pollution, being the land uses, are determined using the Corine Land Cover 2000 and their pollutants are calculated according to the immission factors of WL-Delft et al, (2005). The morphological alterations of pressures were significant if the agricultural land cover was more than 40% (LAWA, 2002) and urban land cover more than 2.5% (Environment Agency, 2005) of the total extent of the river basin.

The pressures from pollution sources would be significant if the total immissions exceeded the proposed limits for irrigation (Decision 4813/98) and for fish life (European Commission 2006/44/EC). All limit scores were adjusted to the river basin, taking into consideration the river flow, estimated as 5.8 m^3/s (Gikas et al., 2006). Multiplied by the estimated river flow, the limit scores were adjusted to the river basin.

The impact assessment, the evaluation of likelihood of failing to meet the environmental objectives and the risk management used the methodology proposed by Castro et al., (2005). Finally, the conceptual model DPSIR (at a river basin level) and SWOT analysis (at the level of Municipalities Mykis and Dimokritos) were applied.

4. Results

4.1 Typology

In accordance with the hierarchical approach, the river flowing in the basin is separated in two main water bodies, due to the canalization of the low-land part of Kosynthos in 1958. Therefore, the diverted part is characterized as heavily modified water body (HMWB), while the rest of the river is characterized as natural water body (NWB). The classification of the river by types leads in 17 types in the catchment area, of which 15 in the drainage network (Figure 4). Finally, the subdivision of a water body of one type into smaller water bodies according to the existing pressures, results in 44 water bodies, from which in 9 sampling of biological, hydromorphological and physico-chemical parameters were executed in June 2011. Based on the European common intercalibration river types (Van de Bund et al., 2009), two types (RM1 and RM2) appear in the river basin.

4.2 Approximate water balance

The climate is semi-humid with water excess and deficiency during winter and summer respectively (Angelopoulos & Moutsiakis, 2011). The annual rainfall (P) is influenced by the elevation (H) of the region (P=0.92H+625, R^2=0.95). The mean annual precipitation in the basin for the period 1964-1999 is 1085.6 mm (Figure 5). Based on Turc method, the coefficient of the actual evapotranspiration was estimated to be 71% of the mean annual precipitation. The remaining amount is allocated to surface runoff (15.3%) and infiltration (13.4%).

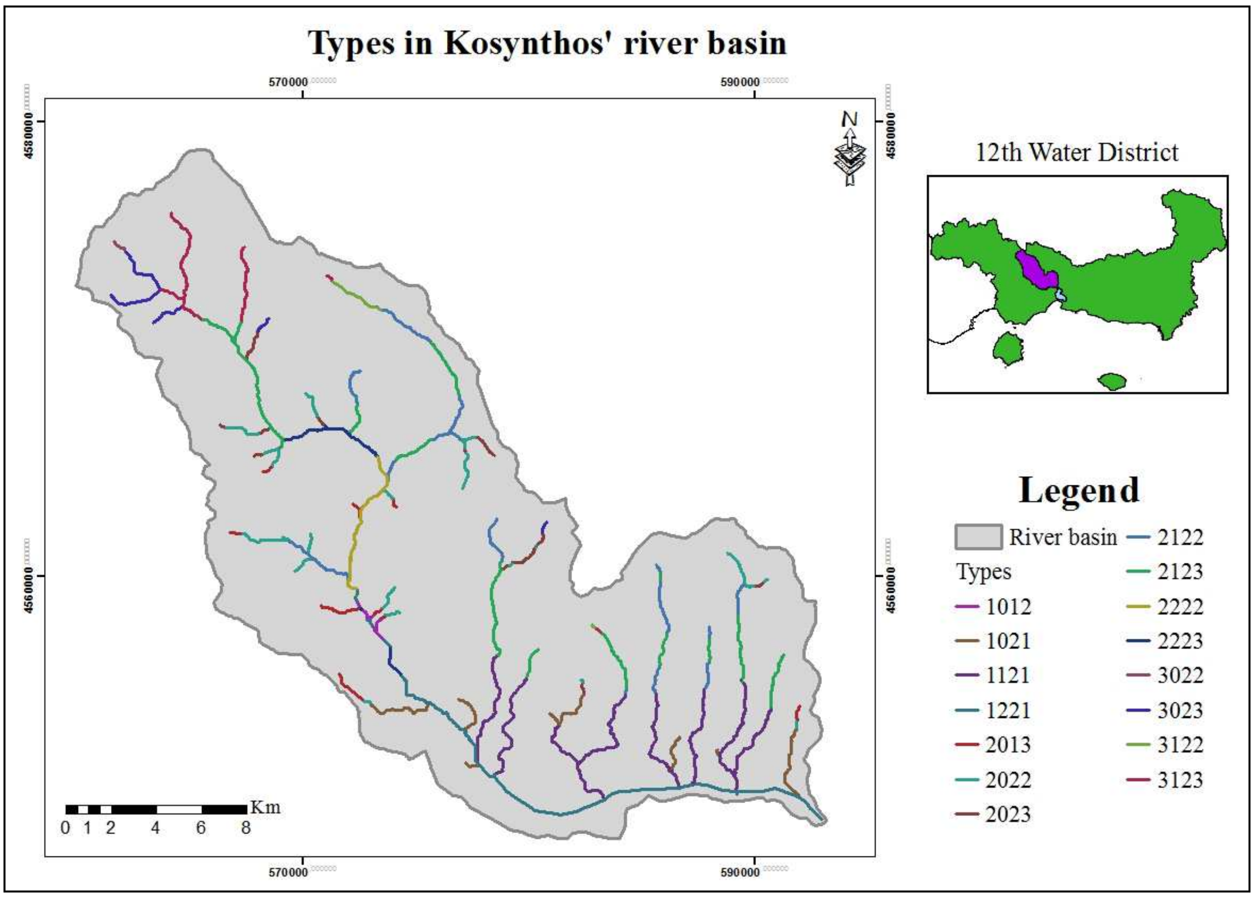


Fig. 4. Types in Kosynthos' river basin according to system B.

A great amount of water infiltrates in marbles and alluvial deposits and then a part of this amount discharged through springs. Instream flow ('environmental flow') is a term that refers to the water required to protect the structure and function of aquatic ecosystems at some agreed level. (Zhang et al, 2006). In accordance with the legislation (M.D. 49828/2008), instream flow equals to 30% of surface runoff and the rest 70% is estimated as available water potential. Assuming that 50% of the infiltration also involves in the available water, the total water potential of Kosynthos basin is calculated to be 86.9x10^6 m^3/yr for the period 1964-1999.

The relevant agents considered for the calculation of water demand are the municipalities that configure the Kosynthos river basin (Municipalities of Myki, Xanthi, Dimokritos, Iasmos). The needs for urban and farming water are calculated equal to 1.7x10^6 m^3 each for irrigation water 62x10^6 m^3 and for industrial water 6.3x10^6 m^3 (demographic and population data 1991-2001. N.S.A.G.). It should be although mentioned that any analysis of water resource management suffers the same handicap with regard to the availability of complete and homogenous information. particularly on municipality level (Torregrosa et al., 2010). Comparing the amount of water potential of Kosynthos catchment for the period 1964-1999 with the water demands, the approximate water balance for the same period is characterized as positive; the water potential is greater that the water demands.

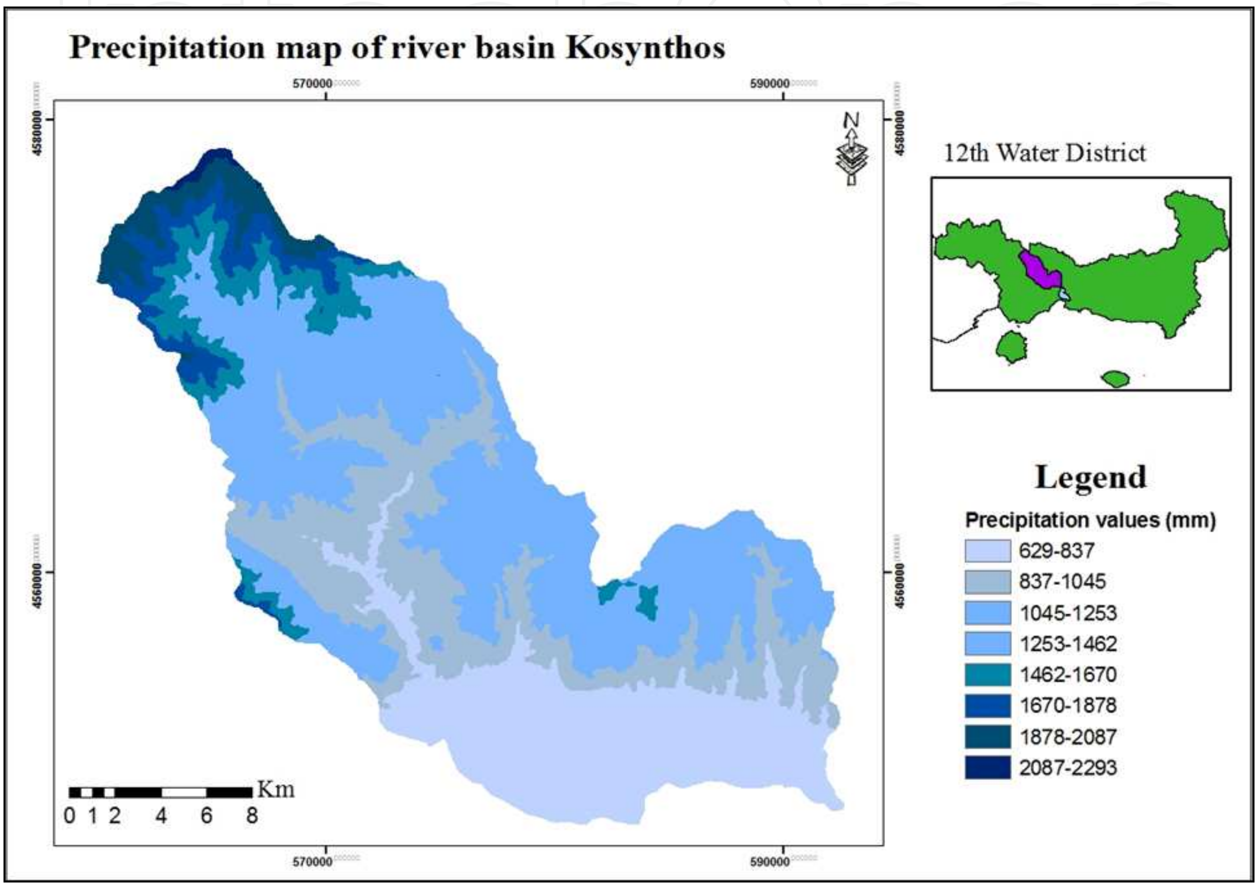


Fig. 5. Precipitation map in Kosynthos river basin.

	P	=	E	+	I	+	R
Water amount (10^6 m^3)	499.4		356.3		66.7		76.4
Precipitation (mm)	1085.6		774		145.5		165.5
Percentage (%)	100		71.3		13.4		15.3

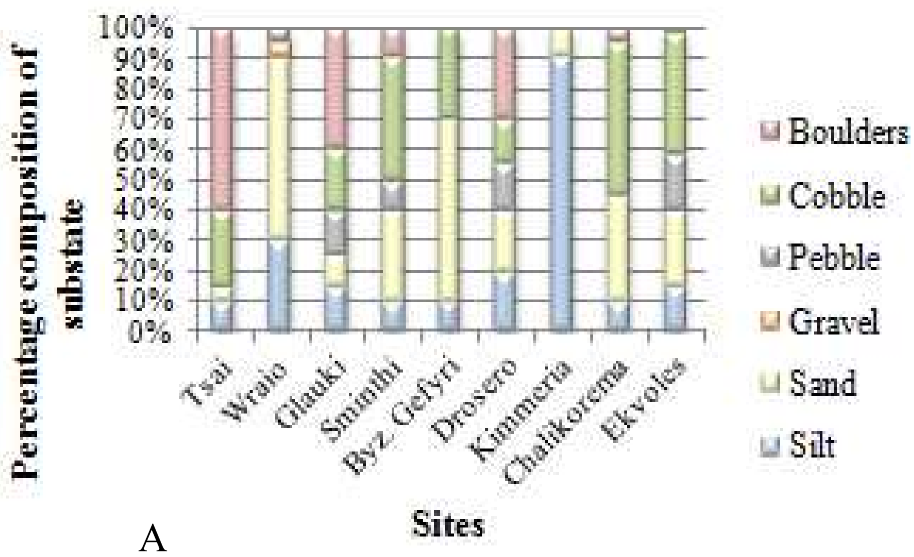
Table 1. Approximate water balance for the Kosynthos river basin (1964-1999).

4.3 Quality elements

The results of the physico-chemical parameters of the river water are presented in Table 2. Ammonium concentration was found to exceed the boundaries of Cyprinid life in all sites, except the site Oraio which exceeded the boundary of portable water and the site Tsai which exceeded boundary of Salmonid life. Also, T.S.S. concentration exceeded the boundary of portable water in sites Kimmeria. Chalikorema and Ekvoles. The substrate composition is represented in Figure 2. The sites Oraio, Byz. Gefyri and Kimmeria are mostly consisted of fine substrate. According to the index HMS most of the sites are characterized as "Predominantly unmodified" (HMS score 3-8, Figure 6).

Sites	D.O. (mg/l)	WTemp (^{0}C)	pH	Conductivity (μS/cm)	T.S.S. (mg/l)	P-PO_4 (mg/l)	N-NO_3 (mg/l)	N-NH_4 (mg/l)	Discharge (m^3/sec)	B.O.D.$_5$ (mg/l)
KYA portable water Y2/2600/2001			**6.5-9.5**	**2.5**		**2.143**	**11.29**	**0.318**		
Boundaries of Directive 2006/44/EC										
(Salmonid)	**6**		**6.0-9.0**		**25**			**0.031**		**3**
(Cyprinid)	**4**		**6.0-9.0**		**25**			**0.155**		**6**
Tsai	10.17	15.7	7.52	0.076	1.2	0.022	0.139	**0.141**	0.307	1.97
Oraio	7.29	18.4	7.68	0.312	20.4	0.146	0.715	**0.393**	<0.001	1.45
Glauki	8.38	22.1	8.05	0.258	3.2	0.120	0.424	**0.215**	0.033	1.5
Sminthi	9.22	19.1	7.7	0.17	8.2	0.030	0.309	**0.282**	0.583	1.76
Byz. Gefyri	8.19	26.6	7.71	0.26	4.4	0.041	0.190	**0.207**	0.441	0.94
Drosero	8.68	28.2	8.16	0.25	7.2	0.030	0.190	**0.214**	0.231	0.64
Kimmeria	6.59	33.2	8.01	0.431	36.2	0.024	1.539	**0.228**	<0.001	1.13
Chalikorema	8.25	20.5	6.83	0.501	41.6	0.045	1.248	**0.308**	<0.001	1.33
Ekvoles	8.14	29.1	7.42	0.42	47.6	0.044	0.396	**0.270**	0.306	2.32

Table 2. Physicochemical parameters of the studied sites in the Kosynthos river basin during the period June 2011(with black letters mentioned the concentrations which exceeded the proposed limits).



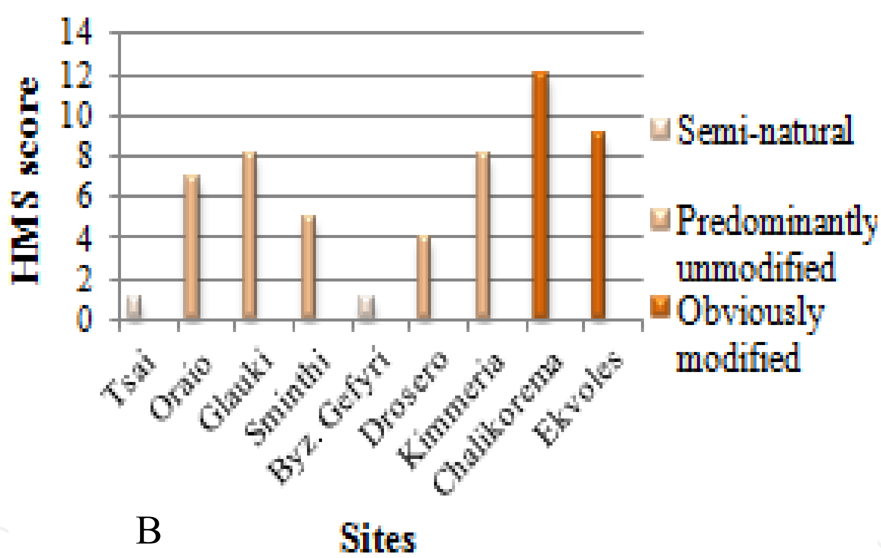


Fig. 6. (A) Percentage composition of substrate, and (B) HMS Score at the studied sites of the Kosynthos river basin in period 2011.

In this study 22.005 benthic macroinvertebrates were identified belonging to 48 different taxa. Abundances were found to be higher in the site Oraio and the site Chalikorema had the lowest. The ecological quality of the sites Tsai, Sminthi and Kimmeria, according to the Hellenic Evaluation Score (HES), was characterized as good, sites Oraio Byz. Gefyri, Chalikorema and Ekvoles as moderate and Glauki and Drosero as poor (Figure 7). By the European polymetric index STAR ICMi it was found the same quality, except for the site Kimmeria which was characterized less than good (Table 3). This difference is related to the fact that the HES index takes into account more sensitive taxa.

Sites	Type	Interpretation of HES	Interpretation of STAR ICMi
Tsai	R-M1	Good	Good
Oraio	R-M1	Moderate	< Good
Glauki	R-M1	Poor	< Good
Sminthi	R-M2	Good	Good
Byz. Gefyri	R-M2	Moderate	< Good
Drosero	R-M2	Poor	< Good
Kimmeria	R-M2	Good	< Good
Chalikorema	R-M2	Moderate	< Good
Ekvoles	R-M2	Moderate	< Good

Table 3. The ecological water quality of the studied sites at the river basin Kosynthos in June 2011.

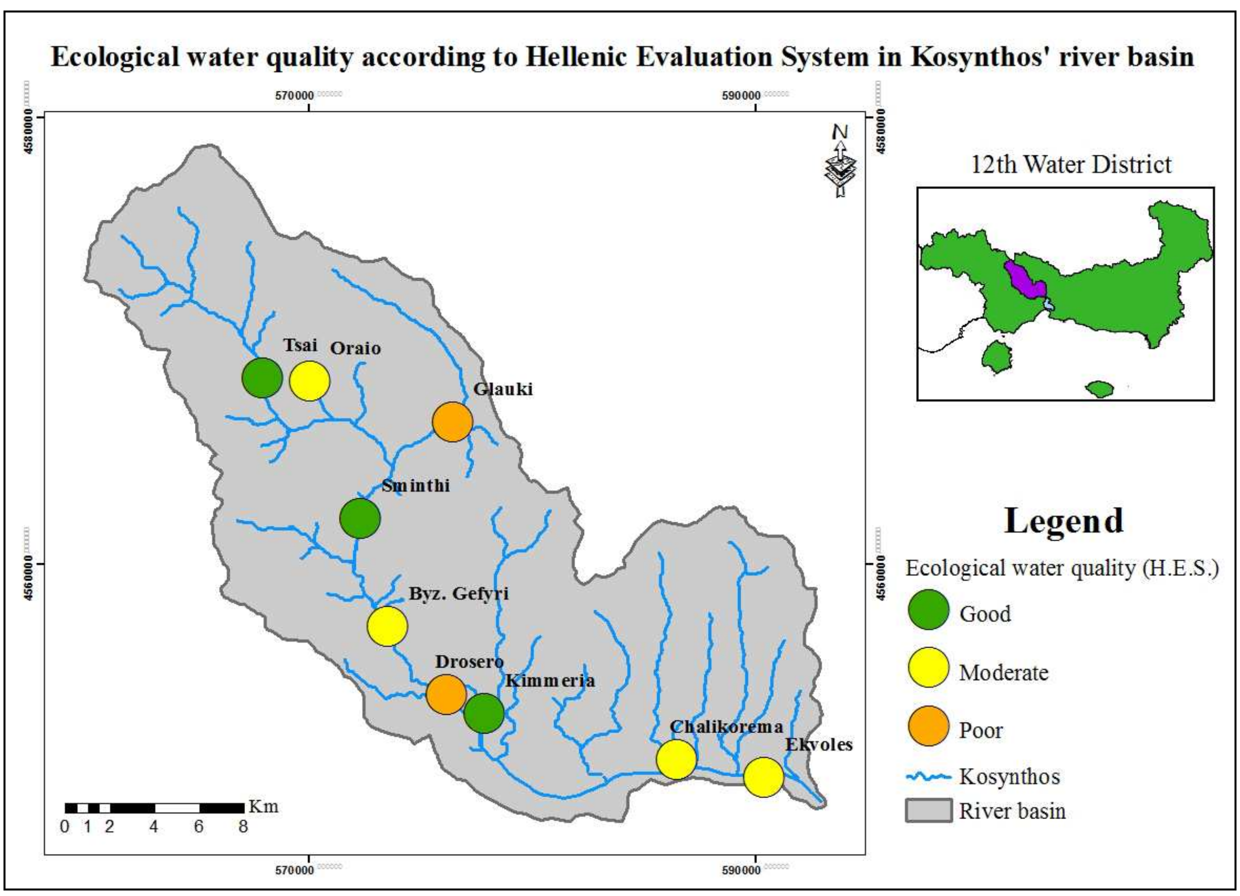


Fig. 7. Ecological water quality according to Hellenic Evaluation System of the studied sites at the river basin Kosynthos in June 2011.

4.4 Statistical analysis

The hierarchical clustering analysis, based on Bray-Curtis index, clustered the benthic macroinvertebrates of the different sites into three clusters (Figure 8). The groups clustered modified sites with an excess of human activities (Ekvoles & Xalikorema) (Group A), the inland delta sites (Drosero & Kimmeria) (Group B) and the high altitude sites (the rest of the stations) (Group C).

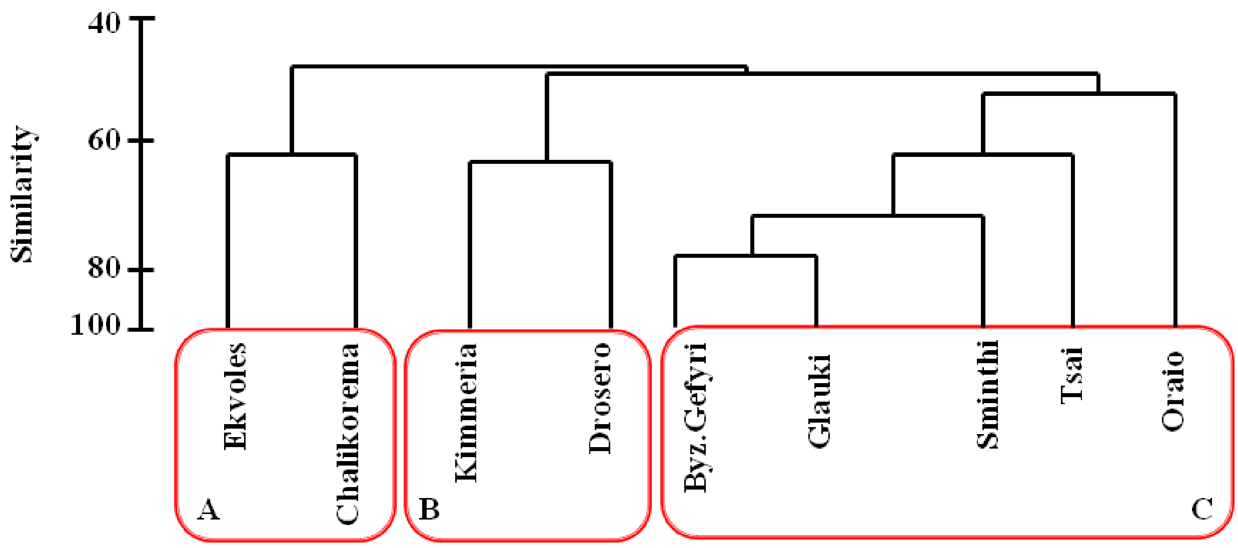
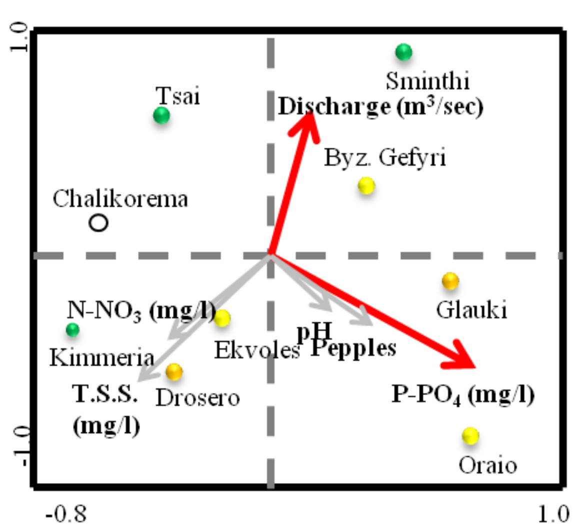


Fig. 8. Hierarchical clustering analysis, based on Bray-Curtis index of the studied sites at the Kosynthos river basin in June 2011.

Simper Analysis showed that the dissimilarity between the groups was around 51%. The families Gammaridae and Simulidae were the key taxa for the differences between the clusters (Figure 9). According to CCA the eigenvalues of the first two axes accounted for 73.8% of the variance. $P\text{-}PO_4$ was the variable best correlated with the first axis, whereas the second axis was best correlated with discharge (Figure 10).

Fig. 9. Benthic macroinvertebrates (A) Gammaridae and (B) Simulidaae which are responsible for the differences between the groups (Photos: Patsia, 2009).



Parameters	ENVI AX1	ENVI AX2
pH	0.319	-0.285
TSS (mg/l)	-0.356	-0.468
$N\text{-}NO_3$ (mg/l)	-0.359	-0.356
$P\text{-}PO_4$ (mg/l)	0.736	-0.506
Discharge (m^3/sec)	0.144	0.673
Pebbles	0.268	-0.248

AXES	I	II
Eigenvalues	0.421	0.221
Species-environment correlations	0.991	0.987
Cumulative percentage variance		
a) of species data	42.1	64.1
b) of species-environment relation	48.4	73.8
Test of significance of I axis. P-value	0.11	
T Test of significance of all axes. P-value	0.03	

Fig. 10. Canonical correspondence analysis diagram with environmental variables and nine (9) sites at Kosynthos river basin in June 2011.

4.5 Pressures from pollution sources and morphological alteration pressures

The total emissions, immissions loads produced within the river basin Kosynthos and the environmental quality standards for irrigation and fish life are presented in Table 4. Only BOD exceeded the limits for the salmonid life standard. It is evident that livestock breeding is the most polluting activity (Figure 11). Agriculture is the second diffuse pollution source of total nitrogen (30%) and nitrogen immissions. The morphological alterations for the urban land cover were 1.5% and the agricultural land cover was 27.7% lower than the proposed levels so not significant.

	Emissions	Immissions	Irrigation standards	Fish life standards Salmonid	Cyprinid
BOD (Kg/day)	11.142	2.744	12.562	1.507	3.500
Total N (Kg/day)	4.051	1.814	25.375	2.900	3.200
Total P (Kg/day)	538	85	-	100	201

Table 4. Comparison of emission and immission loads with maximum permitted immission loads.

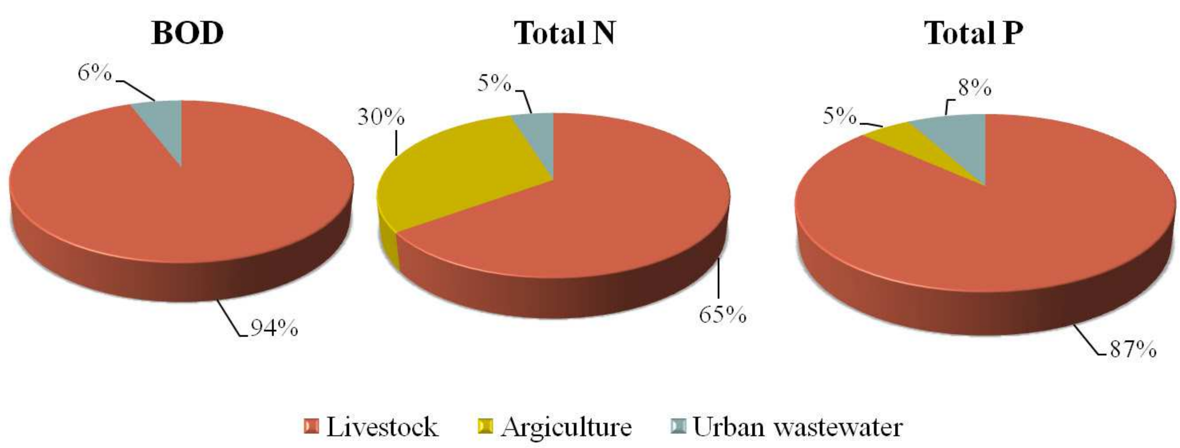


Fig. 11. BOD, total P and total N immissions that each activity produces.

4.6 Impact assessment

The impacts from the morphological alterations are probable, because the mean score of HMS is 5.5. Also, the impacts from the pollution pressures are probable, because the mean biological quality is inferior to good quality and because the nitrogen of $N\text{-}NH_4$ exceeds the limit for potable water in the site Oraio. Hence, the impacts from the morphological alterations and pollution pressures are probable. The likelihood of failing to meet the environmental objectives for the morphological alterations is medium because the impacts are probable and there are no significant pressures (urban land cover 1.5% and agricultural land cover 27.7%). Additionally, for the pollution pressures, the likelihood of failing to meet the environmental objectives is medium because the impacts are probable and there are no data for significant pressures (lack of the inputs of industrial pollutants). So in the Kosynthos river basin, an operational monitoring of the risk management for both the morphological and pollution pressures is proposed.

4.7 DPSIR and SWOT analysis

According to the DPSIR framework there is a chain of causal links starting with 'driving forces' (D) (human and economic activities) through 'pressures' (P) (emissions, waste) to 'state' (S) (physical, chemical and biological) and 'impacts' (I) on ecosystems, human health and functions, and eventually leading to political 'responses' (R) (prioritization, target setting, indicators). Consequently, all the above were examined in the Kosynthos river basin (Table 5).

D	P	S	I	R
Urban growth	1. Sewage 2. Urban waste 3. Morphological alterations	1. High concentration in N-NH_4· organic pollution and medium water quality 2. Reject of urban solid waste 3. Alteration of river channel and bank (bridges, passage of vehicles). HMS score 5.5	1. Degradation of water quality 2. Alteration of natural landscape and degradation of water quality 3. Interruption of continuity of riparian area and degradation of riparian habitat	1. Creation of installation of treatment of sewages 2 & 3. Collection, recycling and environmental sensitization
Farming activity	Untreated forage sewages	High content in N-NH_4· N-NO_2·, P-PO_4· total organic pollution and medium water quality	Degradation of water quality	Creating organized bands & modern livestock units, wastewater treatment and their use as fertilizer.
Rural activity	Use of pesticides and chemical fertilizers	High concentration in N-NO_2 and medium water quality	Degradation of water quality	Sensitization of citizens and farmers
Anthropogenic activities	1 Drilling and over-exploitation of aquifer systems 2. Morphological alterations 3. Deviation and regulation of river watercourse with terraces 4. Forest clearing and sand extraction.	1. Falling water table 2. Degradation of riparian vegetation. low QBR scores in the lowlands 3 & 4. Modification of habitat	1. Depletion of aquifer 2, 3 & 4. Alteration of riparian habitats, increased erosion and input of nutrients.	1.Drilling at regions with highest potential, rational water use and water pricing 2, 3 & 4. Re-establishment of riparian vegetation with native species

Table 5. DPSIR analysis in the Kosynthos river basin

For the sustainable development of the study area, SWOT analysis was applied in Municipality Mykis, which is in the mountainous part of the basin and in Municipality Dimokritos, which is in the lowland part of the basin, in order to estimate the Strengths, Weaknesses, Opportunities and Treats. Based on the SWOT analysis, which is a useful tool for local authorities and decision makers (Diamantopoulou & Voudouris, 2008), some recommendations are proposed to maximize the existing opportunities (Table 6) for achievement of good quality status in Kosynhtos river basin.

Strength Protected areas with biodiversity Byzantine city of 6 AD	Weakness Use of septic tanks Absence of treatment in industries Incomplete maintenance of irrigation supply network Over-tapping ground water	Strength Protected areas with biodiversity Archaeological, historical & folklore interest Riparian forest	Weakness Use of septic tanks Intensive livestock farming Illegal disposal of debris Illegal logging from riparian forest
Opportunities Growth of ecotourism in protected areas Exploitation of traditional buildings **A**	Threats Absence of urban and industrial waste water treatment Incomplete maintenance of irrigation supply network Absence of administrative policy	Opportunities Growth of ecotourism in protected areas and in the riparian forest Exploitation of traditional buildings Investments **B**	Threats Absence of urban waste water treatment Veterinary surgeon units Absence of administrative policy for the riparian forest

Table 6. SWOT analysis in Municipalities: (A) Dimokritos and (B) Mykis.

5. Discussion

In this study System B was selected because of the flexibility in the choice of abiotic parameters and better distinction in relation to the animals than the System A (Dodkins et al., 2005). According to Kanli (2009) the descriptor "Altitude" significantly affects the structure of communities of benthic macroinvertebrates in relation to the other descriptors used in the typology. Also, according to Rundle et al. (1993) and Brewin et al. (1995) "Basin size" is the second most important descriptor that affects the structure of biocommunities after the altitude. In this case, the hierarchical clustering analysis, based on Bray-Curtis index, showed that the descriptor of "Altitude" was the most important descriptor for the separation of benthic macroinvertebrates. For Mediterranean types of RM there was no apparent difference between the stations on the distribution of benthic macroinvertebrates (most of them were R-M2).

The approximate water balance for the period 1964-1999 is characterized as positive, since the water potential in the basin is sufficient to meet the needs arising from activities. The intense infiltration due to the karstic marbles of the Rhodope Mass. and the hydraulic conditions developed in the mountainous area by the presence of impermeable formations does not allow high surface runoff. Moreover, the largest city in the basin (Xanthi) is not watered from this basin.

The concentration of total suspended solids is affected by the dissolution of mineral matter and the intense evaporation (Voudouris, 2009). In this study, the highest TSS concentration measured in the lowland sites (47.6 mg/l) due to the large sediment transportation, mainly fine-grained material derived from the intense erosion, weathering and dissolution of lithological formations because of steep slopes.

The physico-chemical and biological characteristics are modified from the discharge and are related to the ability dissolution of pollutants (Prat et al., 2002). According to Hubbard et al. (2011) the importance of intense flooding in rivers demonstrates the inverse relationship between supply and nutrient concentration. In this study, in the site Kimmeria was found the lowest discharge (0.6 l/s) and low concentration of P-PO_4 and N-NH_4. This occurs because the actual band width is greater than the measured during the sampling period. Instead the highest concentration of N-NO_3 may be due to the influx of water from underground sources upstream of the site. Finally, in the site Oraio it was measured the second smallest discharge (0.8 l/s) and the highest values of nutrients, because the active band width is small and leads to accumulation of nutrients.

The ecological water quality of the site Tsai is connected to the absence of pressures. In the sites Oraio, Glauki and Byz. Gefyri, the ecological water quality is characterized as poor due to the present livestock feeding and the septic tanks. Also, the sites Chalikorema and Ekvoles were characterized as moderate because of the intensive agricultural land use, livestock feeding and septic tanks. Finally, the ecological quality in the site Sminthi and Chalikorema is good, because of the self-purification of the system and the presence of water sources respectively.

Impress Analysis showed that the immissions loads in the basin of Kosynthos is lower than the proposed irrigation limits (Decision 4813/98) issued for another region. It is suggested that an adoption of a similar Decision for Xanthi is important, since it is a rural and agricultural basin with intense activity in the lowland section. Also, the immissions loads did not exceed the limits for the cyprinid life standard, although the total organic load exceeded the limits for salmonid life standard. As livestock breeding appears to be the most polluting activity there is a certain amount of uncertainty involved due to lack of data concerning the location of breeding farms, their grazing fields, their antipollution technologies and the disposal processes of pollutants into the environment (Ioannou, 2009). The latter is mainly due to intense livestock activity observed in the municipality Dimokritos (40% total organic load from the entire river basin). Consequently, a risk management operational monitoring is proposed for both morphological and pollution pressures in the Kosynthos river basin, in order to achieve good quality status in 2015.

6. Conclusions

In conclusion, in the Kosynthos river basin 15 river types are present in the hydrographic network, according to the System B of the WFD. When taking into account the existing pressures in the basin, 44 water bodies are detected. The approximate water balance for the period 1964-1999 is characterized as positive. Among the nine stations selected for sampling benthic macroinvertebrates and according to Hellenic evaluation system of the ecological quality in three stations (Tsai, Sminthi, Kimmeria) water quality was estimated as good, in four stations (Oraio, Gefyri, Chalikorema, Ekvoles) medium and in two (Glauki, Drosero) as poor. Finally, by applying the Impress Analysis, operational monitoring was recommended.

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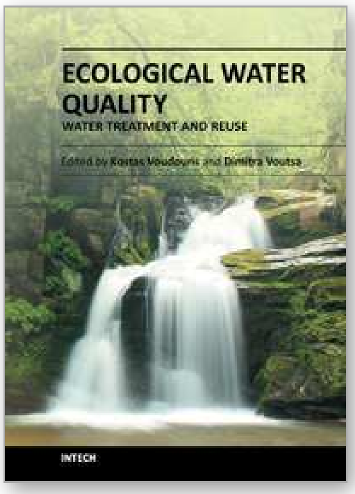

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This book attempts to cover various issues of water quality in the fields of Hydroecology and Hydrobiology and present various Water Treatment Technologies. Sustainable choices of water use that prevent water quality problems aiming at the protection of available water resources and the enhancement of the aquatic ecosystems should be our main target.