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ORIGINAL ARTICLE

Multipurpose Plans for the Sustainability of the Greek Lakes: Emphasis on Multiple Stressors

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Abstract Lake Ecosystems have experienced a significant loss of their ecological value due to various human activities. It has been recognized that the continued alteration of freshwater biodiversity is not sustainable, and also, it has been realized that less modified freshwater ecosystems provide significant economic and social benefits to society. In Greece, changes in land and water management, driven by the increase in agricultural production and the urban expansion, have created multiple stressors on lentic ecosystems which cannot be ignored any longer. The objective of the present study is to describe some of these stressors, and to identify their impacts on Greek lakes. We collected an extensive dataset from twelve natural lakes using several metrics, also suggested by the Water Framework Directive (WFD), along with specific ecohydrological characteristics. Our results demonstrate severe impact on water quality and quantity with consequence to the lake's functions, and extended eutrophication in almost all lakes. The Greek lakes have been subjected to various hydromorphological alterations, which affect their metabolism, while the aforementioned effects are further maximized due to particularities of the Mediterranean climate. The set up of good management practices through multipurpose management plans are also discussed.

Keywords Eutrophication · Multiple pressures · Stressors · Management practices · Greek Lakes

1 Introduction

The sustainability agenda has changed dramatically over the past decade. According to the European Academic Science Advisory (EASAC 2009) there are two key reasons: 1) the

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escalating of human pressure on natural resources, biodiversity and ecosystem functions; and 2) the rapid advancement in Earth systems and sustainability science. This has resulted in a growing recognition that people shape all ecosystems and at the same time they are fundamentally dependent on natural systems and their biodiversity. Crist and Cafaro (2012), speculating about the raising of the standard of living, argued that in order to feed a growing population and enter increasing number of people into the consumer class is a formula for completing the Earths' overhaul into a planet of resources for even more intensified uses of land and water. Freshwater ecosystems have experienced a significant loss of their ecological value due to various human activities. It has been recognized that the continued alteration of freshwater biodiversity is not sustainable and also it has been realized that less modified freshwater ecosystems provide significant economic and social benefits to society. Thus, currently, there is much political drive to quantify ecosystem changes and services provided by freshwaters (Millennium Ecosystem Assessment 2005). Europe's water resources are impacted by multiple stressors which affect ecological and chemical status, and ecosystem services.

The conservation, and further the sustainability of freshwater, requires new water management approaches that consider both societal and ecosystem needs in an integrated fashion (Wallace et al. 2003). Integrated water resources management is particularly needed in Mediterranean-climate regions, where the conservation of inland ecosystems requires the modification of human water use practices.

Lakes provide essential ecosystem goods and services, on which humans depend. These include vital provision of water for domestic, agricultural and industrial use, flood regulation, food production, recreational opportunities and less tangible aesthetic and cultural benefits (Maltby and Ormerod 2011).

In Mediterranean and other water-stressed climates, water management is critical for the conservation of lake ecosystems. To secure and maintain water allocations for the environment, integrated water management approaches are needed, that consider ecosystem flow requirements, patterns of human water demands, and the temporal and spatial dynamics of water availability (Grantham et al. 2010).

Mediterranean lakes are subjected to large variations in water level, determined by naturally intra- and inter-annual variations in rainfall and groundwater discharge or recharge, and in alternating drought and wet periods (Beklioglu et al. 2007). Temperature variations may have considerable further effects on lake ecosystem structure and dynamics. For example, their response to eutrophication seems to be quite different from that of the cold temperate climate in Northern Europe (Kagalou and Leonardos 2009; Moustaka-Gouni et al. 2014; Tsakiris 2015; Alexakis et al. 2016). Prolonged hydraulic retention time because of drought, results in increased salinity with secondary effects on biota, ion toxicity and osmotic stress (Jeppesen et al. 1997, 2007). Such conditions can significantly reduce the resilience of the lake ecosystems, also affecting their goods and services (Kagalou 2010).

During the last years, there have been many re-assessments and changes of strategies concerning lake management across Europe (Tsakiris 2015). National and transnational legislation, such as the European Water Framework Directive (European Commission 2000), requires European fresh waters to be kept at, or brought to, good ecological status. However, lakes, like other ecosystems, are subject to multiple stressors (Ormerod et al. 2010) arising from human activity and from inter-annual and long-term background changes in environmental conditions that can degrade ecological status (Maberly and Elliot 2012). The emphasis in restoration and management studies on lakes has progressively shifted from specific water-quality problems, to dealing with environmental issues at a much broader level. Yet, the more sophisticated solutions are those where the entire catchment, the landscape variables and the variety of stressors of the water body to be adressed, are taken into account. The relevance of these factors differs regionally (EEA 2012): while in Northern Europe the energy plants (hydropower) in temperate lakes have affected lake hydrology, morphology and connectivity, South Mediterranean lakes are impaired by scarcity, pollution and multi-pressures and services.

Although the majority of European lakes is affected by more than one stressor, our knowledge to address multiple stress situations is limited. In the Mediterranean, new stressor combinations, including extended land use changes, climate change, effects on growing periods and alien species, should be taken into consideration.

The objective of the present study is to describe the stressors and their effects on Greek lakes, contributing to the achievement of solid evidence on multipurpose management plans at the catchment level.

2 Materials and Methods

2.1 Biogeographical and Environmental Context of the Study Area

The Mediterranean basin is a densely populated region where intensification of land use activities has been recorded over the last 50 years. This trend, coupled with climate change, strongly interferes with the hydrological cycle in the region. The increasing need of water for human activities (e.g., irrigation, drinking, industrial use) may severely endanger Mediterranean aquatic ecosystems.

Greece forms the southern extension of the Balkan Peninsula, in south-eastern Europe. The land territory occupies an area of 130,800 km^2, while two thirds of it is mountainous/hilly. Greece is located in the Mediterranean temperate climatic zone, with an uneven spatial mean annual and seasonal rainfall distribution. The whole country is characterized by small basins as a consequence of its geomorphology, characterized by mountainous relief with steep slopes and by dry climatic conditions. Greek lakes occupy an area of 600,000 ha and they are of varied origin. Some of them are ancient lakes, products of karstic processes, thought to be formed in the late Tertiary. Generally, the majority of Greek lakes are lowland, shallow, large ones of calcareous origin (Kagalou 2010).

During the last decades, rising trends in agricultural intensification were apparent in Greece with increasing fertilizers and pesticides consumption. Generally, agrochemicals were -and still are-used in all watersheds, but with higher intensity in the lowlands. The uneven rainfall distribution in the Mediterranean area results in scarcity of freshwater resources during peak periods for irrigation, as in high intra-annual water level fluctuations, influencing the lake nutrient concentrations and biota. It is also well documented that diffuse losses by agricultural activities is a main P source for lake ecosystems (Jeppesen et al. 2007, 2015).

Lake restoration and management is now among the most urgent environmental issues, relating to water management at the river basin scale as a Water Framework Directive (WFD) implementation practice. The first River Basin Management Plans (RBMPs) have already been reported, but a number of problems have also been detected, focused mainly on: a) data interpretation for predicting water body assessment; and b) how the set-up of appropriate multipurpose management plans can address multiple stressor generated water degradation.

2.2 Source of Information, Datasets

For the collection and use of a complete, up-to-date, dataset composed of monitoring studies, research projects, and relevant literature, the Web of Science (https://webofknowledge.com/) was used along with the formal governmental management plans for each lake basin. Data deal with abiotic and biotic variables of 12 natural lakes (Fig. 1) and have been examined in terms of homogeneity in order to be comparable. The information from the reviews was collated and used to provide meta-assessments of the different pressures, water quality, ecological status and the key function parameters.

Descriptive statistics were applied in order to depict the current condition of the lakes, and further, to highlight current trends in order to assess the management plan accuracy and their possibility to improve the lake quality and functions. Principal Component Analysis (PCA) was performed (Primer 6.1.6) to test the environmental parameters that differentiate the lakes. PCA was used for the simplification of the group of variables in order to summarize most of their variability in the first two dimensions (Quinn and Keough 2002). All environmental parameters (Lake area/catchment area, altitude, mean depth, max depth, Total Nitrogen / Total Phosphorus [TN/TP]) were log(x + 1) transformed, except agricultural and artificial areas (%), which were arcsine transformed prior to PCA. Spearman correlation (using SPSS 21) followed to test statistically significant correlation ($p < 0.05$) between the parameters applied. Finally, for the calculation of a prediction equation in the case of mean and max depth, significant correlation was tested, and then the regression equation was developed with Multiple Regression Analysis Module (STATISTICA 12) in log-transformed parameters.

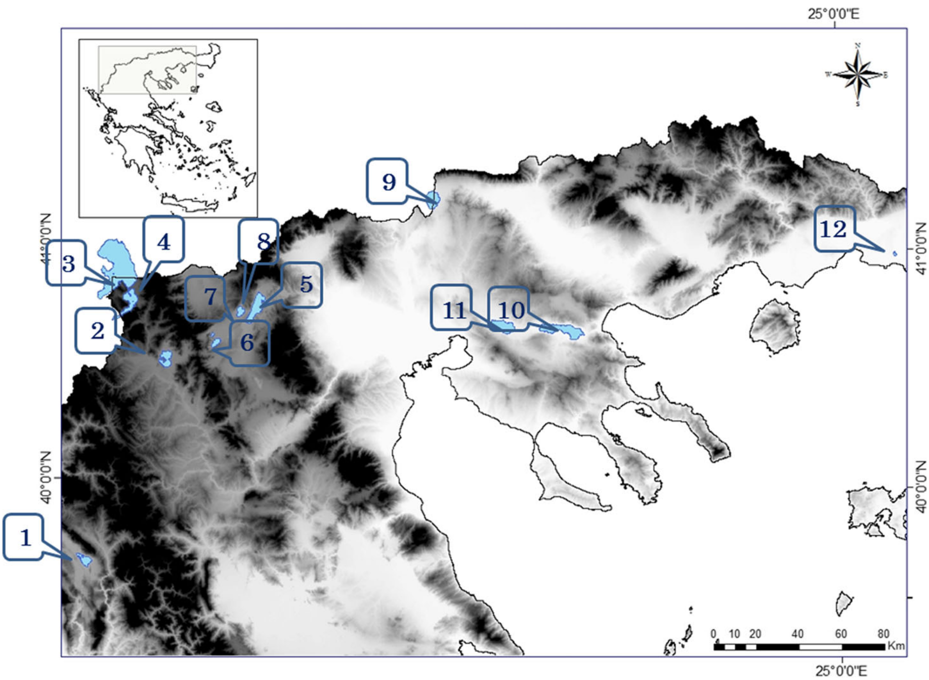


Fig. 1 Map of Northern Greece with marking of the position of the lakes under study

2.3 Status Assessment

The lake status assessment followed the WFD guidelines, using indicator elements and physical-chemical parameters. More sophisticated indices such as retention time, Redfield ratio, lake area/catchment area ratio were also applied in order to highlight the lake function. Interactions of indices were tested to understand how their combination could modify the management approach.

2.4 Identification of Pressures and Stressors

As outlined in the WFD, Member States shall collect and maintain information on the type and magnitude of the significant anthropogenic pressures to which the surface water bodies are liable to be subjected. Furthermore, in the context of the present study, a number of primary and secondary stressors deriving from one relevant pressure, were identified. Thus, we produced a causal analysis scheme, offering a diagnosis of lake deterioration under multiple stressors.

3 Results

3.1 The Hydro-geo-morphological Profile

Among the obligatory typology, descriptors under the WFD are location, size (area) and depth of the lakes. Geomorphologic features provide the regional variability but also affect the in-lake biochemistry, since lake and catchment sizes affect nutrient fluxes from the watershed, both by surface runoff and groundwater inputs, as well as from sediments, through resuspension process, having a significant influence on the lake water chemistry, hydrodynamics, light conditions, biogeochemical cycles and food-web structure (Noges

Table 1 Basic hydro-geo-morphological descriptors of the lakes under study

Lake	Catchment area (km^2)	Lake area (km^2)	Altitude (m)	Depth mean (m)	Depth max (m)	Water Retention Time (yr)
Pamvotis	330.00	22.80	470	4.30	8.0	<1.0
Kastorias	281.00	22.50	630	4.40	8.0	2.3
Macro Prespa	1130.00	253.60	849	17.00	53.0	11.0
Micro Prespa	265.00	40.13	851	4.10	7.8	3.4
Vegoritis	1770.00	21.40	510	28.90	45.0	9.5
Petron	121.78	12.00	571	2.60	4.0	Unknown
Zazari	124.42	2.00	602	2.70	3.0	Unknown
Chimaditis	102.74	10.80	573	1.20	2.5	Unknown
Doirani	276.00	28.00	138	3.00	5.0	2.0
Volvi	1247.00	68.00	37	13.80	23.5	2.6
Koronia	350.00	0.50	68	1.00	4.0	<1.0
Ismaris	185.00	2.10	20	1.20	2.0	Unknown

2009). In Table 1, the geomorphological factors of the studied Greek lakes are presented. Most of them are "mid-altitude", "shallow" and "very shallow", while almost all of them fall to the "large class size" except Macro Prespa which is classified as "very large".

The link between morphometry, hydrology and water quality is extremely strong, hence parameters such as water retention time are considered as valuable descriptors of their function. The majority of the studied lakes have long hydraulic retention time, thus acting more as a sink of pollutants, while the two deep lakes (Macro Prespa and Vegoritis) have very long ones (Table 1). Because of this low renewal ability, it is quite difficult to determine which is the dominant factor for the lake's loading, i.e., the external or the internal one. We suggest that both processes affect Greek lakes. Analysis in these lakes revealed that smaller ones are generally shallower (Fig. 2). The lake mean depth and maximum depth are significantly correlated ($R^2 = 0.754$, $n = 12$, $p < 0.05$), so a linear regression equation was developed that enables the prediction of the one from the other ($R^2 = 0.959$, $p < 0.00001$):

$$\mathrm{LnZmax} = (1.0457) \times (\mathrm{SE} \pm 0.0688) \times \mathrm{LnZmean} + 0.546 \times (\mathrm{SE} \pm 0.119) \quad (1)$$

$$\mathrm{LnZmean} = (0.909) \times (\mathrm{SE} \pm 0.059) \times \mathrm{LnZmax} - 0.443 \times (\mathrm{SE} \pm 0.136) \quad (2)$$

where: Zmax is the maximum depth, Zmean is the mean depth, and SE is the standard error.

Regarding the nutrient limitation, the lakes were divided in three categories (according to Ntislidou 2014): Phosphorus (P-) limitation when the average Redfield ratio was >16, Nitrogen-Phosphorus (N-P) limitation for seasonal limitation variation when 16 > Redfield Ratio > 10, and Nitrogen (N-) limitation when Redfield Ratio <10. Half of the studied lakes are P-limited, and two thirds have P-/N- seasonal variation limitation.

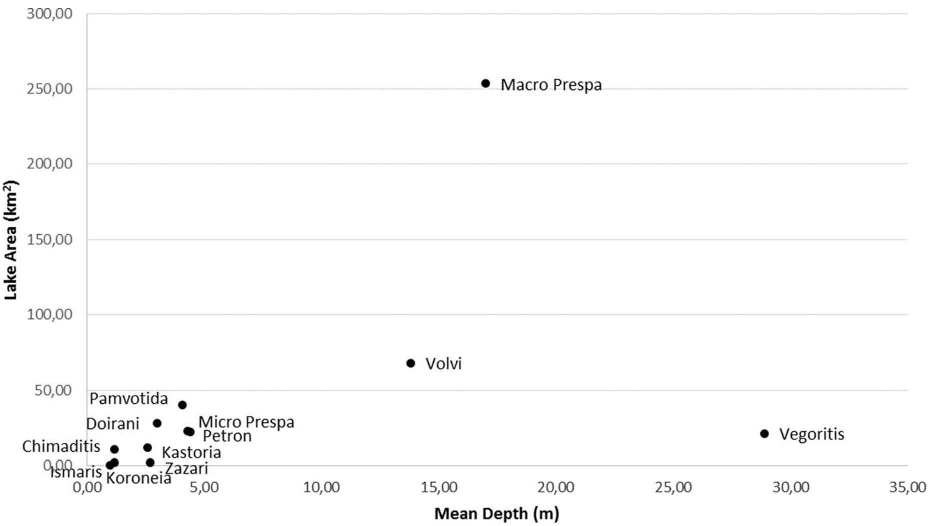


Fig. 2 Lake area versus Mean Depth of the lakes under study

3.2 Assessment of Chemical and Ecological Status

Concerning the lake ecological status classification, WFD suggests the characterization to be based on physical-chemical elements supporting the biological elements. Taking into consideration the ecological assessment methodology suggested by the Common Implementation Strategy [CIS] and developed by the working group on Ecological Status [ECOSTAT] concerning the Mediterranean lakes (JRC 2014), as well as the available datasets, we extracted the classification about both chemical and biological status (Table 2). The nutrient concentration (TP and N compounds), in almost all lakes, varied between 0.1–0.25 mg/L and 0.15–0.30 mg/L correspondingly, thus suggesting a status "lower than good" and they are assessed as being at risk of failing the WFD objective (European Commission 2009). The fluctuation of dissolved oxygen, pH and transparency also support this profile. The biological status, mainly derived from biological quality elements such as phytoplankton, chlorophyll-a, algal blooms and macrophytes, responds to the chemical status, pointing out two classes, i.e., "bad" and "poor", with the exception of Macro Prespa and Volvi which were classified at "moderate" class. According to the Nitrates Directive (91/676/EEC), the majority of the lake catchments are considered as nitro-sensitive regions (Table 2). The increase in concern of over-exposure to cyanobacterial toxins in both drinking and recreational waters, has created an urgent need for ecological data about the distribution of cyanobacteria in natural waters. The World Health Organization (WHO) alert level framework (Chorus and Bartram 1999) has three alert levels to be followed after cyanobacteria detection in a water body. Alert Level 1, occurs when > 20000 cyanobacteria cells/mL or 1 g/L chlorophyll-a is detected and toxin analysis and consultation with health authorities is suggested. Alert Level 2 is reached when cyanobacteria are detected at >100,000 cells/mL or 50 g/L chlorophyll-a. In cases where extended cyanobacterial scum is formed, there is a high adverse health risk effect

Table 2 Lake status assessment based on physical-chemical and biological quality elements of the lakes under study

Lake	Chemical status	Ecological status	Nitro-sensitive	Threat to human health-Alert Level (WHO)
Pamvotis	lower than good	poor		level 3
Kastorias	lower than good	poor	yes	level 3
Macro Prespa	lower than good	moderate	yes	no
Micro Prespa	lower than good	poor		level 2
Vegoritis	lower than good	unknown	yes	no
Petron	lower than good	poor	yes	level 2
Zazari	lower than good	bad	yes	level 2
Chimaditis	lower than good	bad		level 2
Doirani	unknown	poor	yes	level 2
Volvi	lower than good	moderate	yes	level 2
Koronia	lower than good	bad	yes	level 3
Ismaris	unknown	poor		level 2

(Alert level 3). At least three case studies (Pamvotis, Kastorias, Koronia) pose potentially risk in terms of public health.

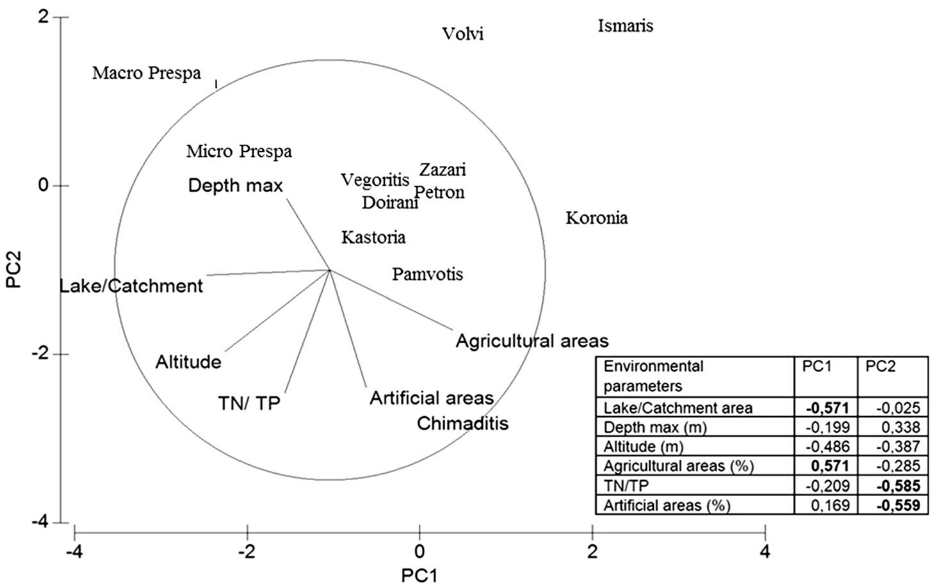
3.3 Lakes Discrimination According to PCA

PCA analysis was applied to explore the significance of environmental parameters in lake profiles. Parameters addressing land uses, geomorphological and physical-chemical descriptors (vectors) were used in order to proceed in lake discrimination (Fig. 3). The first two PC axes explained 67.1 % of the total variance. PC1 correlated negatively to Lake Area/Catchment Area ($r = -0.571$) and positively to agricultural areas ($r = 0.571$) explaining 38.8 % of the observed variance. PC2 correlated negatively to TN/TP and % artificial areas explaining 28.3 % of the observed variance.

PC1 axis separated mainly the two lakes with low percentage of agricultural areas (Macro and Micro Prespa) from all the others. PC2 axis allocated mainly lakes Macro Prespa, Micro Prespa, Volvi and Ismarida due to the low ratio of TN/TP indicating N limitation. A group of six lakes (Zazari, Vegoritis, Doirani, Petron, Kastorias and Pamvotis) is formed at the centre of the PCA analysis witch is almost equally affected by both geomorphological features and human intervention. Ismaris is the most isolated due to its special characteristics, e.g., small depth, low altitude, extremely low Redfield ratio and intense conductivity variation.

3.4 Pressures and Stressors

Among the main pressures put in the Greek lakes are hydro-morphological changes such as urbanization, shoreline modifications, agricultural land use and hydrological alterations (Table 3). A consequent environmental pressure from agriculture is irrigation, which is the



Environmental parameters	PC1	PC2
Lake/Catchment area	**-0,571**	-0,025
Depth max (m)	-0,199	0,338
Altitude (m)	-0,486	-0,387
Agricultural areas (%)	**0,571**	-0,285
TN/TP	-0,209	**-0,585**
Artificial areas (%)	0,169	**-0,559**

Fig. 3 PCA analysis of the lakes under study based on land uses, geomorphological and physical-chemical descriptors

Table 3 Pressures and deriving stressors in the lakes under study and their catchments

Lake	Pressure	Primary stressor	Secondary stressor	Main measures undertaken
Pamvotis	Urbanization, irrigation, introduced species	Wastewater, agricultural effluents, food web changes	Water level fluctuation, sedimentation, nutrients	WWTP, point pollution elimination
Kastorias	Urbanization, irrigation, introduced species	Wastewater, agricultural effluents	Siltation, sedimentation, water level fluctuation, nutrients	WWTP, point pollution elimination, flushing
Macro Prespa	Diffuse sources of pollution	Wastewater and dumpyards	Nutrients	No site specific measures, demand for conservation
Micro Prespa	Land and water uses	Hydrology balance, organic load	Nutrients	No site specific measures
Vegoritis	Water abstraction - coal mines	Hydrology balance, organic load	Water level fluctuation	Attempt for hydro balance
Petron	Land and water uses	Hydrology balance, organic load	Water level fluctuation, nutrients	No site specific measures
Zazari	Land and water uses	Hydrology balance, organic load	Reedbeds growth, nutrients	No site specific measures
Chimaditis	Land and water uses	Hydrology balance, organic load	Extended macrophytic cover, water level fluctuation	No site specific measures
Doirani	Land and water uses, touristic facilities in FYROM	Hydrology balance, organic load	Nutrient pollution, increase pH, conductivity, water level fluctuation	No site specific measures
Volvi	Industry - intensive farming	Hydrology balance, organic load	Water and sand abstraction	Point pollution elimination, hydrology balance
Koronia	Agriculture and farming	Water scarcity, organic load	Nutrients, toxicity	Multi measures
Ismaris	Farming and seawater intrusion	Salinization, effluents	Changes in physical-chemical status	Hydrology balance

main use of the water in almost all studied lakes. It is also acknowledged that diffuse pollution loadings from agricultural activities and point pollution effluents by urbanization are the main relevant stressors since 58.5 % of the studied lakes suffer mostly by diffuse sources of pollution. Greek lakes are also subjected to high hydrological alterations, while water scarcity is the main threat in most of them and consequently the high nutrient budget along with toxicity events stress out the lake ecosystems. Fisheries, and in particular the fish stockings, are also considered to be a major pressure while primary and secondary stressors include food web changes, endemic species threat and eutrophication. Among the measures undertaken, in most case studies, the elimination of point pollution through Wastewater Treatment Plants (WWTPs) was the main measure in order to reduce the organic load. In contrast, the restoration of the hydrological balance has been proposed as a response measure only in three lakes (Table 3). For lakes Petron, Zazari and Cheimaditis, non site-specific measures were proposed but horizontal ones, and measures for habitat conservation and nature protection have been implemented only in Macro Prespa. It is quite important that there are not any biomanipulation plans as restoration measures across Greek lakes.

3.5 Pressure Strength Assessment

The strength of different pressures affecting the sites was studied as follows: The pressure levels are in a six scale range giving the options: 1–unknown, 2-very low, 3–low, 4–moderate, 5–high, 6-very high. The strength and significance of each pressure is in relation to failure of a water body to achieve the environmental objectives (EEA 2012). The pressures could be grouped in three main groups: Hydromorphological (urbanization, land use changes, hydro-alterations), Pollution (organic load, nutrients, metals) and Disturbance (fishing, tourism, introduced species) (Table 4). With the exception of Macro Prespa, all the other lakes appeared to be under moderate to very high pressure level. It is also evident that the majority of the sites sustain strong multiple pressures from each category.

Table 4 Pressures strength assessment in the lakes under study and their catchments

Lake	Disturbance	Hydromorphological	Pollution	Overall
Pamvotis	6	5	6	5.7
Kastorias	6	4	6	5.3
Macro Prespa	3	1	2	2.0
Micro Prespa	5	3	5	4.3
Vegoritis	5	4	4	4.3
Petron	5	5	4	4.7
Zazari	5	5	4	4.7
Chimatidis	5	5	5	5.0
Doirani	4	4	4	4.0
Volvi	4	4	4	4.0
Koronia	6	6	6	6.0
Ismaris	4	4	5	4.3

1–unknown, 2-very low, 3–low, 4–moderate, 5–high, 6-very high

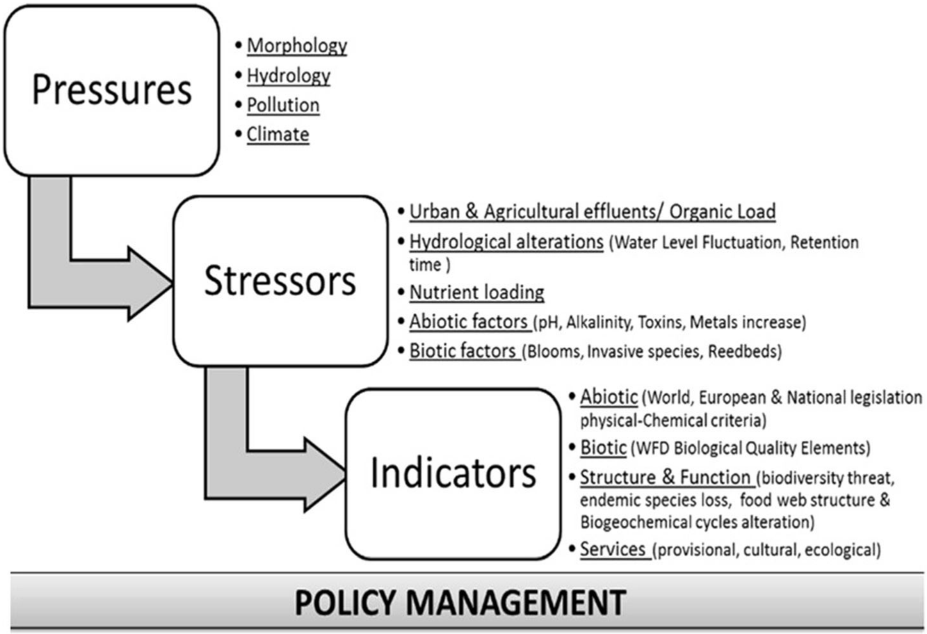


Fig. 4 Conceptual diagram for management policy forming

4 Discussion

Freshwater ecosystems, and particularly lakes, are subject to constantly emerging anthropogenic stressors that act on both fine and broad spatial scales and that affect ecosystems in different ways. In this article, we have described the impacts of multiple stressors on lentic ecosystems in Greece. Our hypothesis about the goal of sustainability and the management policy is summarized in the conceptual diagram (Fig. 4). We addressed questions about the typological characteristics of the studied lakes and their impact on their function, their chemical and ecological status, and how they are affected by pressures and their relevant stressors.

Understanding the hydro-morphological and ecological profile of the studied lakes, and taking into consideration that WFD guidelines are the core of European Water Policy, hopefully we provide a “tool” for shaping the future management plans. The most critical outcome of these 12 Greek lakes classification is that almost all of them fail to meet the WFD objective of good ecological status, and therefore, operational monitoring and extra restoration measures will be needed. We suggest that multiple stressors act synergistically creating complex degradation problems, enhancing the opinion, that this multitude nature of pressures (i.e., water abstraction on top of the other major pressures, diffuse and point source pollution, and hydromorphological pressures) causes half of the Mediterranean lake water bodies to fail good status (ETC./ICM 2012).

In Greece, during the last decades, increased urbanization, regulation of natural lakes and more intensive agricultural practices have changed the hydrological regime of many lakes. Greek lakes experience progressive decrease in water level, significant intra- and inter-annual water level fluctuations (Kagalou 2010), thus considering water abstraction as the most important stressor occurring in all Mediterranean countries (ETC./ICM 2015). This, in turn, has influenced the impact of other stressors such as the nutrient loading and the physical-chemical status (Beklioglu et al. 2007). Regarding pollution stressors, the most important comes from diffuse sources, causing nutrient enrichment impacts in the majority of the lakes. Furthermore, Greek lakes, despite the urban wastewater treatment plans that have been established during the last decade(s), still receive point source pollution appearing highly enriched in organic load. Livestock activities produce both nitrogen and phosphorus loads. Nitrogen is often quickly removed through denitrification, while phosphorus is removed more slowly. As a result, rapid eutrophication became apparent with frequent algal blooms. In fact, special attention should be paid to cyanobacterial blooms as they threaten almost all the lakes in terms of public health and recreation services. While in European lakes the diffuse pollution from agriculture is now the single most important source of pollution, Greek lakes still face point pollution, thus the updated Program of Measures (PoMs), as an official obligation towards WFD implementation, should also include the control of point pollution sources.

Our analysis revealed that the role of lake morphometry is essential for their function and this is in agreement with other studies across European lakes (Noges 2009). Hydro-morphological pressures along the studied lakes comprise all physical alterations not only to the wet areas but also in the whole catchment (land use changes), thus modifying their shores, littoral zones and water level. Unfortunately, we have not any quantification of the hydromorphological pressure effect on the biological or/and chemical status in order to design specific, targeted measures. We suggest that among the main management issues is the set-up of measures in order to minimize the changes in lake morphometry and to preserve the natural variability aiming at the increase of their resilience. Obviously, regarding the pollution stressors affecting the Greek Lakes, the restoration efforts should primarily focus on catchment/regional level. Since the catchment area, as well as the land uses affect lake function pushing towards nitrogen limitation, measures should be focused on establishing perimeter buffer zones and enforcement of agro-environmental friendly practices. This should be included in the River Basin Management Plans (RBMPs). In Greece, the river basins are mainly agro-ecosystems, hence, the restoration and management strategy should target on the ecological effects of the relative pressures rather than the effects of each pollutant. Biophysical processes of agro-ecosystems are strongly affected by the regional environmental conditions, thus, factors such as catchment runoff, extensive erosion, flooding events and climate change should be examined. It is also evident that across the Mediterranean, eutrophication has been intensified (Beklioglu et al. 2007; Jeppesen et al. 2015), because the increased evaporation and lower precipitation augment the nutrients concentrations. Adaptation measures could include changes in agricultural activity (i.e., crop modification, adapted irrigation infrastructure) since longer growing periods are expected, with subsequent effects on water use, fertilizer applications and nutrient leaching. Acknowledging the goal set from the WFD and simultaneously holding in mind the long degradation history of the Greek lakes, along with the climate conditions, our future 5-year management plans should be realistic, achieving, at least, moderate ecological status. Our discriminate analysis suggests that pollution issues, hydrological alterations and human uses should be addressed together through multi-purpose plans. In Greece, lakes sustain small scale economic activities, i.e., fisheries, tourism, contributing to the local economy. Thus, proposed plans must aim at the protection of the environment as well as at the support of the income of the local community and the maintenance of the social net. It is worth noting that more research results are needed in order to link sustainability indices to ecological status, translating them to site specific management actions. Reliable management plans depend on solid input data. In Greece, up to date, the first set of the management plans are typically based on past literature data. Hopefully, the revised plans will be based on monitoring data after the Ministerial decision (Ministry of Environment 2011) for the establishment of an updated monitoring network in all water bodies. Concerning the administrative issues, although policy tools for freshwater management have been implemented at the national level, there have been long lasting problems with the implementation and enforcement of rules and regulations at the regional level. Finally, in terms of governance, we could suggest as general objectives the improvement of horizontal and vertical collaboration among institutions, creation of sense of responsibility by stakeholders and inactivation of awareness raising activities targeted to the local communities.

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