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Full Length Research Paper

Human - induced impact to the environment and changes in the geomorphology: Some examples of inland and coastal environments in Greece

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It has been observed that human activity in the form of engineering works, such as channelization (drainage pits and drainage dams, deepening and creation of canals), dam construction (hydroelectric power dams, irrigation dams and water supply dams), diversion and culverting (arrangement and redirection of river channels), as well as other human interventions and activities (intensification and development of agriculture projects, infrastructure works, embankments, exsiccation, wood cutting, deforestation, deforestation of riparian vegetation, fire wood collection, uncontrolled watering from surface water tables, uncontrolled pumping of underground waters, etc.), may seriously affect the environmental balance of wetlands. The aims of this paper are: 1) to report a synthesis of the environmental and geomorphological studies on the selected wetlands of Nestos, Sperchios, Arachthos river deltas and the estuaries of the river Louros and Alfeios, as well as of the fen of Kalodiki and Katafourko lagoon in Greece, 2) to locate the main human activities as well as the existing or planned infrastructure works, 3) to detect and survey as far as possible the impacts of the aforementioned human activities and the problems that follow, and affect these wetlands and 4) we will produce a manageable "tool" that will be used in order to make decisions relevant to the rational management of the natural resources and the environment in the earlier mentioned areas.

Key words: Environmental impact, geomorphology, human activities, wetlands, lagoons, deltas.

INTRODUCTION

The extensive biodiversity and productivity that characterize the littoral and inland wetlands in Greece, as well as their specific geological, hydrological, geomorphological and soil characteristics, as well as in some cases, their accessibility, are the main factors responsible for the intense human activity in these areas. Characteristic examples of these are the protected wetlands that exist in Greece, such as those in the area of the Nestos River delta in Northeastern Greece, Sperchios in Central Greece, Arachthos in Western Greece and in the estuaries of Louros River and Alfeios River, as well as the fen of Kalodiki and Katafourko lagoon in Western Greece (Marinos, 1984; Tziavos, 1989, 1996; Mertzanis, 1992, 1995; Skoullos, 1992; Gerakis, 1993; Zalidis and Matzavelas, 1994; Efthimiou et al., 2003, 2005; Vavizos and Mertzanis, 2003; Ghionis et al., 2004; Kapsimalis et al., 2005; Kagalou et al., 2006; Poulos et al., 2005, 2008; Hellenic Ornithological Society, 2010a, b; Manariotis and Yannopoulos, 2004; Margoni and Psilovikos, 2010). In the aforementioned areas both in the delta area and in the coastal zone, the presence of human activity as well as infrastructure works is intense (Mertzanis and Papadopoulos, 2003; Mertzanis et al., 2010a, c). Moreover, the presence of

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human activity is equally intense in the drainage basins which supply the wetlands with water volume and sediments, which are an important parameter for the conservation of those wetlands.

Despite the existing strict relevant legal system that applies to these areas and the commitments undertaken by the Greek government for the protection of these specific areas (Ramsar convention, etc) in most cases, human activity in those areas does not take into account the necessary restrictions for the protection of the environment and this leads to unfavorable effects to the relevant wetlands which result in alterations as far as the extent and severity, depending on the type, the extent, the function and the location of the specific activity (Ministry of Environment, Urban Development and Public Works, 1997; Efthimiou et al., 2003, 2005; Kagalou et al., 2006, 2010; Hellenic Ornithological Society, 2010b). It has been noted that the freshwater wetlands around the Mediterranean Sea have decreased considerably in number and quality. Greece has lost two thirds of its wetlands during the last 75 years; however, many wetlands with considerable conservation value remained (Gerakis, 1993; Dimopoulos et al., 2005; Kagalou et al., 2010).

DESCRIPTION OF THE STUDY AREA

Geographical locations and geomorphology - dam and river engineering in the study area

This study focuses on seven littoral and inland wetlands which have undergone intense alterations due to human intervention in the drainage basin, in the delta or on the coastal zone. These areas are found in Greece and more specifically these areas are:

1) Nestos River delta - site 1 (Northeastern Greece): An extended bow shaped delta of “Nile type” (615 km^2) has been formed in the area of the estuaries of Nestos River, which area is supplied with the sediments from its drainage basin and extends in an area of 5.750 km^2. This area is included in the Ramsar Treaty as an internationally important wetland complex and is one of the 11 protected Ramsar wetlands (sites) in Greece (Gerakis, 1993). This site includes the lagoons (Agiasma, Eratino, etc.) and the estuaries of Nestos River to the Thracian Sea and is located east of the town of Kavala, in parts of Eastern Macedonia and Western Thrace (Figure 1). In the surface of the deltaic plain, the River Nestos, from the beginning of the Holocene and approximately up until 1945, it often overflows, the flow of water channels changes, meanders are formed and material deposits which is finally dispersed, due to the action of the waves and currents of the sea (Psilovikos et al., 1986, 1999; Margoni and Psilovikos, 2010; Sylaios et al., 2010). The annual river discharge was estimated between 1.0 and 1.5 × 10^9 m^3/year, while the total sediment transport, before the dams’ construction of “Thissavros” and “Platanovrissi” in the inner mountainous valley, was estimated between 0.5 and 1.0 × 10^6 m^3/year (Psilovikos, 1999). The deltaic plain has suffered human works all through the last half of the 20th century. Most of the natural wetland systems were drained (88.45%) and turned into irrigated fields. Only 11.55% of the total wetland areas were preserved in the deltaic plain.

In the central deltaic plain, a wide artificial channel was constructed (28 km^2 in area), to protect the fertile irrigated areas from flooding (Margoni and Psilovikos, 2010). From the year 1945 onwards, a period in time where appear the early human interferences in the area (drainage and irrigation canals). In 1983, started the engineering works for the construction of the hydroelectric power dams “Thissavros” and “Platanovrissi” on the main river channel of Nestos. The construction of the dam “Thissavros” was completed in 1996, while the dam "Platanovrissi" in 1998. In the year 2010, started the foundation works of the dam “Temenos”. The total capacity of water storage in its reservoirs that exceed 640 × 10^6 m^3. Also, another dam has been constructed in the Bulgarian side of its basin. The “Thissavros” dam, built at 60 km north-west of the town of Xanthi. This rock-fill dam with central clay core, has a total volume of about 12 × 10^6 m^3, and its 172 m high. The reservoir has a capacity of approximately 705 × 106 m^3. The "Platanovrissi" gravity dam is a Roller Compacted Concrete (RCC) dam with a total volume of about 0.45 × 10^6 m^3, and 95 m high. The reservoir has a capacity of approximately 57 × 10^6 m^3.

2) Sperchios River delta - site 2 (Central Greece): Sperchios River drains an area of 1,907.2 km^2. It contributes significant amounts of sediments in the lower area of discharge, due to the presence of erosion prone flysch in its basin. These SPM deposit and enrich the floodplain of Lamia and the Delta (Tziavos, 1977; Zamani and Maroukian, 1979, 1980; Krestenitis et al., 2000; Efthimiou et al., 2003; Sigalos and Alexouli-Livaditi, 2006a). This site includes the estuaries of Sperchios River to the Maliakos gulf and is located east of the town of Lamia, in Fhtiotida (Figure 1). In this delta area, from the year 1945 onwards, a period in time where appear the early human interferences in the area (national road Athens - Lamia, drainage and irrigation canals, etc). The construction of the partial diversion to the north, of the Sperchios River channel was completed in 1958. The diverted river channel is approximately 9.0 km long, 20 m wide and protected by two parallel embankments spaced 60 m. In 2007, started the engineering works to improve Sperchios diverted river channel for the stream discharge of peak flow (flood events), in Maliakos Gulf. A special construction (distributor) for the diversion of the stream discharge was made, while the channel was dredged. The continuous

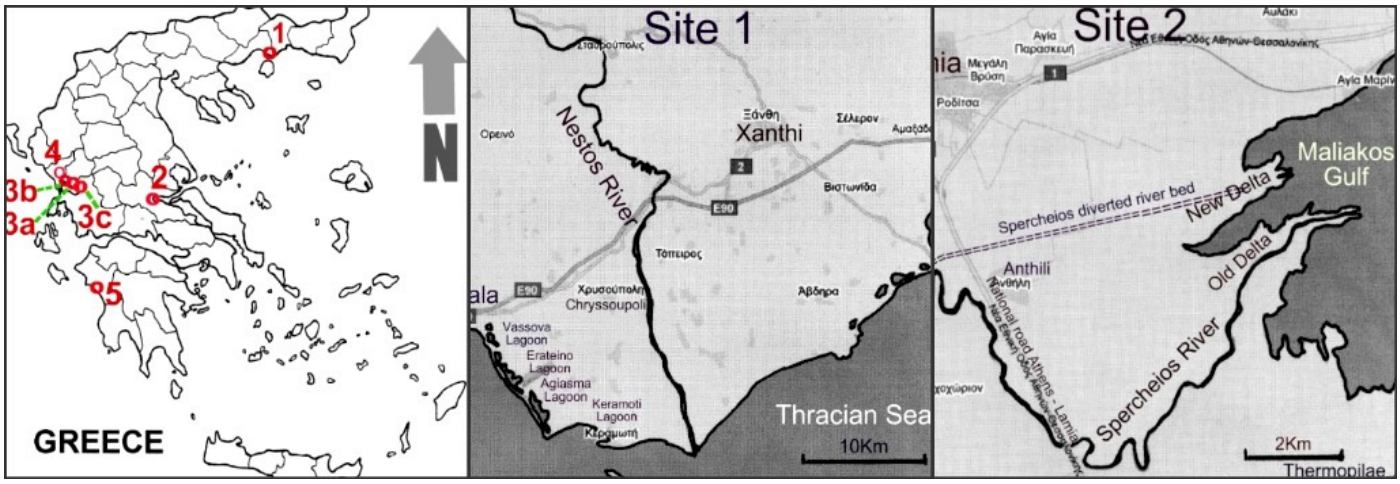

Figure 1. Geographical location of the wetlands under investigation (sites 1 and 2).

flow of drainage in the Sperchios old riverbed (Alamana) guaranteed by the southern embankment culvert upstream of the distributor with the bottom level below the crest overflow.

3) Arachthos River delta - site 3a (Western Greece): River Arachtos drains an area of 1,850.85 km^2. It contributes significant amounts of SPM (around 2,900,000 m^3/year), to the low lying area of discharge, due to the presence of erosion prone flysch in its basin (Therianos, 1974; Mertzanis, 1992; Poulos and Chronis, 1997; Poulos et al., 2005, 2008). These sediments are deposited and enhance the floodplain of the town of Arta and the delta, which morphologically is of the type of "bird pad" (Galloway, 1975). In the area of discharge of the estuaries of Arachthos and its neighboring Louros River, an extended complex of wetlands (lagoons and deltas), has been created (Figure 2). The wetlands area and the estuaries of Arachthos River to the gulf of Amvrakikos, located south of the town of Arta, in Ipiros area (Figure 3). On the main river channel of Arachthos has been built and operates the hydroelectric power dam "Pournari I", during the period 1973 to 1980, which is used for coverage of irrigation and potable water supply and flood protection in the region.

The "Pournari I" dam, built at 4.5 km north-east of the town of Arta, and came into operation in the year 1981. This rock-fill dam with central clay core, has a total volume of about 9 × 10^6 m^3, 107 m high and a length of 580 m at the dam crest. The reservoir has a capacity of approximately 730 × 10^6 m^3, while the surface of the artificial lake is about 20.6 km^2 at full supply level and length 17 km. The operation of the dam "Pournari I", combined with the small dam "Pournari II" newly constructed downstream of the aforementioned and has been operated since 2000. The dam "Pournari II" regulates the flow of river water Arachthos, ensuring minimum continuous flow irrigation.

4) Estuaries of Louros River - site 3b (Western Greece): Louros River drains an area of 685.50 km^2. Due to the calcareous nature of the base of its basin, this river does not accept significant amounts of sediments which could result in apparent differentiations of its delta shape, at least during its recent geomorphological evolution (Mertzanis, 1992). The wetlands area and the estuaries of Louros River to the gulf of Amvrakikos, located north-east of the town of Preveza, in Ipiros area (Figure 3). On the main river channel of Louros, has built and operates the hydroelectric power dam "Louros", during the period 1954 to 1963. The "Louros" dam, built at 20 km north-west of the town of Arta. This arch-gravity dam is 25 m high and has a length of 70 m at the dam crest.

5) Katafourko lagoon - site 3c (Western Greece): The catchment basin of the Katafourko lagoon is at the lower plain part of the eastern side of the Amvrakikos gulf which extends in the western part of Greece (Figure 3). The Krikeliotis and Xirorema rivers are the main hydrographic systems that discharge in the eastern side of the Amvrakikos gulf, the drainage basins which were formed in the western side of the Makrynoros mountain. This site includes the Katafourko lagoon at the eastern Amvrakikos gulf. The Krikeliotis River which is the main supplier of "fresh" water and sediments of the floodplain and of the Katafourko lagoon, during the past it discharged at the eastern side of the Amvrakikos gulf, while ever since 1959, due to human activity has been diverted and is now discharged inside the Katafourko lagoon. The drainage basin of the Krikeliotis River and its three main confluent branches Kakavakia, Kothoni and Hava which are asymmetrically positioned to the main channel of the river, drain a significant part of the

Figure 2. View of Rodia lagoon between the Arachthos and Louros River delta - Amvrakikos Gulf (Mertzanis, 2010).

Makrynoros mountain towards the Amvrakikos gulf. The size of the drainage basin is 62.5 km^2 and the total length of the main bed of the Krikeliotis river Ls = 16.0 km (Mertzanis, 1992). Out of these, 4.0 km are located in delta plain area and exhibit a mainly meander configurationin at least, as far as its naturally developed part which does not contain the diversed bed, is concerned.

The Katafourko lagoon, in 1945 was around 2,500,000 m^2 and it had a long arch shape, while according to recent measurements the “water pane” has been limited to the northern part and extends to an area of less than 500,000 m^2, while its main water volume which is surrounded by marsh-swamp areas where hydrophile plants predominate, it has assumed a “horse shoe” form with slim aquatic endings (Figure 4). It is a shallow lagoon, with a mean depth of 0.2 m and maximum depth of 0.6 m (Tsamarda, 2006). It is characterized as a “closed” type and is segregated from the sea by a sand barrier of approximately 1,000 m long and a mean width of about 25 m which is significantly diminished to the north. It communicates with the sea through an artificial channel of which the exit to the sea shows a bend to the north, due to the fact that it is also the direction of the transfer of the sediments. At the outer side of the lagoon, at the border between the sand barrier and the gulf of Amvrakikos, the slopes of the bottom up to the 30 m depth curve, which is encountered at a distance of 600 to 1,400 m from the coastline, vary from 1:25 to 1:50. The geological substrate which contains the whole drainage basin of the Krikeliotis River, with the exception of the lower alluvional valley, is composed of flysch and especially “Peta sandstone”, and this is a factor which contributes to the creation of a relatively extended hydrographic network (0.89 km/km^2) and to a production and supply of large amounts of SPM, which result from the erosion of the flysch. The total yearly volume of the drained water is estimated to be 20,470,000 m^3.

6) Kalodiki Fen - site 4 (Western Greece): Kalodiki wetland is an inland freshwater fen listed among the Natura 2000 Greek sites, characterized as site of Community Interest (pSCI) and also as a special protected area. It is one of the 39 Greek wetland sites assigned to the wetland type “freshwater marshes and meadows”. It is located in Epirus-NW Greece belonging in the western chain of Greek wetlands (Kagalou et al., 2010) (Figure 5). Kalodiki wetland is a remnant of the oldest extensive fen, with altitude of 108 m a.s.l. and a surface of approximately 195 ha topogenous mire, in a small basin representing a tectonic depression in Epirus Region (Arapis, 1998) (Figure 6). The maximum depth is about 4.5 m while the mean depth of 0.8 m collecting waters coming from adjacent mountain limestone formations. The aquifer is fed by karstic waters, which are derived from springs, mainly lying close to the southwestern and northeastern edge of the fen, as well as by irregular run-off from the surrounding drainage area. The wetland has experienced of high and frequent water level fluctuations between the dry and the wet season (Sarika-Hatzinikolaou, 1994) while Botis et al. (1993) reported that during the summer period of 1992, the wetland had completely dried out (Kagalou et al., 2010).

7) Estuaries of Alfeios River - site 5 (Western Greece): Alfeios is the biggest river of the Peloponnese and the ninth longest river in Greece. It drains an area of almost 2,575 km^2 in Western Peloponnese and discharges at Kiparissiakos Gulf. Due to its extent, the Alfeios basin presents complex physiography and geomorphology (Nikolakopoulos et al., 2007). It

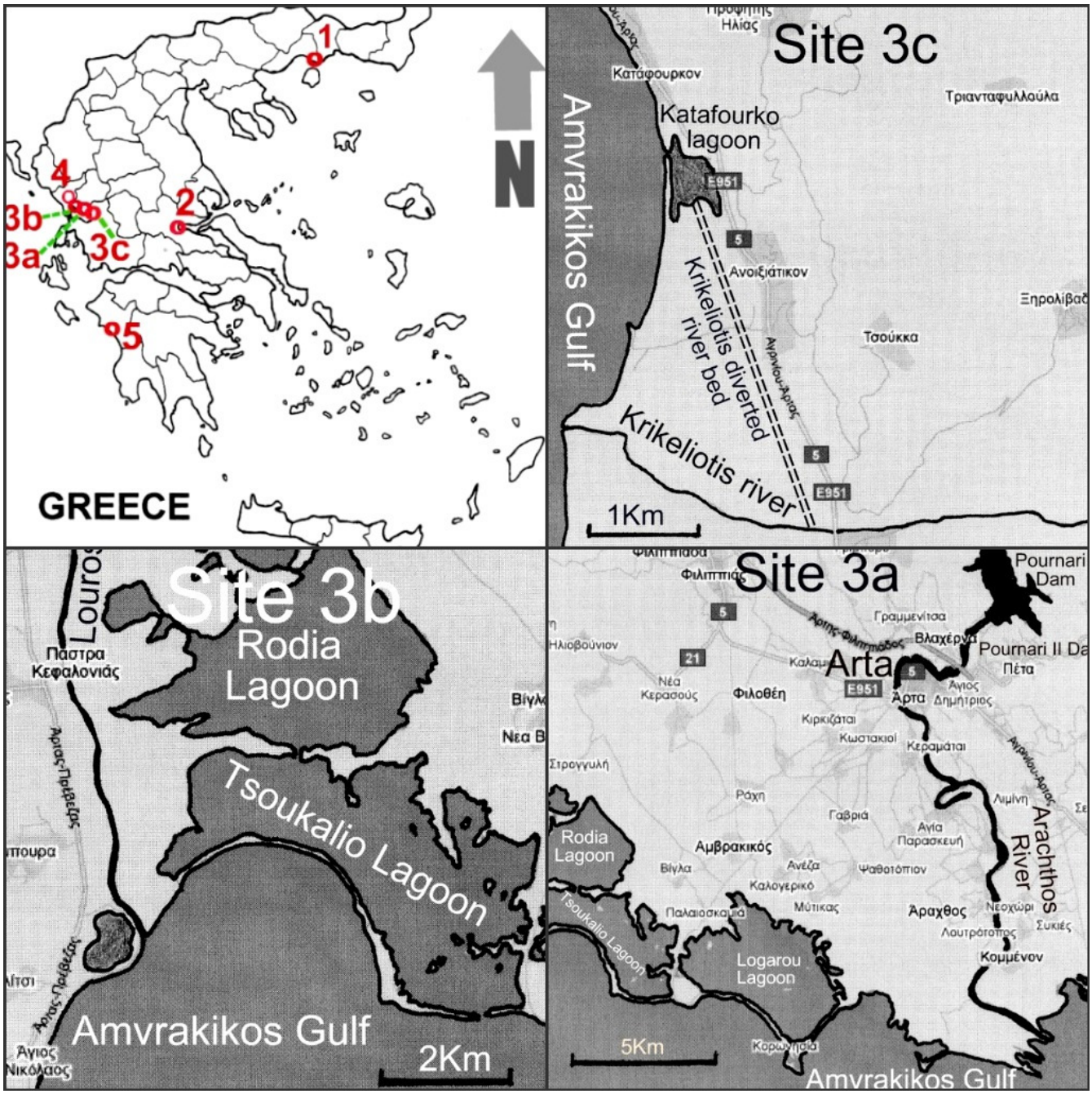

Figure 3. Geographical location of the wetlands under investigation (sites 3a, b and c).

contributes significant amounts of SPM in the lower area of discharge (around 2,500,000 m^3/year) (Argiropoulos, 1960; Ministry of Development, 1996; Ghionis et al., 2004). This site includes the estuaries of Alfeios River to the Kiparissiakos gulf (Ionian Sea), south of the town of Pyrgos, as well as the desiccated lake Agoulinitsa (before the decade of 1970) to the south-east of the Alfeios estuaries in Peloponnesus (Figure 5). On the main river channel of Alfeios has built and operates the irrigation dam “Flokas”, the construction of this dam was completed in 1968. The “Flokas” dam, built at 13 km south-east of the town of Pyrgos. This gravity dam is 10 m high and has a length of 315 m at the dam crest. Since June 2010, the irrigation dam “Flokas”, also served as a hydroelectric power dam. Also, on the river channel of Ladonas, a tributary of Alfeios River, has built and operates the hydroelectric power dam “Ladonas”, during the period 1950 to 1955. The "Ladonas" dam, built at 47

Figure 4. View of Katafourko lagoon (Eastern Amvrakikos Gulf) (Mertzanis, 2010).

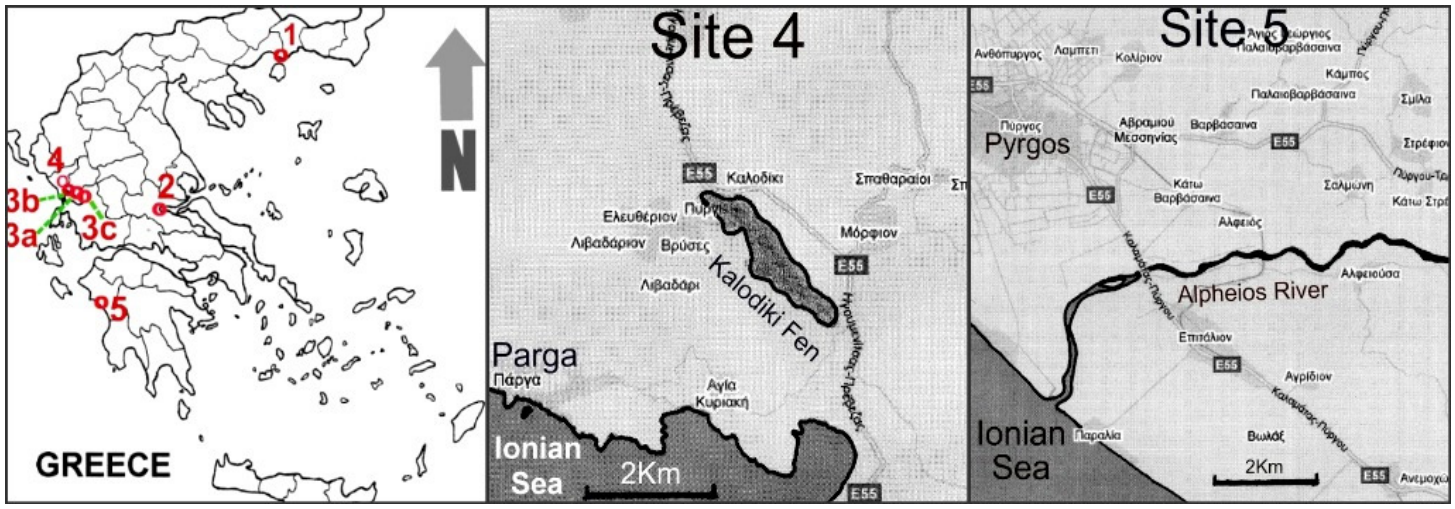

Figure 5. Geographical location of the wetlands under investigation (sites 4 and 5).

km north-east of the town of Pyrgos. This gravity dam is 50 m. high, and the reservoir has a capacity of approximately 46.2 × 10^6 m^3, while the surface of the artificial lake is about 4 km^2 at full supply level and length 8 km.

Environmental protection status

The study areas fall under the "Natura 2000" network, which is a European ecological network of areas that are home to natural habitat types and species habitats that are important at European level (Dafis et al., 1997). It consists of two types of areas: 1) the "Special Protection Areas -SPA-" for the Birds, as defined in Directive 79/409/EC "on the conservation of wild birds" and 2) the "Sites of Community Importance -SCI-" as defined in Council Directive 92/43/EEC of the European Communities "on the preservation of the natural habitats, as well as of the wild fauna and flora". To determine the "Sites of Community Importance -SCI-" taken into account the types of habitats and species in Annexes I and II of Directive 92/43/EEC and the criteria of Annex III. The code numbers of those areas under, which are

Figure 6. View of Kalodiki Fen (Mertzanis, 2005).

included in the Natura 2000 network are: 1) delta of Nestos River (GR 1150001 - SPA and GR 1150010 - SCI). This area is included in the list of Wetlands of International Importance of the Treaty Ramsar, 2) delta of Sperchios River (GR 2440005 - SPA and GR 2440002 - SCI), 3) Gulf of Amvrakikos including delta of Arachthos River, Wetlands and the Estuaries of Louros river and Katafourko lagoon (GR 2110004 - SPA) and only for the deltas of Arachthos and Louros Rivers (GR 2110001 - SCI). The area of Amvrakikos gulf is included in the list of Wetlands of International Importance of the Treaty Ramsar. 4) Fen of Kalodiki (GR 2120006 - SPA and GR 2120002 - SCI) and 5) Estuaries of Alfeios River including dunes and coastal forest of Zacharo, Kaiafa lake, Strofilia and Kakovatos (GR 2330005 - SCI).

The Gulf of Amvrakikos and the Nestos River delta has been termed "National Parks" by the Greek law (Amvrakikos Wetlands National Park, 11989/21 March 2008 Joint Ministerial Decision and Eastern National Park Macedonia-Thrace-Nestos Delta-Vistonida-Ismarida, 4454/17 October 2008 Joint Ministerial Decision) and for the control and management of these ecosystems have been established and operated the "Amvrakikos Wetlands Management Body" and the "Nestos Delta-Vistonida-Ismarida Management Body". The Fen of Kalodiki is under the supervision of "Straits and estuaries Kalama and Acheron Management Body". Specifically, with regard to the protected area of Amvrakikos gulf, which includes the Arachthos River delta, the Estuaries of Louros River and the Katafourko lagoon noted that the area of the Gulf of Amvrakikos is one of the larger wetlands in Greece and also, one of the larger ones in southern Europe. It is characterized by a great diversity of live species and constitutes one of the first wetlands in Greece which were proposed to be under the status of protection and was included in 1971 in the list of International Important wetlands of the Ramsar Treaty. A determinant criterion for the incorporation to this treaty was the number of aquatic birds present in the area and the living conditions of the endangered species. Out of the 11 International Importance wetlands in Greece, the Amvrakikos Gulf is important for the fowl fauna on a European and International interest and is classified amongst the wetlands with the highest registered numbers of aquatic birds, where amongst them some are "rigorously protected species" and are listed in the Appendix I of the Directive 79/409/EC.

In accordance with the Council Directive 92/43/EEC of the European Communities "on the preservation of the natural habitats as well as of the wild fauna and flora" and the Directive 79/409/EC "on the conservation of wild birds" and for the confrontation of environmental issues and for matters of the general management of the Gulf of Amvrakikos, the Greek government has established protection zones of the wetlands of the του Gulf of Amvrakikos, while specific measures are taken for each protection zone (Ministry of the Environment and Urban Planning and Public Works, 1997). As mentioned, the Gulf of Amvrakikos has been termed "National park" by the Greek law (11989/21 March 2008 Joint Ministerial Decision) "Designation of the terrestrial, aquatic and marine areas of the Gulf of Amvrakikos as a National Park and specifications for the uses terms and conditions of it". It is protected by the International Ramsar Treaty

and is included in the ecological network Natura 2000. The wetland of the Amvrakikos is one of the 9 regions of Greece which are included in the Barcelona convention (a convention on the protection of the Mediterranean Sea from pollution) and is protected by virtue of the Berne convention (regarding the conservation of European wildlife and natural habitats) and the Bonn convention (on the conservation of migratory species of the wild fauna).

The purpose of the designation of the Amvrakikos Gulf as a National Park is the protection, preservation and management, of nature and the landscape, as natural inheritance and valuable national natural resource at the terrestrial and aquatic parts of its area, which are of great biological, ecological, aesthetic, scientific, geomorphological and educational value. More specifically, the aim is to preserve and manage the rare habitats and the flora and fauna species and especially the fowl fauna which numbers various and important kinds.

STUDY METHODOLOGY

This study used both secondary and primary data. Secondary data collection involved review of existing reports (unpublished, gray and published reports) from libraries and documentation centers in various institutions in Athens, Thessalonika, Arta, Lamia, Pyrgos and Xanthi. Some reports were also made available through internet search. Secondary information were supplemented by primary data at "wetland unit" level, whereby small meeting were made with the commissions of Arta, Ilia and Fthiotida prefecture and the Executive Director and the Planning Officers of the "Amvrakikos Wetlands Management Body". For the depiction of the condition of the natural environment of the under study wetlands, there were used contemporary and older topographical maps, geological and oceanographic maps, aerial photographs and satellite images (Google Earth, 2010). These aerial photographs and the satellite images were used as a simple comparative assessment of changes in the shoreline of the seven areas under study

The most important of the human interventions and activities (works, constructions, projects) which are in a position to disrupt the environmental balance of the wetlands such as for example, those which constitute the object of this study are (Ghionis et al., 2004; Mertzanis, 1995; Mertzanis and Papadopoulos, 2003; Vavizos and Mertzanis, 2003; Dimopoulos et al., 2005; Efthimiou et al., 2005; Kagalou et al., 2006, 2010; Hellenic Ornithological Society, 2010a, b; Mertzanis et al., 2010b, c) (Table 1):

1. Intensification and development of agriculture - nutrients (pesticides and fertilizers) agricultural run-off transferred by the neighbor cultivations,
2. Fishery, water cultivations,
3. Construction of irrigation canals and drainage pits,
4. Deepening and creation of canals,
5. Construction of drainage - anti flooding protection works,
6. Construction and function of hydroelectric projects (hydroelectric power dams), irrigation dams and water supply dams,
7. Construction of anti-erosion works,
8. Motorway constructions,
9. National road work constructions or improvements on the national road network,
10. Opening up new agricultural and forest roads,
11. Railway line constructions,
12. Infrastructure works,
13. Wood cutting, deforestation,
14. Deforestation of riparian vegetation,
15. Fire wood collection,
16. Grazing in the forest,
17. Industrial activities,
18. Small business activities,
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,
23. Alteration of the physicochemical characteristics - deterioration of the quality of water (salinity, e.t.c.),
24. Embankment - filling of lagoons or lakes with sediment,
25. Exsiccation,
26. Arrangement and redirection of the main beds of rivers,
27. Mining activities (quarries, mines),
28. Sand extraction from river beds,
29. Uncontrolled watering from surface water tables,
30. Uncontrolled pumping of underground waters,
31. Mass touristic activities, recreation,
32. Hunting - poaching,
33. Overgrazing, and
34. All sorts of disturbances to the birds.

For the assessment and the evaluation of the impact and the alterations to the natural environment of the areas under study, as a result of human intervention and especially, to the geomorphological processes (fluvial processes, erosion of the rocks, sediment transport, deposition of suspended load, development of floodplains, coastal sediment and fluvial sediment transport, creation of river deltas, creation of new topographic features - landforms, coastal processes, coastal landforms, beaches, barrier islands, and capes, coastal erosion, etc.), inside and outside the wetlands, have been used aerial photographs from the Hellenic Military Geographical Service (H.M.G.S.). These aerial photographs are of the years 1945, 1960, 1963, 1970, 1972, 1981, 1984, 1985, 1996, 2003 and 2006, on various scales as well as satellite images (Google Earth, 2010), which were combined with data from the systematic *in situ* observations of the evolution of the geomorphological processes (sediment deposition inside the wetlands and the lagoons, erosion of the delta and the coastal zone, etc.) as shown in the pictures attached (Figures 10, 11, 12, and 13).

RESULTS AND DISCUSSION

Threats - burden to the natural environment of the wetlands

The environmental destabilization of the wetlands and especially of the "dynamically" developing areas as far as the geomorphological processes are concerned, is mainly due to certain anthropogenic interventions which alter "critical" parameters of the environment. "Dynamically" developing areas of this kind are the areas of the estuaries and river deltas, coastal valleys, lagoons and fens which are subjected to intense variations as far as the "positive" or "negative" shift of the coast line. This process is defined as "advance" or "regression" depending on the capability of the river to supply the coastal area with sediments or on the inhibition of the

Table 1. Human activities identified in the wetlands under investigation.

S/N	Human activities	Nestos delta	Sperchios delta	Arachthos delta	Estuaries of Louros	Katafourko lagoon	Fen of Kalodiki	Estuaries of Alfeios
1	Intensification and development of agriculture - nutrients (pesticides and fertilizers) agricultural run-off transferred by the neighbor cultivations	●	●	●	●	●	●	●
2	Fishery, water cultivations	●		●	●	●		
3	Construction of irrigation canals and drainage pits	●	●	●	●		●	●
4	Deepening and creation of canals	●	●	●	●			●
5	Construction of drainage - anti flooding protection works	●	●	●	●	●	●	●
6	Construction and function of hydroelectric projects (hydroelectric power dams), irrigation dams and water supply dams	●		●	●			●
7	Construction of anti erosion works	●	●	●				
8	Motorway constructions		●					●
9	National road work constructions or improvements on the national road network		●	●	●	●	●	●
10	Opening up new agricultural and forest roads	●	●	●		●	●	●
11	Railway line constructions		●					
12	Infrastructure works	●	●	●		●		●
13	Wood cutting, deforestation	●						
14	Deforestation of riparian vegetation		●					●
15	Fire wood collection		●					●
16	Grazing in the forest		●					
17	Industrial activities	●	●	●	●			
18	Small business activities	●	●	●	●	●		●
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	●	●	●	●	●	●	●

Table 1. Contd.

23	Alteration of the physicochemical characteristics -deterioration of the quality of water (salinity, e.t.c.)	●	●	●	●	●	●	●
24	Embankment -filling of lagoons or lakes with sediment		●			●		
25	Exsiccation		●	●		●	●	●
26	Arrangement and redirection of the main river channels		●			●		
27	Mining activities (quarries, mines)		●		●			
28	Sand extraction from river beds	●	●	●				●
29	Uncontrolled watering from surface water tables	●	●	●				●
30	Uncontrolled pumping of underground waters	●	●	●	●	●	●	●
31	Mass touristic activities, recreation			●		●		●
32	Hunting - poaching	●		●	●		●	●
33	Overgrazing							
34	All sorts of disturbances to the birds	●	●	●	●	●	●	●

Source: Observations of the study group and various literature sources and existing reports.

supply of the coastal area with sediments, respectively. The phenomena of advance or regression can be attributed to human intervention or natural processes, as well as on the possibility of the deposition of sediments in the area or their withdrawal from it, depending on the geomorphological and oceanographic characteristics of the terrestrial, coastal and marine area. Especially for the delta-lagoon-marine ecosystems, an important element is the rate of supply with water and sediments in the area but also important element is the qualitative data of the earlier mentioned characteristics. It is noted that those interventions that result in the alteration of this dynamic evolution of the geomorphological processes, usually lead to the creation of an “artificial” environment which to a great extent is man controlled, and which in turn 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; Dimopoulos et al., 2005; Kagalou et al., 2006, 2010; Mertzanis et al., 2010a, c).

The impact to the wetlands is reinforced when the coastal zone, the delta or their catchment basin are burdened by human activities with the emission of pollutants or other substances, radiation or noise. This is also the case when in the area there are works or constructions of different kind and size, with no prior consideration of the possibility of the destabilization of the environmental equilibrium and in general of the protection of the natural environment, the wild life and the fowl fauna of the specific area. The most important of these human interventions are engineering works such as channelization (drainage pits and drainage dams, deepening and creation of canals), dam construction (hydro-electric power dams, irrigation dams, water supply dams and small water storage dams), diversion and culverting (arrangement and redirection of river channels), as well as other human interventions and activities (intensification and development of agriculture projects, infra-structure works, embankments, exsiccation, wood cutting, deforestation, deforestation of riparian vegetation, fire wood collection, uncontrolled watering from surface water tables, uncontrolled pumping of underground waters, e.t.c) (Marinos, 1984; Brofas, 1989; Mertzanis, 1992, 1995; Skoullos, 1992; Zalidis and Matzavelas, 1994; Dafis et al., 1997; Ministry of Environment, Urban Development and Public Works, 1997; Mertzanis and Papadopoulos, 2003; Vavizos and Mertzanis, 2003; Ghionis et al., 2004; Manariotis and Yannopoulos, 2004; Efthimiou et al., 2003, 2005; Dimopoulos et al., 2005; Kagalou et al., 2006, 2010; Hellenic Ornithological Society, 2010; Mertzanis et al., 2010b; Sylaios et al., 2010).

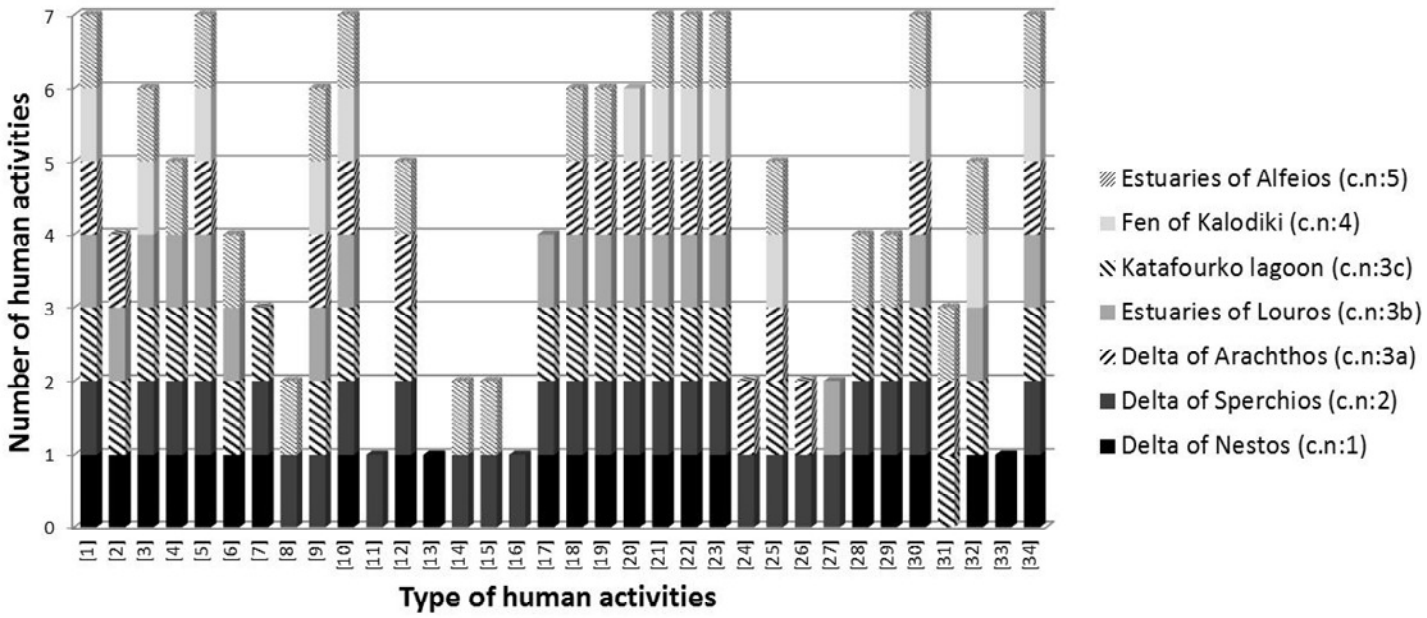

Figure 7. Cumulative chart of different types of human activities identified in the wetlands under investigation.

Figure 7 illustrates the total number and the type of human activities that have been identified in each of the seven study areas. In the delta of the Nestos River (site 1), was found most in number of human activities, while in the area of Kalodiki fen (site 4), fewer.

In order to assess and evaluate the impacts to the environment that result from the construction and operation of a project or an activity, it is necessary to take into account the fact that all human activity as well as the natural phenomena, cause alterations to the environment that are in a position to cause disturbances. The term “disturbance” defines every action or row of actions that cause and affect the structure and the operations of the environment. Whether the alteration becomes disturbance, depends on the kind of natural, chemical, biological or other parameters, which are altered and on the magnitude of their alteration which in turn brings on the events which affect the structure and the operations of the environment. The transformation of “disturbances” into “impacts”, depends on the ability of the environment which is subjected to the disturbances, to restore them. It is underlined that human activities (industrial plant operations, intensification and development of agriculture projects, etc.) can cause environmental impacts not only as a result of the emission of pollutants (disposal of industrial wastewaters, disposal of hazardous waste aerosols, agricultural wastes -pesticides and fertilizers-agricultural run-off transferred by the neighbor cultivations, etc.), but just as a result of their presence (US-EPA, 1997; US-EPA, 1999; C.E.C., 1999; Vavizos and Mertzanis, 2003). The impact to the wetlands environment as a result of human activities.

The intensification of human interventions, especially after the decade of 1950, in the coastal zone and the delta and in the catchment basin of some wetlands, in Greece, that are found at the Nestos, Sperchios, Arachthos River delta and the estuaries of Louros River and Alfeios River as well as of the fen of Kalodiki and Katafourko lagoon, have affected the natural ecosystems one way or another and to a different extent, depending on the type, the size and the operation and the location of the intervention or activities (Figure 2). Following that, we refer to the most important alterations-impacts- that are noted or are expected to be noted to the wetlands under investigation, while for every separate kind (type, parameter), is given the “Name” of the wetland which show or is expected to show these impacts, which are (Tables 2, 3, 4 and 5):

1) Alterations to the fauna, the flora and the natural ecosystems,
2) Landscape changes,
3) Alterations to the surface and underground waters, and
4) Alterations of geomorphological processes (Marinos, 1984; Brofas, 1989; Mertzanis, 1992, 1995; Skoullos, 1992; Zalidis and Matzavelas, 1994; Dafis et al., 1997; Ministry of Environment, Urban Development and Public Works, 1997; Mertzanis and Papadopoulos, 2003; Vavizos and Mertzanis, 2003; Efthimiou et al., 2003, 2005; Ghionis et al., 2004; Manariotis and Yannopoulos, 2004; Dimopoulos et al., 2005; Kagalou et al., 2006, 2010; Hellenic Ornithological Society, 2010; Mertzanis et al., 2010b; Sylaios et al., 2010). We note in more detail

Table 2. Ranking of different impacts/threats on the fauna, the flora and the natural ecosystems due to human activities.

Established impacts/threats	Nestos delta	Sperchios delta	Arachthos delta	Estuaries of Louros	Katafourko lagoon	Fen of Kalodiki	Estuaries of Alfeios
Alterations to the flora and especially decrease of the natural riparian vegetation	●	●	●	●	●	●	●
Diminished bio diversity of the ecosystems	●	●	●	●	●	●	●
Alterations in the flora, the fauna and the natural ecosystems - Shrinkage of the riverside forests and of the wetlands		●			●		●
Creation of new riparian ecosystems in the new river bed and the new mouth		●			●		

Source: Observations of the study group and various literature sources and existing reports.

Table 3. Ranking of different impacts/threats to the landscape due to human activities.

Established impacts/threats	Nestos delta	Sperchios delta	Arachthos delta	Estuaries of Louros	Katafourko lagoon	Fen of Kalodiki	Estuaries of Alfeios
Alteration in the morphology of the relief - partial destruction of the natural characteristics of the relief (vegetation and hilly formations)		●					
Alteration of the optical characteristics of the natural landscape, that is its lines, the texture and color	●	●	●	●	●	●	●
Formation of an artificial - anthropogenic- type of environment with a dense network of roads, agricultural and forest roads in combination with irrigation and drainage canals and embankments	●	●	●	●	●	●	●

Source: Observations of the study group and various literature sources and existing reports.

the threats-impacts- by human activities on the wetlands of interest.

Nestos River delta (site 1)

a) Impact on the Nestos River network shape, on the valley floor morphology, and of the delta due to hydroelectric power dams, irrigation and water supply dams (Thissavros and Platanovrissi) (Psilovikos et al., 1986; Mertzanis, 1992, 1995; Mertzanis and Papadopoulos, 2003; Efthimiou et al., 2003) (Figure 8).

b) Disruption of the transport-deposition of SPM from Nestos drainage basin, towards the downstream from the hydroelectric power dams (Thissavros and Platanovrissi), in the delta, the estuaries and the coastal zone. The SPM are deposited into the artificial lakes of Thissavros and Platanovrissi and so, the deltaic plain, and the coastal zone, are deprived of a significant amount of sediments. It is noted that the deltas of the rivers owe their existence to the deposition of the SPM that are transferred from the upstream drainage water basins, while they constitute dynamic systems, which develop with great speed (Mertzanis, 1992, 1995; Mertzanis and Papadopoulos,

Table 4. Ranking of different impacts/threats to the surface and underground waters due to human activities.

Established impacts/threats	Nestos delta	Sperchios delta	Arachthos delta	Estuaries of Louros	Katafourko lagoon	Fen of Kalodiki	Estuaries of Alfeios
Lowering of the level of the underground waters	●	●	●		●	●	●
Alterations to the surface and underground waters - creation of a situation of extreme supplies with undefined alternations of the artificial phases of flood - dryness	●		●				●
Absence of the naturally expected periodical over flooding incidences of the beds of the rivers, flooding of the Delta and estuaries area as well as the supply of the lagoon system, with water from the rivers	●		●				●
Confinement - deprivation of fresh waters to the estuaries - alteration of the physicochemical characteristics and especially the increase of the salinity of the waters	●	●	●		●		●
Confinement - deprivation of fresh waters to the lagoons - alteration of the physicochemical characteristics and especially the increase of the salinity of the waters	●	●	●				●
Penetration of sea water (salinisation) into the bed of the rivers, at a small distance from their estuaries to the sea, during the dry seasons or during limited river supplies	●	●	●		●		●
Alterations to the qualitative characteristics of the surface and underground waters	●	●	●	●	●	●	●
Disruption of the movement of the surface layer of the underground water supply and of those flooding waters which are found on the ground surface.		●					●

Source: Observations of the study group and various literature sources and existing reports.

2003; Efthimiou et al., 2003). In this site, from the year 1945 onwards, a period in time where we see the early human interferences in the area (drainage and irrigation canals), and up until 1983, the geomorphological conditions in the drainage basin and the Nestos delta are altered. The artificial diversion to the east by 4 km of the Nestos River channel and the realignment of the lowest course of the river, brought about erosion phenomena in a part of the Nestos river in the west (Akroneri area), and these sediments are moved west-northwest along with the waves and the coastal currents (Psilovikos et al., 1986). After the completion of the hydroelectric works

Table 5. Ranking of different impacts/threats on geomorphological processes due to human activities.

Established impacts /threats	Nestos delta	Sperchios delta	Arachthos delta	Estuaries of Louros	Katafourko lagoon	Fen of Kalodiki	Estuaries of Alfeios
Changes at erosion phenomena of the river basins and at the movement-deposition of SPM	●	●	●	●	●		●
Disruption of the face, morphology of the river basins	●		●	●			●
Deposition of sediments into the artificial lakes	●		●	●			●
Disruption of the face, morphology of the Deltas	●		●				●
Creation of destabilization processes of the dynamic of the coastal area	●	●	●		●		●
Decrease of the rate of the advance of the coastline at the Delta and at the coastal zone - regression tendency	●	●	●		●		●
Creation of new Delta - advance of the coastline		●					
Shrinkage of lakes or lagoons - total or partial exsiccation						●	●
Banking up - filling of lakes or lagoons with sediment - shrinkage					●		

Source: Observations of the study group and various literature sources and existing reports

(Thissavros and Platanovrissi hydroelectric power dams) along the main river course, the SPM are deposited in the reservoirs of the dams. It is estimated that the estuaries are deprived of about 2,600,000 m^3 per year of SPM and this has resulted in the appearance of local phenomena of erosion and regression of the coast line in certain areas of the coastal zone (Margoni and Psilovikos, 2010; Sylaios et al., 2010). This situation is expected to worsen in the near future, if the necessary measures to avert the phenomena of “erosion” and “desertification” of the coastal zones are not taken.

c) Alterations in the geomorphological processes following the extraction of fine and coarse sand volumes from the river beds which respectively affect the water bodies of the area, the hydraulics of the rivers, as well as the supply of sediments of the coastal area, resulting in the further deprivation of the SPM at the estuaries and the deltas and the occurrence of local phenomena of regression of the coast line. d) Degradation of surface and underground water quality due to the creation of a situation of extreme supplies with undefined alternations of the artificial phases of flood-dryness due to the irregular working hours of the hydroelectric power plant at Thissavros, Platanovrissi which working hours depend upon the demand of power of the national network (Efthimiou et al., 2003; Sylaios et al., 2010).

e) Absence of the naturally expected periodical over flooding incidences of the river channel in the delta and estuaries area, as well as the supply of the lagoon system, with water from the rivers due to the anti- flooding embankments which have been constructed in their banks, downstream. The result of the confinement of fresh waters to the lagoon and the estuary areas is the alteration of their physicochemical characteristics and especially the increase of their salinity (Sylaios et al., 2010).

Sperchios River delta (site 2)

a) Creation of destabilization processes in the coastal zone that are due to the partial diversion to the north of the main river channel of the Sperchios River. The result of this diversion is the creation of a new delta in the area of the new site of the estuaries to the Maliakos gulf, while there were created new destabilization processes of the dynamic of the coastal area and a set back of the rate of advance of the coast line towards the

Figure 8. View of the artificial lake of Thissavros dam, on the Nestos main river channel– Landscape changes in the Nestos River due to hydroelectric power dam (Mertzanis, 2010).

sea, in the old position of estuary (old delta) or even the creation of regression conditions of the coast line in this site (Krestenitis et al., 2000; Psomiadis et al., 2005; Sigalos and Alexouli-Livaditi, 2006a, b; Vouvalidis et al., 2010) (Figure 9).

b) Alterations due to the construction of both, the old national road of Athens - Lamia before the decade of 1950, the new motorway and the "new railroad". More detailed, in the greater part of this site, the road axis and the new railroad, at the section Thermopylae to Anthili, passes over an embankment of about 5 to 10 m high. An exception to that is the case of the sections where bridges are used, which are the cases of some rivers (Latzorema, Potamia, etc), as well as the Sperchios River from a position 201+200 km, up until 201+300 km. Also, the motorway passes through a bridge of approximately 1,000 m long, over the new railroad track under construction from a position of 202+800 km, up until 203+900 km. The presence of these embankments at least for the section from Thermopilae to Anthili disrupts the possibility of transfer and deposition of SPM from the parts upstream of the water currents and especially from the Sperchios River in the lower deltaic plain.

Despite the intense torrential character and the great solid dragging ability of the Sperchios River, the supply to the deltaic plain of the water current to the Maliakos gulf actually occurs only through the main stream of outflow and the newly formed bed of Sperchios River, while the rest of the lower banking up area downstream of the motorway, towards the Maliakos gulf, does not, as it would be expected, receive in its entirety flooding waters and sediments. Important elements of the final form of the deltaic plain are the drainage basins and the hydrographic network that supply the Sperchios River with water and sediments. These SPM are transported through the river bed, are deposited in it and bank up both the new and old river channels, thus resulting in the containment of its size and its supplying capabilities and furthermore in the presence of flooding incidences upstream of the new motorway. A characteristic example of this is the recent flooding in February 2010, which is attributed to the construction works of the new motorway and the new railroad in the area of Moshohorio in Fthiotida. Often, Sperchios River overflows at the delta and in this way the main flow of its river channel is changed, even though it remains in the southern part of the valley of the river. In 1889, as a result of the disruption of the natural bund, we had the last diversion of flow of the Sperchios River. Also, after 1957 begun the illuviation of a large area of the shallow part north to the present river channel, due to the construction of an overflow channel.

Already, ever since the ancient times (480 B.C) the shift of the coastline and the delta to the east comes to 8-10 km, while the well known historical site of the "narrow passage of Thermopilae" where according to references the sea line was up to the present monument of Leonidas in the old national road Athens - Lamia (Tziavos, 1977; Anagnostou and Tziavos, 1977; Zamani and Maroukian, 1979, 1980; Maroukian and Pavlopoulos, 1995; Psomiadis et al., 2005; Vouvalidis et al., 2010). Kotoulas (1988) studied the evolution of the river delta during 1943 to 1971 and came to the conclusion that the overall size of the delta has increased in these 28 years by 6.62 km^2, which corresponds to 0.236 km^2/year. More

Figure 9. View of Sperchios River delta; has distinguished the new delta, after the partial diversion to the north of the main river channel (Mertzanis, 2009).

specifically, in the diverted river bed, where the delta has increased by 4.0 km^2, which corresponds to 0.33 km^2/year. The aforementioned demonstrates explicitly the great transfer of SPM by the Sperchios River and their deposition into the delta and coastal areas. Also, indicative of the transferring activity of the Sperchios River is the fact that during 1958 to 1970, that is, a duration of 12 years, in the main river channel alone there were deposited 310,000 m^3 of sediments. Over the same period, the river delta in the area of the diverted river channel moved towards the sea 2 km, that is by 160 m/year while the bottom of the sea at a distance of 1.020 m from the delta was limited to only 0.80 m (Kotoulas, 1988). It is noted that the SPM consist an important source of supply of nutrients and organisms that thrive in the deltas which are complicated systems of very fragile balance. The benthic organisms transfer energy from the precipitant and the producers to consumers higher up in the food chain (fishes, birds) and in this way they significantly contribute to the food chain and to the high productivity of the ecosystem.

c) Alterations in the geomorphological processes following the extraction of fine and coarse sand volumes from the river channels which respectively affect the water bodies of the area, the hydraulics of the rivers, as well as the supply of sediments of the coastal area, resulting in the further deprivation of the SPM at the estuaries and the deltas and the occurrence of local phenomena of regression of the coast line.

d) Degradation of surface and underground water quality due which have to do with the partial diversion to the north of the main bed of the Sperchios River, the deprivation of fresh water at the old delta and the increased water supply of the area of the new delta in the location of the new site of its estuary at the gulf of Maliakos (site 2). These alterations are also related to the construction of both the old National Road of Athens - Lamia before the decade of 1950 and the new motorway which act as a barrier and disrupts the movement of the surface layer of the underground water supply and of those flooding waters which are found on the ground surface. These are waters which result from floods downstream of the plain of the Sperchios River and the delta area.

e) Alterations to the flora and especially decrease of the natural riparian vegetation as a result of the development of “agricultural cultivations”. A consequence of the destruction of the riparian vegetation is the diminished biodiversity of the ecosystems, while at the same time the indirect benefits of its existence are diminished.

f) Alterations in the fauna and the natural ecosystems from the continuously increasing “intensification of agricultural cultivations”, the “use of pesticides and fertilizers”, the “over pumping of surface and underground

waters" and the "uncontrolled irrigations" which accumulatively burden the natural ecosystems and endanger the fauna and the quality of the surface and underground waters.

g) Alterations in the flora, the fauna and the natural ecosystems due to "the construction of the motorway or national roads" and "the construction of railroad", which mainly result in the shrinkage or the takeover of part of the riverside forest as well as of the wetlands and especially the wetlands such as those of the protected area in the banks and the delta of River Sperchios which is part of the Natura 2000 network and consists a "Site of Community Interest (SCI)" (GR2440002) and "Special Protection Area" (GR2440005), which has also been recognized as the natural habitat Corine (AG0010047), while severe loss of high yield cultivated land is observed (Zalidis and Matzavelas, 1994; Dafis et al., 1997; Mertzanis et al., 2010b). These impacts are due to the creation of a wide and elongated zone which is occupied by the "new motorway" and the new "railroad" and from which the vegetation is removed and replaced by asphalt and by soil at the slopes of the excavations and the embankments. Another important fact for the alterations in the flora the fauna and the natural ecosystems of the site 2, is the partial diversion to the north of the main bed of the Sperchios River. Due to this diversion of the Sperchios River, a new delta was formed in the area of the new site of the estuary of the river to the Maliakos gulf, the defense mechanism of the river was activated and this resulted in the creation of new riparian ecosystems in the new river bed and in its new estuaries, while in the area of the old "inactive" now riverbed, new species settled in (Efthimiou et al., 2005).

h) Alterations to the landscape due to the "construction of the new motorway" and new "railroad", which causes a differentiation in the morphology of the relief which now shows part destruction of its natural characteristics, such as its vegetation and the hilly formations. The change is accompanied by the alteration of the optical characteristics of its natural landscape, that is its lines, the texture and color and their replacement by new optical characters with intense anthropogenic characteristics, that is intense colors, geometrical lines and shapes, differentiated texture and volumes that are eminent in the area due to the removal of volumes from the excavation sites and the deposition of the excavation material, in order to form banks (Brofas, 1989; Vavizos and Mertzanis, 2003).

Arachthos River delta (site 3a)

a) Impact on the Arachthos River network shape, on the valley floor morphology, and of the delta due to hydroelectric power dams, irrigation and water supply dams (Pournari I and II). Arachthos riverbed has presented vertical and horizontal (lateral) erosion and significant changes to its network shape (Tziavos, 1989; Mertzanis, 1992; Poulos and Chronis, 1997; Kapsimalis et al., 2005; Poulos et al., 2005, 2008).

b) Disruption of the transport-deposition of SPM from Arachthos drainage basin, towards the downstream from the hydroelectric power dams (Pournari I and II) in the delta, the estuaries and the coastal zone. The SPM are deposited into the artificial lakes of Pournari I and II and so, the floodplain area, the delta and the coastal zone, are deprived of a significant amount of sediments.

c) Decrease of the rate of the advance of the coastline at the delta and the estuaries and at some positions an evidence of regression tendency. More specifically, after studying the temporal evolution of the coastal area and of the Arachthos River delta, one can see the overall tendency of the sand barriers to shrink, and a tendency of regression of the coast line to the west part of its estuaries until Koronisia, with the exception of the occurrence of some local phenomena of advance at the mouth of the river (Kapsimalis et al., 2005). This general tendency of regression follows the deprivation of some volume of sediment from the area (around 2,900,000 m^3/year), due to the Pournari I hydroelectric power dam, but it is also due to the natural and artificial movement of the delta towards the east (Coronelli, 1690; Tziavos, 1989; Mertzanis, 1992; Poulos and Chronis, 1997; Kapsimalis et al., 2005; Poulos et al., 2005, 2008; Papadopoulou and Vriniotis, 2007). In the case of the Arachthos River, measurements undertaken in 1982, after the operation of the Pournari I dam, located only 19 km from the river mouth, which blocked of the 98% of its total catchment area, revealed a reduction in 28% in the mean annual water discharge (Marinos, 1984; Poulos et al., 2005, 2008). It is noted that historical charts of the Amvrakikos gulf confirm that the Arachthos River was discharging at Paleobouka at least from the 17th century A.D. to the end of the 19th century (Coronelli, 1690). Since the beginning of the 20th century, the mouth shifted to its present position.

During the last 50 years, human intervention on the deltaic plain, such as artificial diversion and realignment of the lowest course of the Arachthos River, wetlands draining, development of an extended irrigated network, and construction of dams along the main river course, has affected to a great extent the sediment supply, and therefore, the present day sedimentation patterns (Kapsimalis et al., 2005). This tendency, for at least as far as the part of the sand barrier which connects Koronisia with Fidokastro (Logarou and Tsoukalio lagoons) is concerned, has been set back in the last 20 years when its largest part was converted to a road with the necessary coastal protection works along the shoreline (rock armour, riprap, etc.) (Mertzanis, 1992; Mertzanis and Papadopoulos, 2003) (Figure 10). That erosion phenomena of the coastal zone due to human activities, are evidence in the aerial photographs of the years 1960, 1985 and 1996 where, in the Arachthos

Figure 10. Thin sand barrier between Logarou lagoon and Amvrakikos Gulf; has distinguished the coastal protection works along the shoreline (rock armour, riprap, etc.) (Mertzanis, 2011).

River mouth, the local regression phenomena of the coast line has reached about 50 m, for the period from 1960 to 1996. Also, local phenomena of sediment deposition, along the shoreline and of advance of the coastline are observed in the west and east of the mouth of Arachthos River to the gulf of Amvrakikos. This advance was mainly due to the supply of the coastal zone with SPM derived from erosion of the riverbed and the banks of Arachthos River, downstream of the hydroelectric power dams “Pournari I and II”, during the operation of the dams and of the power plants. The SPM despite the small quantity, shipped directly to the mouth of Arachthos River, without "losses" because of embankment built on the banks of that river.

d) Degradation of surface and underground water quality due to the creation of a situation of extreme supplies with undefined alternations of the artificial phases of flood-dryness due to the irregular working hours of the Hydroelectric Power Plant at Pournari I, which working hours depend upon the demand of power of the national network (Marinos, 1984).

e) Absence of the naturally expected periodical over flooding incidences of the river channel in the delta and estuaries area, as well as the supply of the lagoon system, with water from the rivers due to the anti-flooding embankments which have been constructed in their banks, downstream. The result of the confinement of fresh waters to the lagoon and the estuary areas is the alteration of their physicochemical characteristics and especially the increase of their salinity (Skoullos, 1992).

f) Penetration of sea water into the river channel, at a small distance from the mouth to the sea, during the dry seasons or during limited river supplies due to the operation of the hydroelectric power dams which is combined with the appearance of sea water intrusion (salinisation) phenomena of at least the waterside well water supply, at a small distance from the coast. It is also noted that at even natural conditions, we observe an increased salinity in the waters of the River Arachthos which is attributed to the presence of Triassic subsurface evaporates in its drainage basin in the area of Monolithi, Ioannina (Mertzanis, 1992; Mertzanis and Papadopoulos, 2003).

g) Alterations in the geomorphological processes following the extraction of fine and coarse sand volumes from the river beds which respectively affect the water bodies of the area, the hydraulics of the rivers, as well as the supply of sediments of the coastal area, resulting in the further deprivation of the SPM, at the estuaries and the deltas and the occurrence of local phenomena of regression of the coast line.

h) Alterations in the fauna and the natural ecosystems from the continuously increasing “intensification of agricultural cultivations”, the “use of pesticides and fertilizers”, the “over pumping of surface and underground waters” and the “uncontrolled irrigations” which accumulatively burden the natural ecosystems and endanger the fauna and the quality of the surface and underground waters.

i) Direct threat to the local fauna, especially migratory birds, due to hunting and shooting (Kagalou et al., 2006, 2010). These threats are facilitated by the presence of extensive road network.

j) Threats in the local fauna, especially migratory birds, due to human presence and his several activities in the area. A particular problem is the diminished reproduction of the population of the *Pelecanus crispus*, which constitutes a “globally endangered species” and which has abandoned its greater nesting area which is the area of Kamakia of the lagoon of Logarou in the Amvrakikos

gulf (site 3a). According to the Hellenic Ornithological Society (2010a), the abandoning of these traditional places of nesting in the lagoon of Logarou, is mainly attributed to the extreme disturbance to the *P. crispus* from the fishermen of the "Fishing Association", while the eviction of the species from their safe habitat, may result in the extremely high possibility of its reproductive failure this year.

Estuaries of Louros River (site 3b)

a) Impact on the Louros River network shape and on the valley floor morphology due to hydroelectric power dam (Louros) (Mertzanis, 1992; Poulos and Chronis, 1997; Kapsimalis et al., 2005; Poulos et al., 2005, 2008).
b) Alterations in geomorphological processes which are due to the disruption of the morphology of the relief of Louros River drainage basin, due to hydroelectric power dam (Louros), which result to changes at erosion phenomena of the river basin and at the transport-deposition of SPM. Changes in the delta and the coastline are negligible because of the limestone composition of geological substrate in the Louros drainage basin and low SPM production. Despite the construction of the Louros dam (in 1954) in the Louros River (up-dam area: 43%) the sediment load of the river has not changed significantly, due to its initially low sediment load (Poulos et al., 2005, 2008).
c) Alterations in the fauna and the natural ecosystems from the continuously increasing "intensification of agricultural cultivations", the "use of pesticides and fertilizers", the "over pumping of surface and underground waters" and the "uncontrolled irrigations" which accumulatively burden the natural ecosystems and endanger the fauna and the quality of the surface and underground waters.
d) Direct threat to the local fauna, especially migratory birds, due to hunting and shooting (Kagalou et al., 2006, 2010). These threats are facilitated by the presence of extensive road network.

Katafourko lagoon (site 3c)

a) Alterations due to the artificial diversion of the river channel of the Krikeliotis River into the wetland of the Katafourko lagoon, as well as the construction of ports (fishing shelters). More detailed, the extremely fragile and "protected" ecosystem of the Katafourko lagoon, ever since August 1959 and until nowadays is flooded by the water of the Krikeliotis River and at the same time is filled from the SPM from this river. The creation of new artificial geomorphological processes due to the artificial diversion of the Krikeliotis River channel, which has altered the geomorphological processes and landscape of the study area, and this has resulted in the shrinkage of the area of the lagoon and especially of its water pane which has assumed an area of less than 500,000 m^2 as opposed to the 2,500,000 m^2 that it occupied in the year 1945. At the same time in the coastal zone, have been generated conditions of erosion of the coastal zone and regression of the coast line, due to the drawing away of the estuaries of the Krikeliotis River from the eastern Amvrakikos gulf and as a consequence the deprivation of the coast from SPM (Piper et al., 1982; Anastasakis and Mertzanis, 1987; Mertzanis, 1992; Mertzanis et al., 2010a) (Figures 11 and 12). More specifically, before 1945, the outfall of Krikeliotis River entered the Amvrakikos gulf in a trapezoidal formation and without any secondary branches. North of the 1945 outfall, we can spot an older bed of the Krikeliotis River. The presence, in the map of the Hellenic Navy Hydrographic Service of the year 1920, of an acute protuberance of the coastline in the area of its and of the old bed, which cannot be seen in the aerial photographs of the year 1945, supports the view of the presence of an "old bed" rather than of the presence of a "catastrophic channel", a fact meaning permanent or at least of prolonged duration, supply of sediment at the outfall of the river. Aerial photographs of 1945, show an important coastal sediment movement to the north of the outfall which is diminished as we move away from the outfall of the Krikeliotis River. Aerial photographs of 1960, one year after the artificial diversion of the bed of the Krikeliotis River to the north and the movement of the outfall of the river at the south western part of the lagoon of Katafourko, one observes the generation of a typical "constructive delta" with lobe type ends of the outfall "High constructive lobate" type according to Fisher et al. (1969). In the coastal area, one observes a bend-rise of the north part of the sand barrier in the area of the outfall of the artificial channel inside the lagoon.

In the area of the "front" of the abandoned outfall, the initiation of the erosion activities is observed. In the aerial photographs of 1980 and 1985 is depicted the progressive filling of the lagoon of Katafourko, from the supply of SPM of the Krikeliotis River and the eventual limitation of the "water pane" of the lagoon to 500,000 m^2 from the 2,500,000 m^2 before the year 1945. The length of the sand barrier is limited to less than 1,100 m and its width is seriously diminished towards the north, to a mean width of about 25 m. In the area of the abandoned outfall of the Krikeliotis River, are observed intense phenomena of erosion of the coastal zone and regression of the coast line (Anastasakis and Mertzanis, 1987). Aerial photographs of 2006 and in the recent satellite images is depicted the further shrinkage of the "water pane" of the lagoon of Katafourko, as well as the characteristics of the regressing coastline in the area of the old outfall of the Krikeliotis River which are documented by the form and shape of the coast and also by the presence of "witnessing" trees and residues of roots of bushes at the boundary of the coast line with the

Figure 11. Regressing shoreline in the area south of the old outfall of the Krikelliotis River into the eastern Amvrakikos Gulf.

Figure 12. The regression of the coast line is documented by the form and shape of the coast and also by the presence of “witnessing” trees and residues of roots of bushes at the boundary of the coast line with the sea or in the sea (Mertzanis, 2010).

sea, or in the sea (Figures 11 and 12). The artificial diversion of the Krikeliotis River, apart from the alterations that has caused the geomorphological processes and landscape of the study area and especially the shrinkage of the size of the lagoon, it triggered the “defense mechanism” of the ecosystem, which resulted to the generation of riparian ecosystems at the new river channel and estuaries. In the area of the old “inactive” river channel, the erosion conditions and the regression of the coastline generate “unfavorable” conditions for the preservation of the existing vegetation and for the establishment of new species. It is noted that the SPM constitute an important source of nutritious material and organisms specific to the deltas and the lagoons which are systems of complex and fine balance. The benthic organisms transfer energy from the precipitant and the producers to the consumers higher up in the food chain (fish, birds) and thus contribute significantly to the food chain and the high productivity of the ecosystem. The erosion and regression phenomena of the coastal zone, at least in the northern part of the sand barrier, which separates and “protects” the

Katafourko lagoon from sea action, appear to be enforced due to the inhibition of the natural movement of sediments in the coastal - sea area due to the construction of the fishing station in the last 15 years.

The signs of the intense erosion of the north part of the sand barrier, due to the "entrapment" of the sediments which transported in the coastal area due to the construction of the fishing station on the coast of Eastern Gulf of Amvrakikos and in a distance of 1,370 m north east of the old bed of Krikeliotis River, are evident. From the point of view of environmental balance in the coastal area, these branches of the fishing station as they are compact and positioned across the coast, they work as an obstacle and hinder the transport of the sediments which move with a direction from south to north and under the effect of west-south west waves and coastal currents which move anti clockwise (Piper et al., 1982; Anastasakis and Mertzanis, 1987; Mertzanis, 1992). At the south side of the fishing station accumulates the trapped sediments, while in its north side we can see the development of erosion of the coastline.

b) Alterations in the fauna and the natural ecosystems from the continuous increase of "intensification of agricultural cultivations", the "use of pesticides and fertilizers", and the "over pumping of surface and underground waters" which accumulatively burden the natural ecosystems and endanger the fauna and the quality of the surface and underground waters.

c) Direct threat to the local fauna, especially migratory birds, due to hunting and shooting. These threats are facilitated by the presence of extensive road network.

Kalodiki Fen (site 4)

a) Degradation of the surface and underground waters, by the dumping of waste and other materials. Grazing and arable farming largely influence the area and cause detrimental effects to many animal habitats (due to deforestation, uncontrolled water extraction, alterations in vegetation composition, pollution by the overuse of fertilizers and pesticides, riverbank erosion, etc.). In Kalodiki wetland anthropogenic inputs which show distinct, but variable, concentration peaks, mixing with agricultural runoff and water level fluctuation are primarily responsible for wetland's productivity, in terms of nutrients and chlorophyll-a, leading in a progressive cultural eutrophication. Noted that agricultural run-off transferred by the neighbor cultivations was identified as the main source of the nutrients (Kagalou et al., 2006, 2010). According to the previous studies, Kalodiki wetland has displayed a progressive cultural eutrophication as a result of both water abstraction for domestic and agricultural purposes and landscape alterations. However, the vegetation communities are characteristics for mesotrophic-eutrophic ecosystems (Dimopoulos et al., 2005). Degradation of water quality, as well as issues concerning water quantity and availability have been highlighted by Kagalou et al. (2006).

b) Direct threat to the local fauna, especially migratory birds, due to hunting and shooting (Kagalou et al., 2006, 2010).

Estuaries of Alfeios River (site 5):

a) Alterations of geomorphological processes and landscape change. During the last 50 years, major direct human activities have had an important impact on the river network shape and on the valley floor morphology. The most important human activities were the channel straightening caused by meander cut-offs in 1950, the construction of two dams: the Ladonas dam in 1955 and the Flokas dam in 1968 and the illegal in-stream gravel extraction. As a result, the Alfeios riverbed has presented very rapid vertical and horizontal (lateral) erosion and significant changes to its network shape. The drainage network follows a straighter course, the number of meanders has been reduced and the seventh order branch is deeply incised (Nicholas et al., 1999; Nikolakopoulos et al., 2007). Besides the morphological impacts to the river network shape there are also serious economic damages caused by human activity. During the winter of 1999, the Flokas dam bridge was closed for a long period due to damages at its foundation caused by the heavy rain and illegal gravel extraction. Transportation between the villages in the area became extremely difficult and time consuming and the cost of the repairs was estimated at 500,000 euros (Nikolakopoulos et al., 2007).

b) Disruption of the transport-deposition of SPM from Alfeios drainage basin, towards the downstream from the hydroelectric power dam (Ladonas) and the irrigation dam (Flokas), in the estuaries and the coastal zone. The SPM are deposited into the artificial lakes of Ladonas and Flokas and so, the floodplain area and the coastal zone, are deprived of a significant amount of sediments (Kallinskis, 1957; Nicholas et al., 1999; Nikolakopoulos et al., 2007).

c) Regression tendency of the coastline at the estuaries and at some positions on the coastal zone. This general tendency of regression follows the deprivation of some volume of sediment from the area (around 2,500,000 m^3/year), due to the Ladonas and Flokas hydroelectric power dams, but it is also due to the action of the waves and currents of the sea. The waves on the coast, often reaching a height of over 3.00 m with a maximum height of 6.00 m (Ghionis et al., 2004; Nikolakopoulos et al., 2007).

In the case of the Alfeios River, after the operation of the Ladonas dam (in 1955), were blocked of the 25% of its total catchment area, and after the operation of the Flokas dam (in 1968), located only 12 km from the river

Figure 13. Intense erosion phenomena of the coastal zone - regression of the shoreline (Epitalion in the south-east of the Alfeios river estuaries) (Mertzanis, 2010).

mouth, which blocked of the 97%, revealed a significant reduction in the mean annual water discharge (Ghionis et al., 2004). That geomorphological processes and especially advance or regression of the coastline in the delta area, due to human activities, are evidence in the aerial photographs of the years 1945 (before the construction of the dams), and 1960, 1963, 1972 and 1984 (after the construction of the dams) (Ghionis et al., 2004). Already in 1960 after the operation of Ladonas dam, there is considerable regression of the coastline in relation to the position it had in 1945. The construction and operation of the Flokas dam strongly reinforces the erosion phenomena of the coastal zone and regression of the coastline, due the greater retention of sediments in the artificial lakes of the Ladonas and Flokas dams. In the Alfeios River mouth and at the coastal zone at the north-west (Spiantza) and south-east (Paralia Epitalion), the regression phenomena of the coast line has reached about 25 m, for the period from 1960 to 1984, with severe damage to houses and buildings in some coastal areas (Spiantza, Paralia Epitalion, etc). The speed of the coastline regression is estimated about 1 m/year, and in some places at the north-west coast, exceeds 2 to 3 m/year (Ghionis et al., 2004). The year 2010, the regression of the shoreline in some places has reached about 150 to 200 m (Figure 13).

d) Degradation of surface and underground water quality due to the creation of a situation of extreme supplies with undefined alternations of the artificial phases of flood-dryness due to the irregular working hours of the Hydroelectric Power Plant at Ladonas and Flokas which working hours depend upon the demand of power of the national network (Nicholas et al., 1999; Nikolakopoulos et al., 2007).

e) Absence of the naturally expected periodical over flooding incidences of the river channel in the delta and estuaries area, as well as the supply of the lagoon system, with water from the rivers due to the anti-flooding embankments which have been constructed in their banks, downstream. The result of the confinement of fresh waters to the lagoon and the estuary areas is the alteration of their physicochemical characteristics and especially the increase of their salinity (Nicholas et al., 1999; Nikolakopoulos et al., 2007).

f) Alterations in the geomorphological processes following the extraction of fine and coarse sand volumes from the river beds which respectively affect the water bodies of the area, the hydraulics of the rivers, as well as the supply of sediments of the coastal area, resulting in the further deprivation of the SPM at the estuaries and the deltas and the occurrence of local phenomena of regression of the coast line. This illegal in-stream gravel extraction that started in the 1960s and continues until today (Nicholas et al., 1999; Nikolakopoulos et al., 2007).

g) Alterations to the flora and especially decrease of the natural riparian vegetation as a result of the development of “agricultural cultivations”. A consequence of the destruction of the riparian vegetation is the diminished biodiversity of the ecosystems, while at the same time the indirect benefits of its existence are diminished.

h) Alterations in the fauna and the natural ecosystems from the continuously increasing “intensification of agricultural cultivations”, the “use of pesticides and fertilizers”, the “over pumping of surface and underground waters” and the “uncontrolled irrigations” which accumulatively burden the natural ecosystems and endanger the fauna and the quality of the surface and underground waters.

i) Alterations in the flora, the fauna and the natural ecosystems due to “the construction of the motorway or national roads, which mainly result in the shrinkage or the takeover of part of the riverside forest, as well as of

the wetland.

Conclusions

The intense human activity and the engineering works (hydroelectric power dams, irrigation and water supply dams, diversion of river channels, construction of motorways, national roads, etc) in the delta area and in the drainage basins of the rivers which supply water and sediments to the wetlands of interest, have a negative effect on these natural ecosystems. Especially in the sites 1, 3a and 5 (Nestos, Arachthos and Alfeios), the coastal zone erosion and regression phenomena are the results of the same human activities such as the construction of hydroelectric power dams at the main river channel, which cause reduction of the natural input of sediments in the delta area and the coastal zone. In the site 3c (Katafourko lagoon), the coastal zone erosion and regression phenomena and the shrinkage of the lagoon's "water pane" are the results of the artificial diversion of the Krikeliotis River channel, into the wetland. The destabilization processes in the coastal zone and the creation of a new delta in the Maliakos gulf (site 2), are the results of the partial diversion to the north of the Sperchios main river channel. In the site 4 (Kalodiki Fen), the dumping of waste, the agricultural runoff and water level fluctuation are primarily responsible for the degradation of the water quality and the wetland's productivity, in terms of nutrients and chlorophyll-a, leading in a progressive cultural eutrophication. In the site 3b (Louros), despite the construction of the Louros dam (in 1954) in the Louros River, the sediment load of the river has not changed significantly, due to its initially low sediment load.

Despite the strict legislation and the commitments undertaken by Greek Government, for the protection of these wetlands (Ramsar treaty, etc.), in most cases these human activities are completely or partly uncontrolled.

The proper evaluation of the environmental impacts as a result of the human activities, constitute a useful "tool" to the protection of the natural environment. The impact on the environment is intensified when these activities are: 1) located at "dynamically" developing areas, such as the estuaries, deltas or coastal areas, which are in threshold environmental equilibrium and 2) at positions which can possibly affect directly or indirectly wetlands such as those that exist in investigation areas. The prompt and precise evaluation of the magnitude and duration of these impacts, as well as the capability of reversing them during the stage of planning, constitute, the conditions for the containment of the disturbance to the environment. Another condition for the containment of the impact to the environment due to the implementation of the "development projects" is to take suitable measures and to implement specialized works for the restoration of the environment, which will suit the special conditions of these particular environments.

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