ENVIRONMENTAL MANAGEMENT OF AQUATIC RESOURCES AND MANMADE ECO-ENVIRONMENTAL IMPACTS: LAKES, PONDS AND WETLANDS MANAGEMENT IN CENTRAL GREECE

Aristeidis Mertzanis[1], Francesco Marabini[2], Konstantinos Mertzanis[3], Maceo Giovanni Angeli[4], Fabrizio Pontoni[5] and Paolo Gasparetto[6]

[1]Technological Educational Institute of Central Greece, Department of Forestry and Management of Natural Environment, GR-36100, Karpenisi, Greece

[2]National Research Council, Institute for Marine Science (ISMAR-CNR), 101 P. Gobetti str., 40129, Bologna (BO), Italy

[3]University of the Aegean, School of Business, Department of Financial and Management Engineering, GR- 82100, 41 Kountouriotou str., Chios, Greece

[4]National Research Council, Research Institute for Hydrogeological Protection (IRPI-CNR), 06128, Via Madonna Alta, 126 Perugia (PG), Italy

[5]Geoequipe S.T.A., Sandro Pertini str., Tolentino (MC), Italy

[6]IQT Consulting S.r.l., Rovigo (RO), Italy

Abstract

The natural lakes Yliki and Paralimni, lake Vromolimni (Kamena Vourla), the artificial lakes Mornos (r. Mornos) and Kremasta (r. Acheloos), the Mediterranean temporary ponds in Mt Oiti and Mt Kallidromos, and the protected wetlands in the valley and delta of Spercheios (Maliakos gulf) and in the Mornos river fan delta (Gulf of Corinth) are among the aquatic resources and delicate ecosystems of Central Greece region (Sterea Hellas).

The purpose of the present research is to highlight the main manmade interventions, to evaluate the impact-changes on the natural environment of the research areas, and to propose some ecological restoration proposals and monitoring methods.

Key words: *central Greece, environment, geomorphology, lagoons, lakes, ponds, wetlands*

1. INTRODUCTION

Human activities cause the degradation and/or loss of wetland by changing the quality, quantity, and flow rates of water; by increasing pollutant inputs; and by changing species composition as a result of disturbance and the introduction of nonnative species (U.S. E.P.A., 2001). These human activities may also lead to environmental degradation of river waters, lakes and lagoons or to hydro-geomorphological changes and often constitute the cause of environmental destabilization (Vavizos & Mertzanis, 2003). In most cases, anthropogenic interventions lead to the shrinkage of coastal wetlands and the creation of a new, fragile, ecological balance (Zalidis and Matzavelas,1994, Dafis et al., 1997, Mertzanis et al., 2010b, Mertzanis et al., 2011a,b). It should be noted that interventions that result in the alteration of the dynamic evolution of the hydro-geomorphological processes, usually lead to the creation of an "artificial" environment which is largely controlled by humans, and which, in the long run, resupplies and reinforces the environmental threats in the region (Brofas, 1989, Zalidis and Matzavelas,1994, Dafis et al., 1997, Vavizos and Mertzanis, 2003, Mertzanis et al., 2010a,b,c).

According to Gerakis (1993), efforts to improve land, in order to make it more productive for agriculture, have been undertaken since antiquity. Homer, Hesiod and Strabo mention drainage works in the Copais wetlands (Homer, Hesiod), while Philip of Macedonia was said to have constructed the tunnel of Angilos to drain the Filippi marshes to the north of Kavala (Stamatopoulos, 1967). Similar works were carried out by the Romans. All of these were abandoned during the Ottoman occupation (1453-1829) and many of the drained wetlands returned to their former status. Drainage works started

again around Copais Lake in 1880 (Stamatopoulos, 1967). Drainage was intensified during the period 1925 to 1940, mostly due to the need to resettle refugee farmers from Asia Minor. Within 15 years, besides Copais, the lakes Yannitsa, Artzan, Amatova and Achinos were drained, as well as the marshes of Loudias and Filippi, while the river beds of Axios, Aliakmon and Strymon in Macedonia, and Louros and Arachthos in western Greece were rearranged (Gerakis, 1993). Major drainage works were also carried out in Thessaly (Evelpidis, 1967, Homer. Iliad, Hesiod, Strabo). According to estimates made by the Ministry of Agriculture, these works resulted in the drainage of 89,900 ha of wetlands, the irrigation of 14,000 ha and the protection from floods of 369,000 ha. Thus the total loss of wetlands, including periodically flooded areas, was truly enormous (Gerakis, 1993).

After World War II, in the period 1948-1958, land "improvement" works were boosted by U.S. aid and advanced technology (Gerakis, 1993). Within that decade, diversion dams were erected on Acheloos, Tavropos, Aliakmon and Axios Rivers, while three drainage tunnels were constructed (Karla in Thessaly, destroying the invaluable Karla Lake, Lapsista and Langasta in Epirus) (Gerakis, 1993). Xyniada Lake, near Domokos, was drained in 1942.From 1960 onwards, land reclamation by draining wetlands was carried out in all parts of the Country, but on a smaller scale, as seen, for example, along the lakes Prespa and Vistonis, and in Amvrakikos and Evros (Stamatopoulos, 1967, Gerakis, 1993).

The timely and accurate information regarding the stressors causing deterioration on aquatic resources and delicate ecosystems, the proper environmental impact assessment and the systematic monitoring can provide important input in managing and mitigating the negative effects of human management of freshwater ecosystems and sensitive wetland habitats.

2. MATERIALS AND METHODS

2.1 Geographical location of the study area

This paper deals with the aquatic resources and delicate wetland ecosystems, i.e. the natural and artificial lakes, seasonal lakes, freshwater springs, hot-water springs, coastal lakes, lagoons and marshes that exist in administrative region of Central Greece (prefectures of Boeotie, Evrytania, Phocis and Phthiotis). The prefecture of Euboea is excluded. Most of these aquatic resources and delicate ecosystems, have suffered serious alterations caused by manmade interference, in the broader area and in the watersheds or on their coastal zone. This study mainly focuses in some delicate wetland ecosystems which have undergone alterations due to human activities. These delicate ecosystems, are located in the Central Greece region and especially:

a. Natural lakes: 1. Yliki (1BoeNatL) and 2. Paralimni (2BoeNatL) near Thebes (Figures 1&2).

b. Freshwater springs with a small permanent lake: 1. Chariton springs (1BoeFWSp) near Orchomenos, 2. Krya Vrysi springs (2BoeFreWSp) near Livadeia, 3. Kato Agoriani springs (Kefalovryso) (3PhoFreWSp) near Kato Agoriani and Amfikleia, 4. Agia Eleousa springs (4PhoFreWSp) near Polydrosos and Amfikleia (Fig. 16), 5. Agia Paraskevi Springs (5PhthiFreWSp) near Agia Paraskevi, Lamia and Stylida.

c. Natural hot-water springs with a small permanent lake: 1. Kallidromos thermal springs I (Psoroneria I) (1PhthiTherSp) near Kato Damasta (Lamia), 2. Kallidromos thermal springs II (Psoroneria II) (2PhthiTherSp) near Kato Damasta (Lamia) (Fig. 17), 3. Thermopylae thermal springs (3PhthiTherSp) near Thermopylae (Lamia), 4. Loutra Koniaviti Thermal springs (4PhthiTherSp) near Kamena Vourla.

d. Delicate wetland ecosystems, coastal lakes, lagoons and marshes: 1. Agios Sostis lake (Glyfa lake) (1PhthiWETL) southeastern of Glyfa, 2. Pelasgia lagoon (2PhthiWETL) southwest of Paralia Pelasgias, 3. Almyropotamos marsh (Achladi) (3PhthiWETL), western of Achladi near Stylida, 4. Spercheios river delta-estuaries (4PhthiWETL) and surrounding marine ecosystems (Figures 9&10), 5. Latzorrema (Ag. Triada) river delta (5PhthiWETL), near Ag. Triada and Thermopylae, 6. Molos I marsh, (6PhthiWETL) northwest of Molos, 7. Molos II marsh (7PhthiWETL), Potamia stream estuaries, northeastern of Molos, 8. Skarfeia marsh, (8PhthiWETL), Liapatorrema stream estuaries

north of Skarfeia, 9. Agios Serapheim marsh (9PhthiWETL), western of Neo Thronio, Voagrios river estuaries, 10. Vromolimni lake (Asproneri) (10PhthiWETL), near Kamena Vourla and Agios Konstantinos (Figures 5&6), 11. Kalamos (Loggos) (11PhthiWETL) Xerias stream estuaries, northeastern of Loggos, 12. Atalanti lagoon (12PhthiWETL) near Scala and Tragana (Figures 7&8), 13. Larymna I (13Phthi WETL), Anonymous torrent estuaries, northeastern of Larymna, 14. Larymna II (14Phthi WETL), Anonymous torrent estuaries, northeastern of Larymna, 15. Larymna III (15Phthi WETL), Anonymous torrent estuaries, southern of Larymna, 16. Paximada (16BoeWETL), Anonymous torrent estuaries, northeastern of Paralimni Lake, 17. Glyfa lagoon (17 EuboWETL), southeastern of Xirovrysi near Chalkida, 18. Faros Avlida lagoon (18EubWETL), northeastern of Faros Avlida, 19. Marshes of river Mornos fan delta (19PhoWETL), near Nafpaktos, 20. Parathalassos lagoon (Monastiraki) (20PhoWETL), western of Monastiraki, Nafpaktos (Figures 13&14), 21. Alyki salt lake near Xironomi and Thisvi (21BoeWETL) (Figures 11&12).




Figures 1, 2: View of Yliki lake (1BoeNatL) (Photos by Konstantinos Mertzanis).

e. Alpine, subalpine lakes and temporary ponds: 1. Velouchi (1EvryTPo) (Mt Tymphristos), 2. Leivadies (2PhthiTPo), 3. Greveno (3PhthiTPo), 4. Louka (4PhthiTPo) (Mt. Oiti) (Fig. 4) and 5. Zirelia (5PhthiTPo) (Mt. Vardousia) (Kousouris, 2014, 2016, www.foropenforests.org). Also, in the Central Greece region, at lower altitudes, there are a number of "mediterranean seasonal lakes" or "temporary ponds" such as: 6. Nevropolis I (6PhthiTPo) (Mt Kallidromo), 7. Nevropolis II (7PhthiTPo) (Mt Kallidromo), 8. Paliosouvala (8PhthiTPo) (Mt Kallidromo), 9. Livadi Arachovas lake (9BoeTPo) (Mt Parnassos) (Fig. 3), 10. Varko' lake (10BoeTPo) (Mt Parnassos) (Figures 21&22), 11. Palio Mikro Chorio (11EvryTPo) (Mt Chelidona), 12. Loutsa Skaritsas (12BoeTPo) (Mt Elikonas) and 13. the artificial pond Metalleio lake (13PhthiTPo), Omvriaki, near Domokos.

f. In Central Greece region many dams and reservoirs (artificial lakes) have been constructed, as mentioned below. These dams have various uses (hydroelectric power, irrigation and water supply): 1. Mornos dam (1PhoArtL) in river Mornos, near the city of Lidoriki, 2. Kremasta dam (2EvryArtL) in river Acheloos, near the city of Karpenisi.

It should be noted that most the names of aquatic resources and wetlands and all the codes (e.g. 1EvryTPo) have been given by the study group for the studied areas. These codes are combinations of letters and numbers. The number represents the scenting number of the relevant category (e.g. 1). The letters represent the initials of the prefectures' name (e.g. Evry=Evrytania). The end of the code represents the initials of these aquatic resources and wetlands (e.g. TPo= Temporary Ponds).




Figures 3, 4: View of Livadi Arachovas lake/temporary pond (9BoeTPo) in Mt. Parnassos, near Arachova (Fig. 3) and a Temporary pond in Mt. Oiti, Katavothra plateau (Fig. 4) (Fig 3: Photo by Theodora Lanara, Fig 4: Photo by Konstantinos Mertzanis).

2.2 Study Methodology

This study used both secondary and primary data. The collection of secondary data involved review of existing reports (unpublished, gray and published reports) from libraries and documentation centers in various institutions in Athens, Lamia, Livadia, Thebes and Amfissa. Some reports were also made available through internet search. The secondary data were supplemented by primary data at "aquatic resource unit" level, whereby small meeting were made with local non-governmental environmental organizations, the relevant Forest Services, the Parnassos National Park Management Body, the Management Body of Mt Oiti National Park, and the Hellenic Alpine Club of Lamia.





Figures 5, 6: Aerial photo of Vromolimni lake (Asproneri) (10PhthiWETL) near Kamena Vourla and Agios Konstantinos (Fig. 5) (Source: TripInView/Geotag Aeroview 2014). View of Vromolimni lake (Fig. 6) (Photo by Konstantinos Mertzanis).

For the depiction of the environmental situation of the aquatic resources and delicate ecosystems (natural and artificial lakes, temporary ponds, lagoons, deltas, wetlands) of Central Greece region, different stages are invovled: the study of bibliographical references, systematic in situ observations (field-work), measurements using the Global Positioning System (GPS) satellite signals, observation and direct digitizing on the basis of different aged aerial photos and satellite images (Landsat, Google Earth, TripInView).

For the assessment and evaluation of the impact caused by certain human activities to the environment and geomorphology of the areas under study and especially, to the hydro-geomorphological processes in the coastal zones, shorelines, lagoons, deltas, lakes, ponds, marshes, wetlands and watersheds, aerial photos of various years and scale have been used as well as satellite images (Landsat, Google Earth, TripInView).

The in situ observations were conducted, at least, every 5 years during the months of April, July, October and January for the years 1996, 2001, 2006, 2011 and 2016, in selected places of each aquatic resource and sensitive ecosystem under study.

Contemporary and older topographical maps have also been used (Hellenic Military Geographical Service, scale 1:50.000 and 1:100.000), as well as geological maps (Institute of Geology and Mineral Exploration, scale: 1:50.000), hydrological and oceanographic data and maps of vegetation and land use (Ministry of Reconstruction of Production, Environment & Energy, scale: 1:200.000). All primary data were imported I database and were transferred into topographical map and satellite images. Thus the database was developed and updated with data deriving from different sources. Data were analysed quantitative and qualitative, while apposite thematic checklists, cumulative charts and tables were created.

3. RESULTS - DISCUSSION

3.1 Anthropogenic pressures and interventions on the aquatic resources and delicate ecosystems of Central Greece region

Anthropogenic pressures and interventions in the areas under study, had different aims in each location, but all of them resulted in the disruption of the natural environment and alteration of the dynamic evolution of the hydro-geomorphological processes, leading to the creation of an "artificial" environment, controlled to a considerable extend by humans. The the possibility of environmental destabilization is re-strengthened and re-enforced in the long run (Figures 7&8) (Brofas, 1989, Zalidis and Matzavelas,1994, Dafis et al., 1997, Vavizos and Mertzanis, 2003, Mertzanis et al., 2010a,b,c).



Figures 7, 8: Aerial photos of Atalanti lagoon (12PhthiWETL) near Scala and Tragana (Fig. 7) and of the marshes of river Mornos fan delta (19PhoWETL), near Nafpaktos (Fig. 8). Anthropogenic interventions in the lagoon study areas, resulted in the disruption of the natural environment and alteration of the dynamic evolution of the hydro-geomorphological processes, leading to the creation of an "artificial" environment, controlled to a considerable extend by humans (Source: TripInView/Geotag Aeroview 2014)).

Unfortunately, most of the aquatic resources and delicate ecosystems of Central Greece region are being degraded while being under imminent threat by multiple human-induced pressures. The main anthropogenic degradation and stresses on these ecosystems include wetland draining, intensification and development of agriculture projects, river engineering works, hydroelectric dams, water pollution, holiday home building, and uncontrolled water abstraction from surface & underground water tables. Pollutants such as sediment, nutrients, pesticides, and heavy metals degrade wetlands and water quality. Diverse land use changes concerning the coastal and inland plains, lakes, deltas and coastal wetlands are also being detected. Sprawling urban areas are located near and within the lowland plain of Spercheios river delta, including the conurbation of Lamia. The intensification of multiple anthropogenic pressures and interventions in recent decades in the river mouths, deltas and lagoons

and in the drainage basin of its rivers has affected the natural ecosystems, especially degrading sensitive wetland habitats.

The construction and operation of large dams and reservoirs in the drainage basins of the rivers Acheloos and Mornos, for energy production, irrigation and water supply, may seriously affect the environmental balance of wetlands in the delta areas. Also, the artificial diversion of the main river channel of the Spercheios, river to the north, caused the creation of a new Delta in the area of new mouth to the Maliakos gulf and the shrinkage of old delta (Figures 9&10).



Figures 9, 10: Aerial photos of Spercheios river delta-estuaries to the Maliakos (4PhthiWETL). Is distinguished the old delta (Fig. 9) and the new delta (Fig. 10), after the diversion to the north of the main river channel (Source: TripInView/Geotag Aeroview 2014).

These anthropogenic interventions have a significant impact on the natural environment and the hydro-geomorphological processes of the aquatic resources, delicate ecosystems and "vulnerable" and "dynamic" areas (deltas, river mouths, marshes, lagoons and lakes) such as those which constitute the object of the present research. Also, these manmade interferences contribute to the vulnerability of the aquatic resources and delicate ecosystems. The most common man-made changes on the natural environment of the delta areas, river mouths, marshes, lagoons and lakes, under study, are: a. Alterations to the fauna, the flora and the local natural ecosystems, b. Landscape changes, c. Alterations to the surface and underground waters and c. Alterations on the geological-geomorphological features and the hydro-geomorphological processes.

An important role in the eco-environmental impact and geomorphological evolution of dynamic coastal areas and wetlands (river mouths, deltas and lagoons), seems to be played by the climate change with the subsequent sea level rise. One of the consequences of the global climate change is the loss of coastal land, coastal wetlands, deltas, lagoons and marshes (inland and coastal environments), of economic and environmental value, that may be lost due to a potential sea level rise on a global scale. The latter has been predicted to be between 38 and 68 cm for the year 2100, according to the latest report by the IPCC (2007). This prospect had led the IPCC, in 1988, to define the term "vulnerability" as "the level in which the coastal system is influenced by the various factors that consist the climatic changes", aiming at the improvement of coastal zone management by developing strategies that will provide solutions to this problem (IPCC, 2001, IPCC, 2007, Alexandrakis et al., 2009a,b). Researchers have studied the influence of climate changes on the evolution of some river deltas around the Adriatic Sea (Marabini, 1994, Marabini and Veggiani, 1990).

These sea level changes will be considerable for the coastal environment, mostly in gently sloping coastal zones of low elevation, which will face the danger of being inundated by the sea. Sigalos and Alexouli-Livaditi (2006a,b) attribute the future change of the shoreline of Spercheios River Delta (Central Greece region), primarily to the climate change and sea level change. In the Maliakos gulf, high risk areas are estimated to comprise 23.9 km^2, with the greater part of it placed at the lower reaches of the river Spercheios delta mouth areas and specifically in the southern and western section of the gulf. It is assessed that apart of these areas, about 13.4 km^2, are also likely to be flooded by the sea, until the year 2100. At the Delta of the river Spercheios, high risk areas occupy 19.17% of the

total deltaic plain, when areas with high possibility to be submerged occupy 11.43%. As these regions host intensive rural and economic activities, their owners and users will be strongly affected by sea level rise. It is possible that they will be forced to transfer their activities into safer areas. In addition, some important biotopes are likely to be vanished (Sigalos and Alexouli-Livaditi, 2006a,b). This situation is reproduced in all the gently sloping coastal areas of low elevations in Greece and particularly in the areas under study, and it appears that these changes of shrinking of wetlands will be considerable for the coastal environment (Figures 11,12,13&14).



Figures 11, 12, 13, 14: View of Latzorrema river delta (5PhthiWETL), near Ag. Triada and Thermopylae (Fig. 11), Molos I marsh, (6PhthiWETL) northwest of Molos (Fig. 12), Alyki salt lake near Xironomi and Thisvi (21BoeWETL) (Fig. 13) and Parathalassos lagoon (Monastiraki) (20PhoWETL), western of Monastiraki, Nafpaktos (Fig. 14). (Figures 11,12&13. Aerial photos: TripInView/Geotag Aeroview 2014). (Fig.14: Photo by Konstantinos Mertzanis). The future regression of the shoreline, primarily caused by the climate change and the rising sea level, is expected to affect harshly the low lying coastal areas, such as those in the pictures above.

Presented below are the cumulative charts of the anthropogenic pressures and interventions that stress the aquatic resources and delicate ecosystems of Central Greece region. More specifically, the cumulative charts for the various categories of the aquatic resources and delicate ecosystems are presented separately: 1) Natural and artificial lakes, Freshwater springs and Natural hot-water springs under investigation, 2) Wetlands, Coastal lakes, Lagoons and Marshes under investigation, and 3) Alpine, Subalpine lakes and the Temporary ponds, under investigation. Figure 20 shows all the categories of "aquatic resources and delicate ecosystems" of the Central Greece region.

The legend of Figures 15,18,19&20 are: [1]. Intensification and development of agriculture, [2]. Construction of irrigation channels and drainage pits, [3]. Deepening and creation of channels, [4]. Construction of drainage - anti flooding protection works, [5]. Construction and function of large dams and reservoirs (hydroelectric power dams, irrigation dams and water supply dams) on the main bed of the river (>15.0 m height or reservoir volume > 3.0 million m^3), [6]. Construction and function of large dams and reservoirs (hydroelectric power dams, irrigation dams and water supply dams) on tributaries of major rivers (>15.0 m height or reservoir volume > 3.0 million m^3), [7]. Intense construction of anti-erosion works in mountainous catchment basins (small dams, etc.), [8]. Intense construction of coastal defence management schemes (seawalls, breakwaters, groins, revetments, rock

armour, gabions, beach replenishment, sand dune stabilization, etc.), [9]. Construction of jetties in the coastal zone, [10]. Motorway in operation or under construction, [11]. National or provincial roads in operation or under construction, [12]. Opening up new agricultural or forest roads, [13]. Railway line in operation or under construction, [14]. Infrastructure works, [15]. Wood cutting, intense deforestation/Forest fires, [16]. Intense deforestation of riparian vegetation, [17]. Industrial activities upstream, [18]. Small business activities upstream, [19]. Urban and industrial development without any planning, [20]. Uncontrolled deposition of urban waste, industrial effluents, solid domestic and industrial waste, [21]. Excessive use of pesticides and fertilizers, [22]. Contamination-pollution (water & soil pollution, etc.), [23]. Alteration of the physicochemical characteristics - deterioration of the quality of water (salinity, etc.), [24]. Embankment - filling of lagoons or lakes with sediment, [25]. Drain of marshes, lakes lagoons/Exsiccation-desiccation of marshes and lakes, [26]. Canal shifting and entrenchment of the main river channels/river diversion projects, [27]. Intense mining activities (quarries, mines) upstream, [28]. Sand and gravel extraction from river beds upstream, [29]. Uncontrolled watering from surface water tables, [30]. Uncontrolled pumping of underground waters, [31]. Mass touristic activities, recreation, [32]. Domestic use, [33]. Intense urbanization of large coastal zones impacting the natural environment and the local natural ecosystems, [34]. Summer house building, [35]. Sources of water pollution upstream, [36]. Solid wastes/ Water pollution, [37]. Grazing in the forest, [38]. Overgrazing, [39]. Hunting-poaching, [40]. Various off-road 4x4 and motocross races, [41]. Use of lagoons or lakes for fishery, water cultivations, [42]. Coastal farming - Fish farming in coastal waters <500 m from shore and <10 m water depth, [43]. Coastal farming - Fish farming in coastal waters <500 m from shore and >10 m water depth, [44]. Off-coast farming - Fish farming in coastal waters 500 m to 3 Km from shore and 10 to 50 m water depth, [45]. Use of lagoons for salt production.

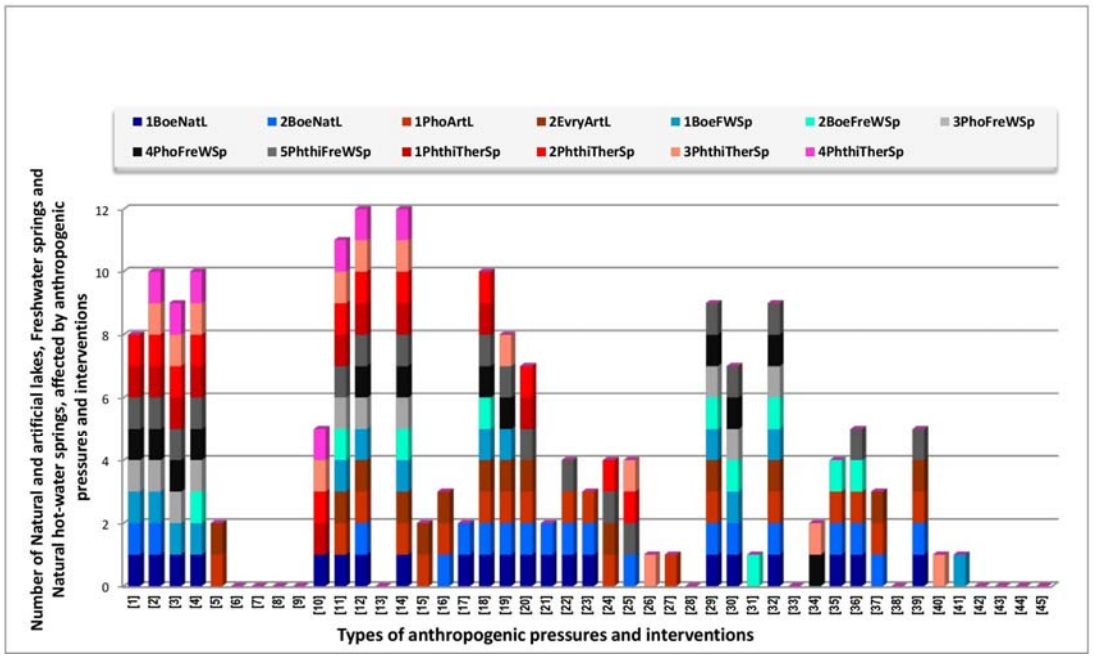


Figure 15. Cumulative chart of the anthropogenic pressures and interventions that stress the Natural and Artificial lakes, Freshwater springs and Natural hot-water springs under investigation.

It should be noted that in the cumulative chart of Figures 15,18,19 and 20, each one of the anthropogenic pressures and interventions that stress the aquatic resources and delicate ecosystems of Central Greece region, receives one point.

As shown in Figure 15, there are several established anthropogenic pressures and interventions that stress the natural and artificial lakes, Freshwater spring and Natural hot-water springs under

investigation. The most important ones are the following, in decreasing order: "Infrastructure works-Code 14", "Opening up new agricultural and forest roads-Code 12", "National or provincial roads in operation or under construction-Code 11", "Construction of irrigation channels and drainage pits-Code 2", "Construction of drainage - anti flooding protection works-Code 4", "Small business activities upstream-Code 18", "Deepening and creation of channels-Code 3", "Uncontrolled watering from surface water tables-Code 29" and "Domestic use-Code 32".




Figures 16, 17: Agia Eleousa freshwater springs (4PhoFreWSp) near Polydrosos and Amfikleia (Fig. 16). Kallidromos thermal springs II (Psoroneria II) (2PhthiTherSp) near Kato Damasta (Lamia) (Fig. 17) (Photos by Konstantinos Mertzanis).

It should be noted that Acheloos is the main river of Western Central Greece region. Along its valley many hydroelectric power dams have been constructed (Table 1). The dam of Kremasta is included among the Acheloos river dams. Dams are structures built in the bed of a natural stream to cut off the flow; they are used for storage, discharge for power generation (hydroelectric dams), irrigation, water supply or flood protection. These structures have caused several impacts on the natural and the built environment.

Table 1. The features of dams and reservoirs in Acheloos river

Name of dam in Acheloos River	Nearest city	Type of dam	Height (m)	Volume of Dam (10^6 m^3)	Storage capacity/ Reservoir (10^6 m^3)	Year of Completion
Kremasta	Karpenisi	Earthfill/Rock-fill riprap dam (sand and gravel with central clay core)	165	8,1	3.828	1965
Kastraki	Agrinio	Earthfill dam with central clay core	96	5,2	---	1969
Stratos I	Agrinio	Earthfill dam with central clay core	26	2,8	14,9	1988
Sykia	Arta	Earthfill dam with central clay core	170	12,4	600	Under Construction
Mesochora	Mesochora / Trikala	Rock-fill dam (Concrete Faced Rockfill Dam)	150	5,5	358	Under Construction
Tavropos (Plastiras Lake)	Karditsa	Arch-gravity dam	83	0,10	400	1959

Source: Various literature sources and existing reports

The large dams and reservoirs (artificial lakes) construction in the Acheloos river catchment, in conjunction with forest fires, illegal woodcutting, deforestation and grazing constitute the main burden to the natural ecosystems in the mountain drainage basins, while the channelization, sand extraction

from river beds, development and intensification of agriculture projects and industrialization, infrastructure works, embankments, exsiccation, deforestation, etc. constitute the main burden to the natural ecosystems and the wetlands in the coastal areas and the deltas (Vassilopoulos et al., 2005, Mertzanis and Mertzanis, 2013, Mertzanis, 2013). These interferences led to the creation of a peculiar environmental entity and an "artificial" environment which to a great extend is man controlled. The manmade characteristics of this environmental entity are aggravated by the extensive road works in the forests and in the wetlands (Mertzanis et al., 2011a,b). Climate change is likely to affect coastal ecosystems through of mean sea level (C.E.C. 1999).

The water supply dam of Mornos river, was constructed in 1980. The erosion of the active bed in the area of the estuary is at a rate of 11,4 m /year ad it is attributed to the dam (Karymbalis and Gaki-Papanastasiou, 2008). The artificial lake of Mornos, alongside the natural lake Yliki, are supplying the city of Athens with water.

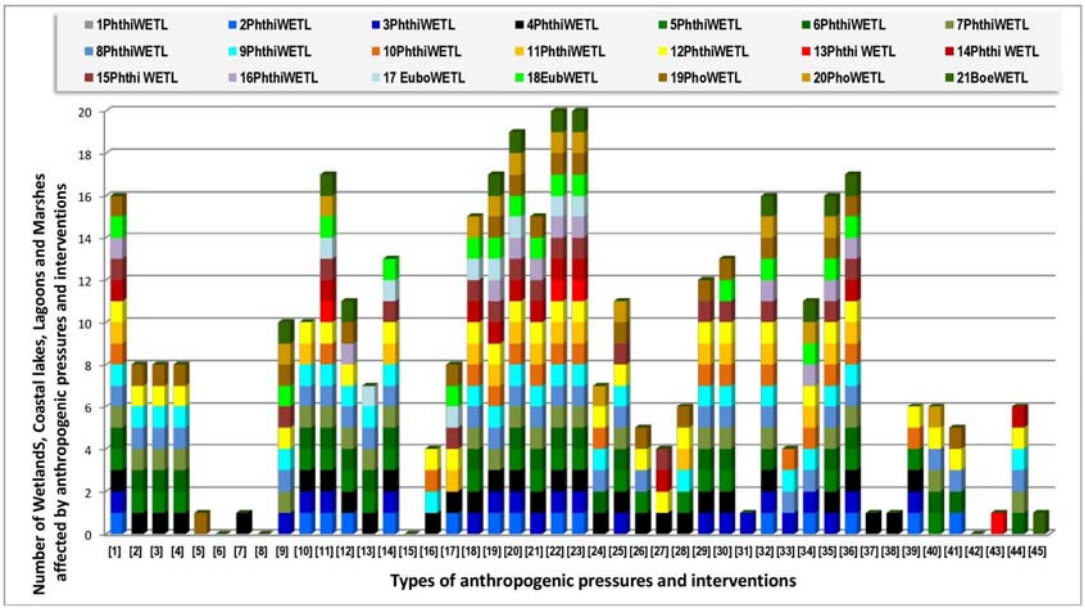


Figure 18. Cumulative chart of the anthropogenic pressures and interventions that stress the Wetlands, Coastal lakes, Lagoons and Marshes under investigation.

As shown in Figure 18, there are several established anthropogenic pressures and interventions that stress Wetlands, Coastal lakes, Lagoons and Marshes under investigation. The most important once are the following, in decreasing order: "Contamination - pollution (water & soil pollution, etc.-Code 22", "Alteration of the physicochemical characteristics -deterioration of the quality of water (salinity, etc.)-Code 23", "Uncontrolled deposition of urban waste, industrial effluents, solid domestic and industrial waste-Code 20", "National or provincial roads/in operation or under construction-Code 11", "Urban and industrial development without any planning-Code 19" and "Solid wastes/Rubbish water pollution-Code 36".

It should be noted that Spercheios is the main river of Phthiotis Prefecture. Spercheios river drains an area of 1907,2 Km^2. It contributes significant amounts of brought materials in the lower area of discharge, in Maliakos gulf, due to the presence of erosion prone flysch in its basin. These material are deposited in the plane of Lamia and the Delta enriching it. The canal shifting/ partial diversion to the northern Maliakos gulf, of Sperheios river, resulted in the creation of a new Delta in the area of a new mouth to the Maliakos gulf and the shrinkage of old delta (Tziavos, 1977; Zamani and Maroukian, 1979, 1980; Efthimiou et al., 2005; Sigalos and Alexouli-Livaditi, 2006a,b, Mertzanis et al., 2010b,c).

Most of the Mediterranean seasonal lakes of Central Greece region, have a temporary status, while some of them may retain the water throughout the year, when it is allowed by climate conditions and anthropogenic interventions.

Mediterranean temporary ponds are, by definition, wetlands that present a seasonal hydrologic period. Ecosystem functions and, consequently, the biota of the ponds depend strongly on the hydrological status. The characteristic flora and fauna are highly specialised and vulnerable to any changes in hydrology. The establishment of a quantitative assessment of the hydrological functions and the identification of potential direct or indirect modifications require frequent monitoring of the components of the water cycle, and of their effects on the seasonal and interannual variations of the pond water level. In addition, the biological phenomena of the ponds strongly depend on the hydric state and geochemistry of the sediments, the water chemistry, and their interactions. These are also controlled by flooding/drying cycles through soil redox potential changes (www.foropenforests.org).

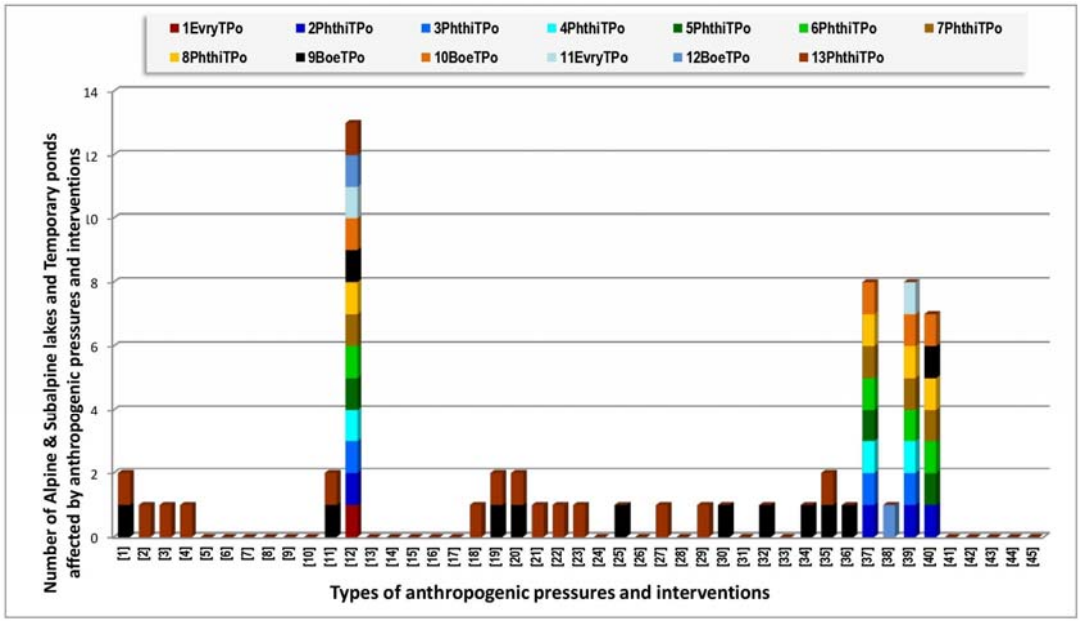


Figure 19. Cumulative chart of the anthropogenic pressures and interventions that stress the Alpine and Subalpine lakes and the Temporary ponds, under investigation.

Some alpine, subalpine lakes and temporary ponds, that exist in Central Greece region, such as the ponds Velouchi in Mt Tymphristos, Leivadies, Greveno and Louka in Mt. Oiti, Zirelia in Mt. Vardousia, Nevropolis I & II and Paliosouvala in Mt Kallidromo, and Varko' in Mt. Parnassos, remain relatively unaffected by uncontrolled anthropogenic interventions (Figure 19). Some influences applied onto them are those of "Opening up new agricultural and forest roads-Code 12", "Grazing in the forest-Code 37", "Hunting-poaching-Code 39" and "Various off-road 4x4 and motocross races-Code 40" and of the climate conditions and consequently of the global climate change (Figures 21&22).

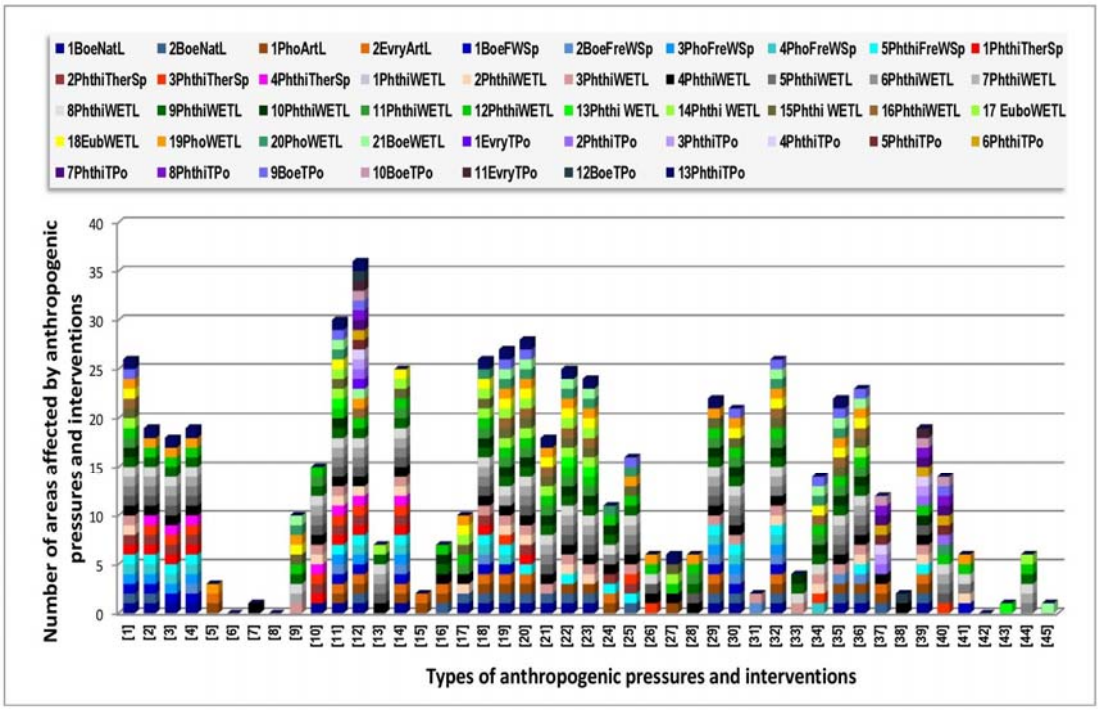


Figure 20. Cumulative chart of the anthropogenic pressures and interventions that stress the aquatic resources and delicate ecosystems of Central Greece region.

The identification, recording and evaluation of the multiple anthropogenic pressures and interventions that have been encountered as of now in the aquatic resources and delicate ecosystems of Central Greece region, have been summarized in Figure 20. The most important ones are the following, in decreasing order: "Opening up new agricultural and forest roads-Code 12", "National or provincial roads in operation or under construction-Code 11", "Uncontrolled deposition of urban waste, industrial effluents, solid domestic and industrial waste-Code 20" and "Urban and industrial development without any planning-Code 19".

This Cumulative chart serves as a tool for the rational environmental management of the aquatic resources and delicate ecosystems, offering an overall visualization of the pressures/impact, in order to protect the function and value of wetlands.





Figures 21, 22: The temporary pond Varko' lake (10BoeTPo) on Mt. Parnassos, during the winter (Fig. 21) and in the summer season (Fig. 22) (Fig 21: Photo by Theodora Lanara, Fig 22: Photo by Konstantinos Mertzanis).

3.2 Environmental management of aquatic resources and delicate ecosystems of Central Greece region - Ecological restoration proposals and monitoring

For the rational environmental management of the aquatic resources and delicate ecosystems of Central Greece region, in order to address the environmental impact of projects and activities and in order to gradually restore the disturbed balance of affected natural ecosystems, many measures have to be taken. These include the use of specialized environmental protection measures, strict control and monitoring of these measures and the safeguarding of the boundaries of protected areas.

The main protective measures listed below and are: 1. Detailed surveying, identification and high resolution spatial mapping of the aquatic resources and delicate ecosystems under study. A related program LIFE11 NAT/GR/1014 is implemented in the mountains of Oiti and Kalidromos (http://www.foropenforests.org), 2. Comprehensive study of all habitats in the different sites of Central Greece region, 3. Comprehensive study of the geological, geomorphological and hydrogeological characteristics of the areas under investigation, such as the natural and artificial lakes, freshwater springs and natural hot-water springs, deltas, coastal wetlands, coastal lakes, lagoons and marshes, alpine or subalpine lakes and temporary ponds, that exist in Central Greece, 4. Reduction of pollutant emissions and more generally of the environmental impact of the different anthropogenic pressures and interventions, 5. Redefinition of the location of different anthropogenic pressures and interventions under study and taking adequate measures, 6. Reevaluation of the operation of treatment plants of urban waste water and taking adequate measures, 7. Reevaluation of the operation of industrial wastewater treatment plants and livestock installations and taking adequate measures, 8. Reevaluation of the operation of industrial and manufacturing installations wastewater treatment plants as well as livestock installations and taking adequate measures, 9. Reduction of gaseous pollutant emissions and aerosols, 10. Implementation of municipal solid waste management projects, 11. Implementation of projects on waste management and recycling, 12. Implementation of hazardous and toxic waste management projects, 13. Implementation of water saving programs in irrigation and industrial production, 14. Reduction of fertilizers, herbicides, and pesticides in agricultural production, 15. Implementation of ecosystem restoration project for the improvement and expansion of aquatic and terrestrial habitats and ecological function in the lakes, lagoons, delta and their tributaries. The "Ecosystem Restoration Progam" is guided by the following six strategic goals (www.wildlife.ca.gov): a. Recover endangered and other endangered species and native biotic communities, b. Rehabilitate ecological processes, c. Maintain or enhance harvested species populations, d. Protect and restore habitats, e. Prevent the establishment of non-native invasive species and progressively reduce their impact, and f. Improve or maintain water and sediment quality, 16. Long term monitoring of the broader area of the aquatic resources and delicate ecosystems under study.

4. CONCLUSIONS

A significant segment of Central Greece region (inland and coastal environments) is in a fragile equilibrium, mainly because of the anthropogenic interventions that were carried out without preliminary studies regarding their long-term consequences. The intensification of human activities, such as, engineering works, intensification and development of agriculture projects, exsiccation of lagoons and lakes, river damming, canal shifting and entrenchment of the main river channels - river diversion projects, waste disposal and water pollution, fertilizers, herbicides, and pesticides, uncontrolled watering from surface and underground water tables, etc., combined with the climate change, its influence on the local natural environment and the geomorphological evolution processes, constitute the main causes of the environmental degradation.

The environmental destabilization of most of the aquatic resources and delicate ecosystems of the administrative region of Central Greece (Prefectures of Boeotie, Evrytania, Phocis and Phthiotis), is mainly caused by certain anthropogenic pressures and interventions that alter critical parameters of the environment, leading to wetland alteration or degradation and have a significant impact on: a. Flora and local natural ecosystems, b. Landscape, c. Surface and underground waters and c. Geomorphology. Diverse land use changes concerning the coastal and inland plains, natural and

artificial lakes, freshwater springs and natural hot-water springs, deltas, coastal wetlands, coastal lakes, lagoons and marshes are also detected, while the alpine or subalpine lakes and temporary ponds that exist in Central Greece, remain unaffected or less affected, by the uncontrolled anthropogenic interventions. Some influences applied onto them are those of "Opening up new agricultural and forest roads-Code 12", "Grazing in the forest-Code 37", "Hunting-poaching-Code 39" and "Various off-road 4x4 and motocross races-Code 40" and of the climate conditions and consequently of the global climate change.

The appropriate design and the application of methods and techniques for the management of aquatic resources and delicate ecosystems is a condition for the preservation of the equilibrium of the natural hydrological and geomorphological processes, the renewal of the natural resources and, in general, environmental protection.

This acquires special importance for the region of Central Greece that hosts many important and sensitive natural ecosystems, most of which are protected by national, European and international treaties, Greek law and the corresponding European Community Law and especially in the EU Natura 2000 Network. Despite the existing strict relevant legal system that applies in some of these areas and the commitments undertaken by the Greek government for the protection of these specific areas (protected by Greek law, Natura 2000 Network, etc.) in most cases, anthropogenic interventions in those areas do not take into account the necessary restrictions for the protection of the environment. This leads to unfavourable effects to the relevant wetlands, resulting in their alteration or degradation. The extent and severity of alteration or degradation depends on the type, the extent, the function and the location of the specific activity.

To address the impact and gradually restore the disturbed equilibrium of the ecosystems under investigation, it is necessary to use methods and technics that are environmentally friendly and will restore the natural function and dynamics of the mentioned ecosystems.

ACKNOWLEDGMENTS

The authors thank the company Geotag Aeroview Ltd. (TripInView) for the free geotagged aerial photos they provided, from the site www.tripinview.com.

The authors also wish to thank the local non-government environmental organizations, the relevant Forest Services, the Parnassos National Park Management Body, the Management Body of Mt Oiti National Park, and the Hellenic Alpine Club of Lamia. In particular the Presidents, the Executive Directors and the Planning Officers of the Parnassos National Park Management Body and Management Body of Mt Oiti National Park, are thanked for availing information concerning the environmental protection status of the mountains and the protected areas of Central Greece.

REFERENCES

1. Alexandrakis G, Karditsa A, Poulos S, Ghionis G, Kampanis N. (2009a) Assessment of the vulnerability the coastal zone to a potential rise of sea level. Proc 9th Symposium on Oceanography & Fisheries. Athens, Greece. 2009; Volume I. 327-332. (in Greek).
2. Alexandrakis G, Karditsa A, Poulos S, Ghionis G, Kampanis N. (2009b). Vulnerability assessment for to erosion of the coastal zone to a potential sea level rise: The case of the Aegean Hellenic coast, in Environmental Systems. Ed.Achim Sydow, in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford ,UK. Accessed 17 August 2009. Available: http://www.eolss.net.
3. Brofas G., (1989). The restoration of vegetation at the land mines. Conference GEOTEE, 12-13 April, Athens. (in Greek).
4. California Department of Fish and Wildlife. "Ecosystem Restoration Progam", www.wildlife.ca.gov Retrieved from http://www.dfg.ca.gov/erp/ on 27 April 2016.

5. C.E.C. (1999). "Guidelines for the Assessment of Indirect and Cumulative Impacts as well as Impact Interactions". DGXI.
6. Dafis S, Papastergiadou E, Georgiou K, Babalonas D, Georgiadis D, Papageorgiou M, et al. (1997). Directive 92/43/EEC. Wetlands works in Greece: Network Natura 2000. Contract. B4-3200/84/756, General Directorate XI Commission of the European Communities, The Goulandri Natural History Museum, G.B.W.C. 932 p; 1997. (in Greek).
7. Efthimiou G, Mertzanis A, Sapountzis M and Zakynthinos G. (2005). Anthropogenic effects at the Spercheios river delta-Protection measures for the depiction and management of the natural ecosystems. Minutes 5th International Conference for the Environmental Technology - «Heleco' 05», CD-ROM, 3-6 February 2005, Athens. (in Greek).
8. Evelpidis, C. (1956). Agricultural policy. Athens (in Greek).
9. Gerakis P., (1993). Conservation and management of Greek wetlands workshop. Proceedings of Greek wetlands workshop. Thessaloniki, Greece, 04.1989, IUCN, Gland, Switzerland. p. 493.
10. Homer. Iliad B. 511, B. 520-524.
11. Hesiod. Theognossia 6.
12. Intergovernmental Panel on Climate Change (IPCC) (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability, Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Cambridge University Press, Cambridge, UK, 976 pp., 2008.
13. Intergovernmental Panel on Climate Change (IPCC) (2001). Climate Change, Synthesis Report. (Stand-alone edition), Watson, R.T. and Core Writing Team editors, Geneva, 184 pp., 2001.
14. Karymbalis E. and Gaki-Papanastasiou K., 2008. Geomorphological study of the river Deltas of Pinios, Kalamas, Evinos and Mornos. Proceedings of the 4th Panhellenic *Conference* Management and improvement of coastal zones. Laboratory of Harbour Constructions. National Technical University of Athens, 86-94 (in Greek).
15. Kousouris, Th., 2014. The lakes in Greece. 2/6. Epirus. "Lakes recordings & Testimonials", Athens. pp. 73. (in Greek).
16. Kousouris, Th., 2016. The small lakes in Greece. "Small lakes images and tours", Athens. pp. 498. (in Greek).
17. LIFE11 NAT/GR/1014. Preservation of Forests and Forestry Openings Priority in Oiti National Park and Mt Kallidromo in Central Greece. Retrieved from http://www.foropenforests.org. on 5 May 2016.
18. Marabini F (1994). Climatic changes evidenced by the coastal zone cartography. Proc Geoprospective 94, UNESCO, Paris. 1994. 129-136.
19. Marabini F. and Veggiani A., (1990). The influence of climatic changes on the evolution of the Po Delta from the 16th century to the present time. Atti Convegno sull' ecologia del delta del Po, Albarella. 1990; 1-15. (in Italian).
20. Mertzanis A. (2013). Geomorphological evolution and climate change caused by river damming: The case of Acheloos river (Greece)». Proceedings of the Fourth International Conference on "Environmental Management, Engineering, Planning and Economics (CEMEPE 2013)", June 24-28, 2013, Mykonos island, Greece, Editors: A. Kungolos, K. Aravossis, A. Karagiannidis, P. Samaras, K.-W. Schramm, p. 1031-1036. ISBN 978-960-6865-68-8.
21. Mertzanis A, Goudelis G, Pantera A, Efthimiou G and Kontogianni A (2010a). Human intervention in torrents and the littoral zone and their impact on the environment and the hydro-geomorphological processes of the littoral wetlands: the case of the Katafourko lagoon (Eastern

Amvrakikos gulf). Proceedings of the International Conference Protection and Restoration of the environment X, 05 – 09 July 2010, Corfu, Greece.

22. Mertzanis A, Papadopoulos A and Pantera A (2010b). Changes in the geomorphs and the hydro-geomorphological processes as a consequence of the construction of the new National Road Athens-Lamia in the section Molos-Lamia (Ftiotida-Greece). Proceedings of the International Conference Protection and Restoration of the environment X, 05 – 09 July 2010, Corfu, Greece.
23. Mertzanis A, Goudelis G, Efthimiou G and Kontogianni A (2010c). The impact to the environment and the hydro-geomorphological processes as a result of human activity in littoral and inland wetlands in Greece. Proceedings of the International Conference Protection and Restoration of the environment X, 05 – 09 July 2010, Corfu, Greece.
24. Mertzanis A. and Mertzanis K. (2013). Impact of River Damming and River Diversion Projects in a Changing Environment and in Geomorphological Evolution of the Greek Coast. SCIENCEDOMAIN international. British Journal of Environment & Climate Change (BJECC), Volume 3(2), Special Issue, pp. 127-159.
25. Mertzanis, A., Papadopoulos, A., Goudelis, G., Pantera, A. and Efthimiou, G., (2011a). Human-induced impact to the environment and changes in the geomorphology: Some examples of inland and coastal environments in Greece. Academic Journals. Journal of Ecology and the Natural Environment (JENE), 3 (8), 273-297.
26. Mertzanis A, Marabini F, Galvani A (2011b). The interference of human activity on the environmental changes and the geomorphological evolution in Italy and Greece: The cases of the Po and Arachthos river deltas - Venice and Katafourko lagoons. Journal of International Scientific Publications: Ecology & Safety. 2011;5(2):17-34. ISSN1313-2563.
27. Sigalos G, Alexouli-Livaditi A (2006a). Investigation of the long term evolution of a coastline-future adjustment prediction. The Malian gulf example. Bulletin of the Geological Society of Greece. 2006; vol. XXXIX/III, 162-173. (in Greek).
28. Sigalos G, Alexouli-Livaditi A (2006b). Shoreline migration analysis due to sea level change, and estimation of its impacts for the Maliakos gulf region. Bulletin of the Geological Society of Greece. 2006. vol. XXXIX/III, 174-182. Greek.
29. Stamatopoulos, G. A. (1967). Land improvement works and land improvement cooperatives. Athens. (in Greek).
30. Strabo. Geography Th. 40.
31. TripInView/Geotag Aeroview. Retrieved from http://www.tripinview.com/en?path=home on 28 April 2016.
32. Tziavos C. (1977). "Sedimentology, ecology and palaeography of the Sperchios valley and Maliakos gulf - Greece". Thesis, University of Delawere.
33. United States Environmental Protection Agency (U.S. E.P.A.). (2001). Treats to wetlands. EPA 843-F-01-002d, September 2001.
34. Vassilopoulos, A., Green, D. R., Gournelos Th., Evelpidou N., Gkavakou P. and Kousouris S. (2005). Using GIS to study the Coastal Geomorphology of the Acheloos River Mouth in West Greece. COAST GIS: 6th International Symposium Computer Mapping and GIS for Coastal Zone Management, Aberdeen, Scotland, U.K., August 2005.
35. Vavizos, G., Mertzanis, A., 2003. Environment - Studies of Environmental Impact. Papasotiriou, Athens. pp. 342. (in Greek).
36. Zalidis HG, Matzavelas AL. Inventory of the Hellenic Wetlands as Natural Resources, G.B.W.C.-XVII, p.587; 1994. (in Greek).

37. Zamani A. and Maroukian H. (1979). “A morphological study of an old delta of the Spercheios River”. VI Colloquium on Geology of the Aegean Region, Proceedings, Athens, 1977, 417-423. (in Greek).
38. Zamani A. and Maroukian H. (1980). “Deltaic sedimentation of the Spercheios River in historical times”. Annales Geologiques du Pays Helleniques, 30, 430-440. (in Greek).