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Water quality and benthic fauna biodiversity in a unique small wetland at Messinia, Greece

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Abstract

The wetland of Aghios Floros is located in the Prefecture of Messinia (S.W. Peloponnese, Greece) and occupies a small area, covered permanently with water. Flooding of the surrounding area is defended by an artificial channel that discharge large quantity of water into Pamisos River in whose river basin the Aghios Floros station belongs. At the sampling site various physico-chemical and conventional pollution parameters as well as hydrochemical variables were measured during the wet and the dry period of 2011. The hydromorphological and multihabitat approach of RIVPACS method was applied in situ, which gives an overall image of the landscape. The site was classified as 'Good' according to the Greek River Nutrient Classification System (GR_NCS) and the benthic macroinvertebrate fauna assemblages that dominated the area pointed out a 'Good' biological status as well. The biotic and abiotic sample processing, carried out in compliance with the demands of the Water Framework Directive, in general revealed high ecological status of the station. Specifically, a rich diversity and abundance of some macroinvertebrate families was recorded and regarding the aquatic flora the area is dominated by the water lilies species of Nymphaea alba which are unique in the area of Peloponnese.

Key words

Benthic, Biodiversity, Water quality, Wetland

Introduction

Wetlands are among the most productive and valuable ecosystems in the world since they support richly diverse communities of organisms and provide ecological functions with significant value to society, (Mitsch and Gosselink, 2007; Gücel *et al.*, 2012).They are also essential concerning the preservation and protection of functions such as fish provision, wildlife habitat, natural water quality improvement, flood storage and protection from shoreline erosion. These ecologically and functionally significant ecosystems possess a potentially important role in respect to achieving sustainable river basin management. A big variety of wetlands exists worldwide due to regional and local differences in various characteristics such as: soil, climate, water chemistry, topography, hydrology, vegetation and other factors including anthropogenic activities and their disturbance. Indeed, these landscapes are found from tundra to tropics and on every continent, except Antarctica. Finally, two general categories of wetlands recognized are coastal or tidal wetlands and inland or non-tidal wetlands. Worldwide there are thousands of wetlands such as West Siberian Plain, Amazon River catchment area, Congo River Basin, the Pantanal, the River Nile Basin, Maggelanic moorland etc. (Keddy *et al.,* 2009), the Kerkini Lake (Pyrovetsi and Papastergiadou, 1992) the Kotychi Lake, Peloponnese, Greece, (Kalivas *et al.,* 2003) etc. During the past decades due to anthropogenic activities worldwide an enormous area of those wetlands has been downgraded. Thus, the scientific community has focused on various environmental problems concerning the wetland's ecology considering certain conservation methods such as the Wetlands Horizontal Guidance (2003), the Directive 2008/105/EC (2008), the World's Largest Wetlands Ecology and Conservation (Fraser and Keddy, 2005) etc. Also it has focused on monitoring methods such as in San Francisco Bay and throughout Dakota and Hennepin Counties. For the reasons mentioned above, *i.e.* due to the fact that these landscapes are of paramount importance and because they are

under certain pressures resulting in a dramatic reduction of their numbers, their significance should be revealed and the ecological features of such habitats should be highlighted.

The wetland of Aghios Floros (Fig. 1) possesses rich flora and fauna, important habitats and two CORINE biotopes (Pamisos River, A00020019 and Mount Ithomi A00030040) European Environment Agency, (1994). Due to high water supply it is incorrectly believed that the springs of the river are located there. Significant fish species encountered here are *Gasterosteus aculeatus* (local name: Agathero), *Tropidophoxinellus spartiaticus* (local name: Bafa), *Phoxinellus pleurobipunctatus* (local name: Liara), Salaria fluviatilis (local name: Potamosaliara), significant mammals like *Lutra lutra* (Otters) and large population of water turtles and avifauna *i.e., Ardea cinerea*. At Mount Ithomi a rare endemic orchid has been reported as well (*Orchis coriophora* ssp. *coriophora* and *O. coriophora* ssp. *fragrans*) while at the same time the area is threatened by uncontrolled grazing (Filotis, 2014). A historical perennial tree 'Natural Monument - Plane tree St. Florus Messinia' is also present which is associated with the events of 17th and 18th century (Filotis 2014; MedWet Web Information System 2011; EEA - CORINE Biotopes, 1994; Gritzalis, 2011). Concerning the linear sources of pollution only an irrigation network is present in the area (Aghios Floros - Valira, water originating from Pamisos springs) which irrigates an area of 12x106m^2. This constitutes a major source of pollution as it provides the soil and the aquifer with used irrigation water (water drainage), burdened with pesticides and fertilizers, (Lampropoulou, 2011).

The present study aimed to record the chemical and biological status of Aghios Floros wetland, using the approaches and methods suggested by the Water Framework Directive 2000/60/EC, as is the case with other wetlands in Europe, to reveal its importance and to record the unique flora present in the area. The particular wetland studied at the present work falls within the scope of the Directive's monitoring programmes. The integration of the wetlands to the monitoring requirements of the Directive, demonstrates their significance in reaching the Directive's environmental objectives. Moreover, the relevant Directive gives special emphasis to the wetlands that are designated as water bodies or form part of the latter and to those included in the Registry of Protected Areas both of which apply to the wetland of Aghios Floros.

Materials and Methods

Characterization of study area : The wetland of Aghios Floros (Fig. 1) is located in the homonymous community (Ag. Floros), which is built on the banks of Pamisos river, the biggest river in the area (ca 80km length). It belongs to the Prefecture of Messinia at southern Greece (SW Peloponnese) and located at an altitude of 28 m and its distance from the capital city of Kalamata is 20 km (Demetriou and Mentzafou, 2011); Gritzalis, 2011). The catchment area of Pamisos river is mainly plain and it spreads over 618 km^2 (Fig. 1). The wetland of Aghios Floros, consists a very important characteristic of Pamisos river basin, is a small area covered permanently with water and constitutes a typical karstic system. The landscape is characterized as karstic due to its geology; it is formed from dissolution of soluble rocks including limestone, dolomite and gypsum and is also characterized by high infiltration rate (Gritzalis, 2011). This karstic system supports rich aquatic and riparian vegetation, especially water lilies, common reeds and other aquatic plants. It has been hydrologically categorized as a riverine wetland. Generally in this area, besides small urban settlements and small units of agricultural processing products, agricultural land prevails which is dominated by complex farming systems and olive groves. Natural pastures, small restricted areas receiving aggregates, fisheries and large areas of natural vegetation are also present (Gritzalis, 2011). The meteorological features of the area show that the climate is temperate Mediterranean type, with mild winter and extensive and warm summer. The average annual rainfall reaches 751.2 mm/yr in the prefecture. The maximum level has been recorded during winter period (332.4mm yr^{-1}) and minimum during summer (22.4 mm yr^{-1}), while the driest month has been reported to be July and November (Anastasopoulou, 2012).

The parameters recorded at the Aghios Floros station, during winter and summer sampling period of 2011, include

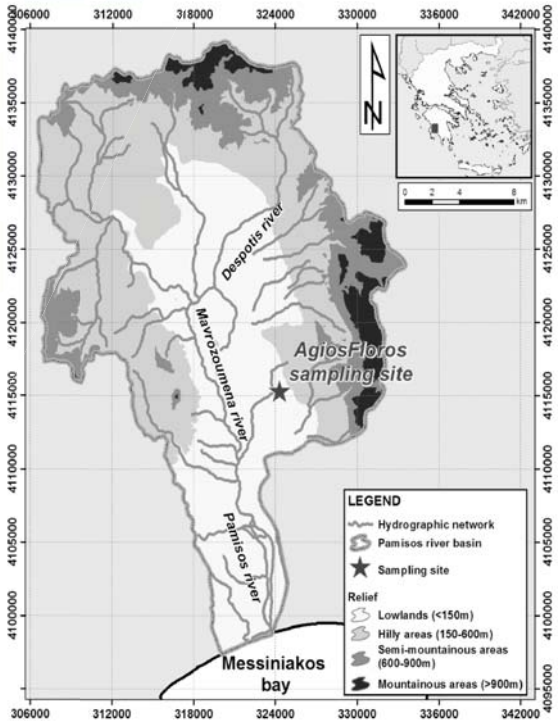

Fig. 1 : Study area (Aghios Floros sampling site) and Pamisos River Basin, in Messinia Prefecture, Peloponnese, Greece

physico-chemical parameters, main ions, nutrients, trace metals, phenols and total organic carbon. The physico-chemical parameters were determined *in situ* by portable multi parameter instrument HI 9828 of Hanna Company. Prior to each sampling, the instrument was calibrated in accordance with the requirements of the International Scientific Practice. The key features of the instrument include of measurement of dissolved oxygen (D.O. mg l^{-1}), pH, temperature (°C), conductivity (µS cm^{-1}), redox potential (ORP), salinity (%) and total dissolved solids (TDS). The main ions, Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, SO_4^{-}, Cl^{-} and NO_3^{-}, were determined by Metrohm's ion chromatography (Jackson and Haddad, 1990), while nutrients (NO_2^{-}, PO_4^{-3}, NH_4^{+}) total phosphorus (TP), total nitrogen (TN) and SiO_2 were determined photometrically by spectrophotometer, MERCK (2009). Alkalinity and total hardness were measured by automatic titration (APHA, 2005). Heavy metals (Cu, Zn, Pb, Cr, Mn, Fe, Ni and Cd) in the soluble phase were determined by Inductively Coupled Plasma Technique (ICP-MS Thermo-XSeries II), Cutter and Radford-Knoery (1991). Total organic carbon was measured by catalytic oxidation at high temperature (HTCO), (Sugimura and Suzuki, 1988), using TOC-5000A Shimadzu analyzer. Total phenols were measured by Folin Ciocalteau method. Absorbance was read with a UV-Vis spectrophotometer at 765nm and the results were expressed as mg of Gallic acid based on relevant calibration curve (Folin and Ciocalteau, 1927; Lamuela-Raventos, 1999; Gritzalis, 2011).

The station was also classified according to the Greek River Nutrient Classification System (Laschou, 2010). Aquatic macroinvertebrate organisms were sampled with the worldwide used method of RIVPACS (Armitage *et al.,* 1983; Alba-Tercedor and Pujante 2000). The River Habitat Survey, which is a standard methodology for accessing hydromorphology and other important features, was also applied (Raven et al. 1998). This method is very important for implementation of the EU Water Framework Directive 2000/60/EC and constitutes a tool for monitoring river habitats and assessing potential impacts of developments. Classification according to the Greek River Nutrient Classification system: The chemical and physicochemical characteristics were recorded and the station was classified pursuant to Tables 1 and 2 according to the Greek River Nutrient Classification system, Laschou (2010), which constitutes a development of the Skoulikidis et al. (2006) classification system and refers to geographical zone 3 in which the study area belongs (Fig. 2). The Norwegian system, which is the strictest one in Europe, was applied for the classification of dissolved oxygen. This system is part of the classification procedure of the Greek River Nutrient Classification System. Each quality element receives a value from column C according to the quality class to which it belongs (Table 3) and the average value of the parameters determine the physico-chemical status according to column A. Sampling of benthic macroinvertebrates: The aquatic macroinvertebrate organisms, in the present study, were collected by RIVPACS method (Alba-Tercedor and Pujante, 2000; Wright *et al.,* 2000; Alba-Tercedor and Sànchez-Ortega, 1978; Armitage *et al.,* 1983) which gave an overall image of the landscape, including hydrogeomorphology, riparian conditions, anthropogenic pressures and land uses, and was based on the multi-habitat approach (Barbour and Yoder, 2000). The biological indices of BMWP and IBMWP (Spanish version) were also calculated. This method was designed in such a manner so that the sampling units from specific habitats could be taken in accordance to the rate of their presence in 180sec. Each sample was sealed in a jar after addition of 95% ethanol and the macroinvertebrates were identified in the laboratory. Subsequently, the station was classified according to the results. The River Habitat Survey (RHS) was used as a standard methodology for assessing hydromorphology and the physical character of the river, in accordance with the Water Framework Directive in Europe. RHS is a tool for monitoring river habitats and assessing potential impacts. Habitat quality was determined by the occurrence and diversity of habitat features and data collection was based on a standard 500m length of river channel. Map information was collected (altitude, slope, geology, height, distance from source) together with the features of the channel.

Results and Discussion

Wetlands play an important role in achievement of environmental objectives of the Water Framework Directive, since they help in fulfillment of programme measures and adjustment to regional and local conditions (Directive, 2000; Directive, 2008). During winter of 2011 (January), the physico-chemical status of Aghios Floros station was classified as 'Good' according to the Greek River Nutrient Classification System (Laschou, 2010), despite slight decrease in dissolved oxygen concentration and elevated value of total nitrogen, recorded in the present study. A number of sites in the prefecture of Messinia, however, have been classified as 'Poor' during same period and according to same system (Gritzalis, 2011). These sites belonged to the following rivers: Epis, Tzanes, Karyas, Mourtia, Lygdou and Despotis all of which are located in the prefecture of Messinia. They have been classified as 'Poor' due to elevated concentration of phosphates. Also high value of phenols were recorded in all of these stations as a result of the great olive oil mill wastewater quantities that are being generated annually in the nearby area and end up in rivers (Gritzalis, 2011; Anastasopoulou, 2012). Contrary, Aghios Floros station was classified as 'High' with respect to $N\text{-}NH_4$, $P\text{-}PO_4$ and Total P and as 'Good' regarding NO_3 (January, 2011) (Table 4). During dry period (June 2011), the station was classified as 'High' since most of the parameters were found at satisfactory level (Table 4), while the overall status concerning 2011 was 'Good' (Table 5). More specifically, the concentration of NO_3 (average 3.22mgl^{-1}), NO_2 (<0.016mg l^{-1}), NH_4 (average 0.040mgl^{-1}) and PO_4 (<0.08mg l^{-1}) were found rather low at both sampling periods at Aghios Floros station. Finally, a slight increase in the concentration of total N, during wet period could be attributed to surface runoff from small settlements and agricultural

land. In parallel, total phenols were not detected during both the period of 2011.

Trace metals (Cu, Zn, Pb, Cr, Mn, Fe, Ni and Cd) were also detected at low levels and far below the permissible limit, pursuant to Directive (2008). Total organic carbon content in Aghios Floros wetland was recorded in low level at both periods, indicating that no major input of organic load took place. Overall, considering other aquatic bodies in Messinia organic input in the riverine system was much high during winter, due to discharge of large quantities of olive mill waste water in nearby small streams (Anastasopoulou, 2012). This was also confirmed by high values of phenols that was recorded in many other river sites in prefecture during several winter periods (Karaouzas, 2010; Gritzalis, 2011; Anastasopoulou, 2012). Although, Aghios Floros station in not located close to olive oil industries, therefore it was slightly affected by these discharges as reported in the present study. Therefore, specific site did not seem to be influenced by great discharges of olive oil mill waste water which was estimated to be more than 200.000 ton during winter period, in the Prefecture of Messinia Anastasopoulou (2012). Concerning the physico-chemical parameters the average value of total hardness was recorded at low level (402 mg l^{-1}) but electrical conductivity was found to be elevated (1154 µS cm^{-1}) during January 2011 and June 2011 (1027 µS cm^{-1}). This could be attributed to the geological formations and to the karstic rocks located in the area (Gritzalis, 2011). All the major cations analyzed did not differ between two sampling campaigns and ranged at normal level (Average values: Ca 102.33 mg l^{-1}; Mg 35.57 mg l^{-1}; Na 105.4 mg l^{-1}; K 2.84 mg l^{-1}).

Table 1 : River Classification System based on nutrient concentrations in the geographical zone 3 (Greek River Nutrient Classification System GR-NCS) (Laschou, 2010)

	Quality classes towards nutrients (mgl^{-1})				
	High	**Good**	**Moderate**	**Poor**	**Bad**
N-NO_3^-	≤0,19	≤0,89	≤1,28	≤1,40	>1,40
N-NO_2^-	≤0,002	≤0,016	≤0,021	≤0,066	>0,066
N-NH_4^+	≤0,016	≤0,036	≤0,063	≤0,555	>0,555
P-PO_4^{3-}	≤0,017	≤0,028	≤0,058	≤0,064	>0,064
TP	≤0,023	≤0,084	≤0,092	≤0,138	>0,138
TN	≤0,41	≤2,27	≤2,90	≤4,09	>4,09

Table 2 : Classification of dissolved oxygen concentration according to the Norwegian System

		Quality classes towards dissolved oxygen				
Norway	mgl^{-1}	High	Good	Moderate	Poor	Bad
		> 9	9–6.4	6.4-4	4-2	< 2

Table 3 : Scoring system of quality classes

	Scoring System Indicators		
Classes	**A** Score boundaries	**B**	**C** Average
H (High)	>4-5	(4.1+5)/2	4.55
G (Good)	>3-4	(3.1+4)/2	3.55
M (Moderate)	>2-3	(2.1+3)/2	2.55
P (Poor)	>1-2	(1.1+2)/2	1.55
B (Bad)	<1	1/2	0.5

With respect to biological results it was observed that during wet period of 2011, the most dominant species belonged to Gammaridae, Hydrobiidae and Chironomidae family while Planorbidae, Neritidae and Asellidae species were found in small percentage. During dry period of 2011, the most dominant species were once again the families of Gammaridae, Hydrobiidae, Asellidae, and Neritidae, while the families of Baetidae, Aphelocheiridae were also present during the summer sampling campaign. Thus, no major alteration was recorded between dry and wet period concerning the type of species recorded most of them will additionally found in great abundance.

22 and 18 different families of macroinvertebrates were recorded in study area during wet and dry period of 2011. Their abundance did not differentiate between the two seasons either. This number of families was highest among 19 stations of 12 rivers studied during a local monitoring programme in Messinia (Gritzalis, 2011). The water quality of Aghios Floros wetland, according to bioindicator for assessing the health of wetlands (Sharma, 2009), was based on taxa richness, classified the water quality of station as 'Very Good". According to biological integrity index, which has a tertiary scale, the studied station was be classified as Moderate (15–22 number of families), at both sampling periods of 2011. However, 22 different families of macroinvertebrates recorded, during wet period classified station close to next category of this tertiary scale, which correspond to 'Excellent' water quality (23-30 number of families).

Also, the biological status of Ag. Floros was classified as 'High' during winter sampling campaign and as 'Good' during

Table 4 : Classification of Aghios Floros station during winter and summer period, 2011.

Station	**D.O.**	**N-NO_3**	**N-NO_2**	**N-NH_4**	**P-PO_4**	**Total N**	**Total P**	**Average**
Ag. Floros	mgl^{-1}	mgl^{-1}	µgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	
Winter	Moderate	Good	Good	High	High	Moderate	High	Good
Summer	High	Good	Good	Good	High	High	High	High

Table 5 : Classification of the chemical–physicochemical status of Ag. Floros station during 2011

Station	Classification
Ag. Floros	3.91 / Good

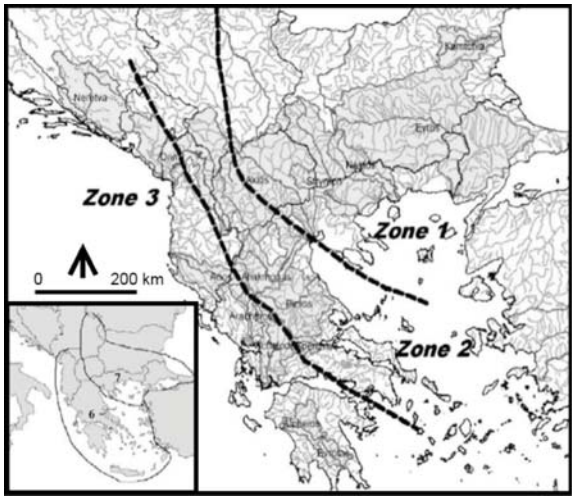

Fig. 2 : Geographical (geological-climatic-hydrochemical) zones Greece (according to Skoulikidis, 2009)

Fig. 3 : The Aghios Floros wetland in Messinia Prefecture dominated with the water lilies species of *Nymphaea alba*

summer campaign of 2011 according to the biological indicators of BMWP (Armitage *et al.,* 1983) and BMWP Spanish version (Alba-Tercedor and Sànchez-Ortega, 1978; Alba-Tercedor *et al.,* 2000). Therefore, the biological results pointed out good biological status of the studied station. Moreover, the studied wetland is at a natural state (Fig. 1 and 3) where no disturbances occur and it is directly discharged into a channel. The channel has been subject to certain modifications and its status according to the results of RHS survey was classified as 'significantly modified', during 2011. As far as aquatic flora is concerned, the station is dominated by water lilies of *Nymphaea alba* (Fig. 3), which are unique in Peloponnese, common reeds, as well as species of *Juncus* sp., *Isoetes* sp., *Sagittaria* sp., *Typha* sp., *Myriophyllum* sp, *Potamogeton* sp., *Lemna* sp., according to the results of the present research. Also several individuals of water turtles were found and significant avifauna, (Filotis, 2014). Water lilies were present only in two areas in Greece (Aghios Floros) and in the artificial lake of Kerkini in Strymonas River near Greek - Bulgarian borders (Pyrovetsi and Papastergiadou, 1992). They were considered to be rare since they were not reported in any other relevant survey and thus their importance should be recognized and special attention should be attributed towards their preservation.

Overall, Ag. Floros site was classified according to physico-chemical and biological parameters, in the present study using a consistent methodology, following the guidelines of Water Framework Directive considering wetlands (Directive, 2008). The results of both chemical-physicochemical classification as well as from the communities of microinvertebrates demonstrated that wetland was good status. In general, the results primarily revealed the importance and uniqueness of wetland not only in of Messinia area but in the wider Mediterranean region as well, due to its rich biodiversity and aesthetics within a relatively small urban landscape. Regarding the research perspectives if study area, these results could be used in future for implementation of an integrated management plan of specific river basin, since it fulfills all the necessary criteria.

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