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ECOLOGICAL ASSESSMENT OF THE KIFISOS RIVER CHANNEL AND THE RIPARIAN FOREST VEGETATION

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Abstract

The objective of this study is to determine and evaluate the current condition of Kifisos River in Attica (Greece) as far as the status of riparian forest ecosystems; phytosociology and habitat structure is concerned. Four (4) different sampling sites were examined, covering a representative section of the river: one near the springs, one at the estuary and two intermediate (non-boxed section) in the residential zone. The status of riparian forest ecosystems was investigated, according to the RHS protocol, and especially by means of the HMS index and HQA score. Concerning the RHS protocol, 10 spot-checks were surveyed and the following data were recorded: substrate of the channel, type of water flow, special characteristics of the channel, types of vegetation, use of the riverbank, complexity of vegetation structure of the bank and type of artificial modifications of the channel and the banks. The calibration system HQA (Habitat Quality Assessment) was used as a measure of diversity and "naturalness" of each sampling site, including the channel and the 'river corridor', while the artificial change in the physical structure of the channel was expressed as the degree of modification of the habitat (Habitat Modification Score). Results have revealed strong modifications in the riparian vegetation and in the river corridor at the residential sites; mostly at the one that is located in the center of the city. The riparian vegetation was dominated by cosmopolitan species, resistant to pollution, a result of the impact of urban waste and polluted drainage that end up to the river ecosystem. The sites closer to the springs, have been subjected to less disturbance by human activities and, as the HQA score has indicated, can be suitable habitat of animal species, especially macroinvertebrates. The results mentioned above have led to proposals for the management of Kifisos river ecosystem in a holistic way, as part of the urban landscape.

Keywords: Kifisos River, ecology, riparian ecosystem, riparian forest, river quality, RHS

1. INTRODUCTION

One of the main goals of the Water Framework Directive 2000/60 is to achieve sustainable management of surface water ecosystems using four categories of biomarkers, i.e. benthic macroinvertebrates, diatoms, physicochemical parameters and the riparian ecosystem. Macrophytes, due to their 'immobility' and their long life cycle, can be used as biomarkers in the early stages of pollution by heavy metals through tissue accumulation, individually or in combination with other organisms (in Birk et al., 2012; Feio et al., 2012).
The strip of land bordering a river channel is called 'riparian zone'. Plants growing in this zone define the riparian vegetation, which, despite the fact that covers a small part of land, it is an integral part of the aquatic ecosystem and plays a disproportionately significant role in the river functions (in Vourkas, 2007) and also in water control and chemical exchange between surrounding land and the water system (in Dosskey et al., 2010). Riparian vegetation contributes to the supply of organic matter through input of dead plant material (in Efthimiou, 2000; Efthimiou & Smiris 2002) as well as to the preservation of water quality through nutrient retention, which may come from various sources of pollution, while it further affects river geomorphology (in Greet et al., 2011). Indirectly, it supplies with reactive detritus land and channels, alters water movement and stabilizes the soil (in Dosskey et al., 2010).

Riparian vegetation interacts dynamically with both allogeneic and homogeneic factors. Practically these organisms must constantly respond to a complex set of hydrological (floods, sediment transport), non-hydrological (fires, anthropogenic intervention) and biotic (species competition, epidemics) effects (in Efthimiou et al., 2003), thus determining biodiversity and heterogeneity, specifically the coexistence of different species and the dependence of these patterns on space and time. Allogeneic factors related to hydrology, play an important role in determining the distribution of plants in sections of rivers, affecting the depth of aquifer. Processes of erosion and sedimentation are related to vegetation dynamics, since they can cause erosion. Riparian vegetation also increases channel's stability, due to the roots of plants (in Efthimiou, 2000, 2012) even affecting flow resistance and flow rate while reducing shear stress of the soil surface. This positive feedback is obtained from herbs and shrubs, rather than trees which can instead increase erosion, creating a vortex region behind the trunk (in Tealdi et al., 2013).

Moreover, composition of riparian stands depends on interspecific relations with the interaction between species being both positive and negative (in Tealdi et al., 2013).

Deforestation of riparian ecosystems leads to reduced supply of detritus in a stream or river system, thus causing a decrease in retention of sediment and nutrients. The removal of riparian vegetation increases the risk of erosion of the river channel and also increases water temperature due to reduced shading. Such ecological services of riparian systems are critical to maintaining high quality habitat and biogeochemical cycles of nutrients (Tullos & Neumann, 2006).

Camporeale & Ridolfi (2010) studied geomorphological and hydrological characteristics in combination with types of vegetation and showed that the relationship between helix of the river and biomass of the vegetation is nonlinear. Their research indicated that the distribution of biomass of riparian vegetation is sensitive to hydrological, hydraulic and vegetation changes. Altering intersections, sediment export, reactivation or suppression of meanders, felling of riparian vegetation, changes in the type of vegetation (i.e., replacement of typical riparian species with agricultural species) and also changes in the hydrological regime due to regulations or dam structures are examples of human activity that can significantly affect the fragile and partly unknown balance between biotic and abiotic elements of river ecosystems. Therefore, any activity in river ecosystem, such as management or rehabilitation projects, should be carefully planned in order to take into account the effects on the distribution of riparian vegetation along rivers.

In addition to morphology, water chemistry affects riparian vegetation and specifically the nutrient content (in Baattrup-Pedersen et al., 2011). A decrease in groundwater level increases the aeration of the root system, enhances digestion and thus the availability of nutrients that can be used for plant growth. On the other hand, it is generally accepted that flooding plays an important role in the biodiversity of river ecosystem.

Submerged macrophytes play an important role in structuring habitats, which are important for other aquatic organisms, such as invertebrates, fish and diatoms and help stabilize river channel, promote conservation of rich in nutrients particles and directly affect sediment dynamics and flow. Macrophytes may be apparent only during one period of the year, particularly in areas where rainfall is highly seasonal, such as the Mediterranean region. Due to size and patchy distribution, macrophyte species are often found in this habitat and their cover is nowadays used as a measure of abundance for ecological quality assessment and monitoring. Measurements of macrophytes respond to nutrient enrichment and hydromorphological degradation even though the latter relationship is less studied.

Because aquatic plants are constantly exposed to the effects of various pollutants, these organisms reflect not only current conditions, but also temporal changes in conditions as well as their accumulative effects, which is a particularly useful information in holistic management (Harguinteguy et al., 2013). Negative effects of poor water quality can range from a shift to mainly pop types to a complete collapse of the macrophyte community. Specifically, sediments and nutrients through runoff from land use cause eutrophication resulting in decline of submerged aquatic plants (in Rosso & Cirelli, 2013).

1.1 Study area

Kifisos is one of the two major rivers of Attica, collecting 67% of rainwater of the area (in Papapetrou –Zamani, 1989). Its length is 22 km, 14 km of which run through the urban part of Attica. The drainage basin area is 381,10 km^2; Kifisos stems from the mountain Parnitha and flows in a 9.5m deep channel at the haven of ‘Faliro’. The length of the streams that end up in Kifisos is 150 km, while only the upper part of the river is natural. Regarding geological substrate, the mountainous and hilly parts of the basin consist mainly of limestone, marble, schist and alluvial deposits, while the plain is occupied by concrete blocks (in Mountrakis, 1985). The use of land that dominates both upstream and downstream is the poorly regulated urban construction (in Exarxou et al., 2004), while the dominant riparian species observed is *Platanus* spp. Kifisos has been serving Attica with water for irrigation purposes during centuries; nowadays, due to interventions, it is a degraded ecosystem (in Exarxou et al., 2004), in spite of the attempts of regulators to protect it. Pollution from solid waste, hazardous liquid industrial waste, but also from urban wastewater degrade Kifisos ecosystem, not allowing it to provide services like drinkable water, fresh air and recreational services.

The value of the hydrographic frequency[1] for the hydrographic network of Kifisos is 1.33, while the value of the hydrographic density[2] is 1.44. The relatively low values of the two parameters indicate coarse drainage texture and poor drainage. Certainly, in the formation of these parameters lithology of the area plays an important role. At the foot slopes of mountains, in the mountain of Parnitha and in the estuary of the river, the lowest values are being observed, values that significantly affect overall rates of the basin (in Kotambasi & Skentos, 2005).

Land uses in the areas, on either side of Kifisos and streams, vary and show differences between the boxed and the non-boxed part. Upstream and near to the springs, there are forests and shrublands, in the intermediate zone urban construction is the main land use, while downstream and near the boxed part urbanization and industrial activities are dominating.

Four representative sampling sites were selected: the first near the springs, the second downstream and in the most natural environment, the third in the center of the city and the last one at the estuary (Figure 1). Of course, the study of the riparian ecosystem could not be carried out at the fourth site, as it is totally boxed.

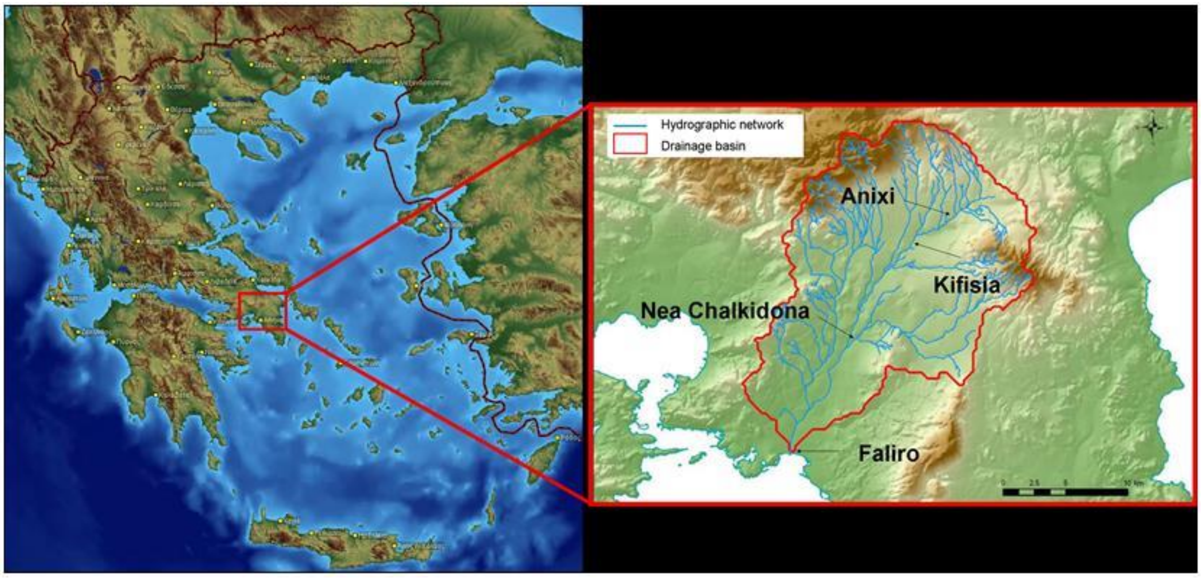

Figure 1. Geomorphological map of Greece and map of the study area in the former prefecture of Attica with the sampling sites pointed out (www.googlemaps.com)

2. MATERIALS AND METHODS

Study of the riparian ecosystem was carried out by identification of the dominant woody taxa and investigation of the physical structure of the river by means of the River Habitat Survey (RHS) protocol.

The RHS was carried out along a part of the channel of the river, 500m of length and extending outwardly on each bank of the river for 50m. RHS protocol, which was completed in the field, included observations in ten control points (spot-checks) - which were equally spaced at intervals of 50m (in Raven et al., 1998). Then a sweep-up check for the 500m length of the study is being made to ensure that characteristics and changes not appearing in the selected control points (spot-checks) are recorded. Table 1 shows characteristics recorded at the checkpoints and the sweep-up check.

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[1] Hydrographic frequency: The ratio of the total number of branches of the channels of all classes in one basin, to the area of the basin.

[2] Hydrographic density: The ratio of the total length of all branches of classes within the basin, to the area of the basin.

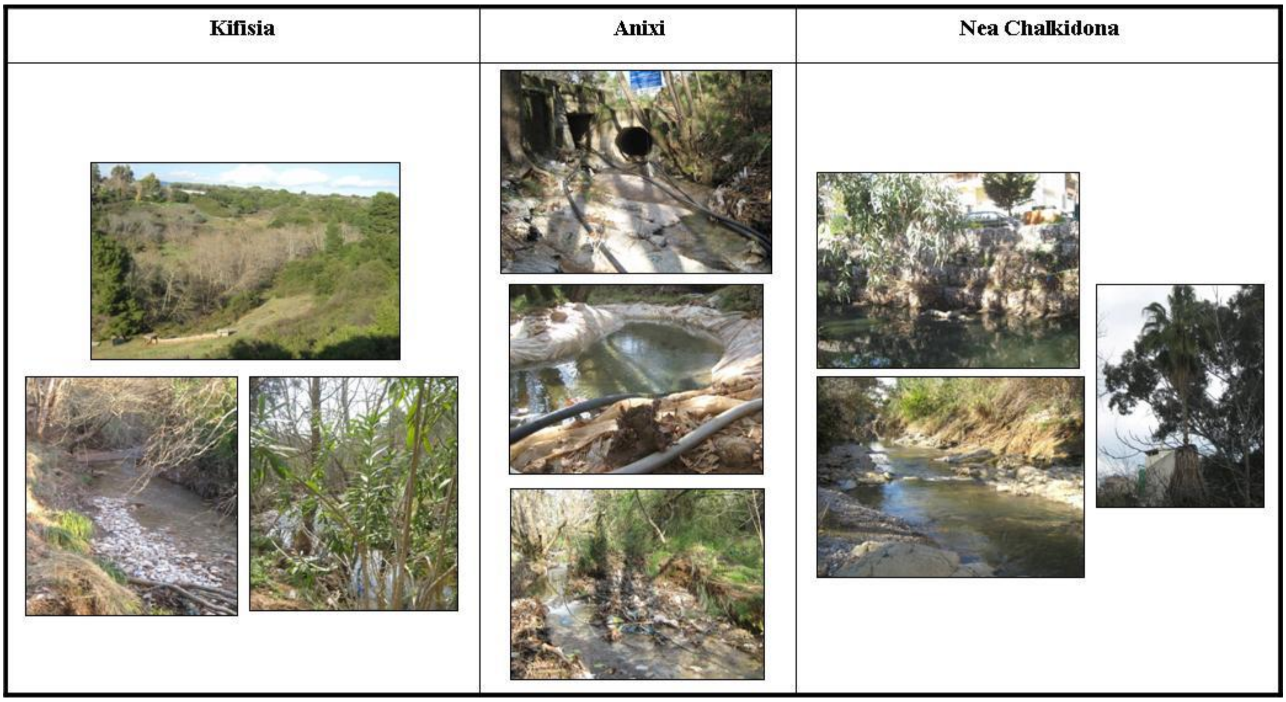

Figure 2. Characteristic views from the three study areas

Table 1: The main characteristics recorded during an RHS survey (in Raven et al., 1998).

Features recorder	At 10 spot-checks	In sweep-up
Predominant valley form		✓
Predominant channel substrate	✓	
Predominant bank material	✓	
Flow type(s) and associated features	✓	✓
Channel and bank modifications	✓	✓
Bankface and banktop vegetation types	✓	
Channel vegetation types	✓	✓
Bank profile (unmodified and modified)		✓
Bankside trees and associated features		✓
Channel habitat features	✓	✓
Artificial features	✓	✓
Features of special interest		✓
Land use	✓	✓

2.1 Habitat quality assessment (HQA)

Calibration is a tool for the description of any ecological system and in particular for complex and dynamic riparian systems (in Efthimiou, 2000) such as rivers. The calibration system HQA (Habitat Quality Assessment) is basically a broad measure of diversity and ‘naturalness’ of an area, including the channel and the 'river corridor' (in Raven et al., 1998).

2.2 Habitat modification score

Artificial change in the physical structure of the channel can be expressed as the degree of modification of habitat or Habitat Modification Score (HMS) (in Raven et al., 1998).

3. RESULTS & DISCUSSION

The results of HMS and HQA are shown in Tables 2-5.

Table 2: Results based on the Habitat Modification Score

Site	**HMS score**	**Descriptive category of channel modification**	Code color
Kifisia	11	Obviously modified	
Anixi	26	Significantly modified	
Nea Chalkidona	45	Severely modified	

Table 3: HQA for 'Kifisia' site

	Channel	Banks	Phytosociology (5 dominant taxa)
Kifisia	Swallow vee with substrate of pebbles and gravel and mainly smooth flow Side bars and discrete sand deposits observed Emergent broad-leaved herbs	Natural, eroded gravel/sand banks *Vegetation type*: Broadleaf/mixed woodland Extensive shading	*Platanus orientalis* *Pinus halepensis* *Eucalyptus* sp. *Olea europea* *Arundo donax*

Table 4: HQA for 'Anixi' site

	Channel	Banks	Phytosociology (5 dominant taxa)
Anixi	Swallow vee with substrate of pebbles and gravel and mainly smooth flow Marginal deadwater and discrete silt deposits observed Emergent broad-leaved herbs	Natural, eroded banks consisted mainly of earth *Vegetation type*: Broadleaf/mixed woodland Extensive shading	*Pinus halepensis* *Platanus orientalis* *Cupressus sempervirens* *Arundo donax* *Olea europea*

Table 5: HQA for 'Nea Chalkidona' site

	Channel	Banks	Phytosociology (5 dominant taxa)
Nea Chalkidona	Swallow vee with substrate of pebbles and gravel, smooth and rippled flow Unvegetated side bars, underlying solid rock with cobbles and discrete sand deposits Liverworts/mosses/lichens	Artificial, reinforced banks Right: cobbles, gabion, concrete reinforced, unvegetated/vegetated side bars, artificial berms Left: boulders, unvegetated/vegetated side bars, unmodified Vegetation type: Broadleaf/mixed woodland	*Eucalyptus* sp. *Pinus brutia* *Arudo donax* *Olea europea* *Fragmites* sp.

3.1 HMS

The HMS index indicates the degree to which the ecosystem has been altered. HMS results for Kifisos were rather expected, taking also into account the results of physicochemical parameters and macroinvertebrate fauna (reference in press). The site 'Kifisia' actually appears as the least disturbed, 'Anixi' as obviously modified, while the riparian environment with the greatest modification and disruption seems to be ' Nea

Chalkidona '. Consequently, it is obvious that, despite the fact that in the site 'Anixi' the river is flowing near an industrial zone and it is not expected the industrial wastewater and modifications of the channel and banks to have a stronger effect on the riparian ecosystem, however, the most serious impacts are due to urban wastewater that end up completely untreated to the 'Nea Chalkidona' site and to all the interventions this site has been subject to.

3.2 HQA

The HQA indicates quality of the habitat. The most important elements defining habitat conditions are: flow rate of the river, oxygenation of the water, presence of food and temperature fluctuations.

In 'Kifisia', another stream – of small width and depth - ends up to the main river and the substrate of gravel and cobbles ensures smooth flow of water. The silt and sand deposits (islands) create conditions for the development of life as animal populations are denser in those places where the shape of the bottom forms regions of calm water with continuous precipitation of nutrients (Argyropoulos & Dasenakis, 1997).

In 'Anixi', where the river is fed mainly by a smaller stream, the bottom is sandy-gritty with a small slope ensuring smooth flow. The absence of fauna species indicates pollution from nearby factories. Because the river is shallow with a bed of sand and silt, the root system of the plants prevent the water flow and facilitate mud deposition, which gradually alters the substrate.

'Nea Chalkidona' site is mainly an urban area and the artificial banks along with the municipal waste as well as rubbish that is being deposited do not allow vegetation growth.

In describing separate RHS areas, HMS and HQA should be used in combination, because together they can provide a broad indication of how the overall quality of the habitat and the structural modifications could be connected. However, it is important to consider that the HMS score refers only to the channel modifications, while the HQA score is determined by the channel characteristics and the 'river corridor' (in Raven et al., 1998).

4. CONCLUSIONS

Even if nowadays the lower part of Kifisos river is totally connected to the big highway that is named after it, many measures could be taken to improve its ecological status. End-pipe solutions in Mediterranean rivers are not efficient (in Prat & Munne, 2000) and what is really needed is quality management subject to the River Continuum Concept (RCC) (in Economou-Amilli, 2006) and based on the four basic management principles of the WFD: a) Sustainable development, b) 'The polluter pays', c) Stand-still principle and d) Precautionary and preventive action. Having been established by the European legislation as the primary element of management needs for surface waters, ecological status is used to monitor and manage ecosystems sustainably with the aquatic biological evaluation to be a transaction between legislative requirements, better scientific knowledge and socio-economic implications (in Birk et al., 2012). Information and awareness of the citizens and the state can result to Kifisos functioning again as an ecological corridor, preventing floods, helping to the renewal of the atmospheric air of the city (with a positive effect on the climate), forming a habitat with high aesthetic and ecological value, an area of environmental education that is a substantial part, not only of the urban landscape but also of residents' life.

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