Anthropogenic impact on the environment: the case study of Lake Koronia, Greece

Introduction

The entire area of Lake Koronia is affected from agricultural and industrial activities (mainly in the past) and has suffered severe human impacts. Although it is a Natura 2000 site protected under the EU Birds and Habitats Directives and is listed under the Ramsar Convention, an international treaty for the conservation and sustainable use of natural wetlands, the Lake is affected by heavy water abstraction for irrigation purposes, and is seriously polluted by discharges of nutrients, heavy metals and other pollutants from agricultural activities, industry and towns in the surrounding area (EC Press Release, 2010). As a result of water losses, a continuous shrinking of the lake and degradation of aquifers water level was recorded with the exception of some rainy years (e.g. 2013-2014).

Impacts on the Lake

Fertilization of cultivations and lack of treatment facilities of the villages and local industries operated in the area, had as a result the direct disposal of untreated waste in Lake Koronia or the aquifers of the area, causing degradation to the qualitative characteristics of the water resources (Mattas Ch., et. all, 2016). Lake Koronia was affected by industrial production not only via wastewater discharge but also via alteration of the hydrologic budget of the watershed through groundwater pumping. Industrial operations in the Mygdonia Basin was diverse (fabric making/dying, food products, and clothing manufacturing) with 80% located close to the lake (Tsagarlis G., 1998). The most water-demanding and potentially the most polluting was fabric dying operation.

Some of the results of anthropogenic impacts which have been identified in Koronia Lake are (Kampa E., 2007):

- Eutrophication and anoxic conditions on the lake bottom.
- Decrease of fish population and of habitats suitable for birds and amphibians.
- Reduction of the lake surface by ca. 15 km² until October 1995 (Fig. 1).

Measurements of the physicochemical characteristics of lake’s waters such as specific conductivity, showed an increase from 1300 μS cm^{-1} in 1977 to > 6000 μS cm^{-1}. Increased phosphate concentrations from the late 1970's (8–45 μg/L) to the late 1990's (100–1000 μg/L) indicate that the previously eutrophic system with a limited littoral zone switched to hypertrophy dominated by massive cyanobacteria blooms. Oxygen saturation of the water column increasingly ranged from about 80% in 1983 to full saturation about 1993, after which it decreased progressively to only 20% saturation in 1997. In spite of cyanobacteria dominance, community metabolism of the lake switched from progressively increasing autotrophy to rapidly advancing heterotrophy associated with progressive water-level reduction leading to fish extirpation in the lake (Mitraki Ch. Et all, 2004).

Figure 1: Lake Koronia. The surface of the 4th largest lake in Greece declined progressively in 30 years and its volume and surface area of water was reduced by 80% (Valavanidis Ath,. et all, 2015).

In summary, the environmental problem of Lake Koronia has two dimensions:

− Quantitative, with the progressive decline of the surface and of the depth of the lake from 8 m during the 1960s to less than 1 m by 2001 and

− Qualitative, with the deterioration of the water quality and the classification of the lake from eutrophic to hypertrophic. The Eutrophication of the lake is the reason for the degradation of the whole aquatic ecosystem and brought several other problems such as toxic algal blooms, low transparency, death of fish, minimisation of fish productivity, severe depletion of dissolved oxygen, loss of biodiversity, etc (table 1) (Manakou V., et al, 2008). **As a result, degradation of both quantity and quality of water resources in the basin has an impact on environmental values and wildlife** (Arabatzi-Karra et al., 1996).

Table 1: Wetland treats and their impact (Manakou V., et al, 2008)

Pressures	Consequences
Intensive agricultural activities	
Increase of irrigation drillings	Decrease of water level
Increase of fertilizer and pesticide use	Qualitative degradation of water
Industrial activities	
Industrial effluents	Qualitative degradation of water
Groundwater pumping by industries	Decrease of water level
Urban activities	
Domestic effluents	Qualitative degradation of water
Livestock	
Waste discharge into the lake	Qualitative degradation of water
Overgrazing	Vegetation degradation

The very low species diversity and disturbed local plankton communities caused by the heavy pollution of the Lake, increased invasibility by toxic phytoplankters. Blooms of the established invaders, *P. parvum* in 2004, and *A. fusiformis, A. arnoldii* in 2007 coincided with mass kill of birds and fish (Moustaka-Gouni et al, 2007; MEDWET. www.medwet.org; EKBY press conference 19 September 2007).

Fishing and bathing in the lake are no longer possible; causing a big problem to several hundred families once earned a living by fishing, as Lake Koronia used to be one of the most fish productive lakes in Greece, the source of livelihood for hundreds of families as well as a place for recreation (Birtsas, 2005).

Rescuing Plans – Proposed Measures

After the incident of mass fish kills in 1995, which indicated the environmental collapse of the lake, the Sub-prefecture of Langadas initiated the drafting of a first Rescuing Plan for the lake which was the first effort to describe its environmental problems. The Plan was funded by the EU Cohesion Fund. The Master Plan was drafted in 1998 and its dominant focus was on large-scale technical works. Several of the proposed technical works, and especially a proposed water transfer scheme from the River Aliakmon in western Greece, faced opposition from different parties including the central administration, international institutions and academics. Under pressure from different sources, the Master Plan had to be revised. Revised MP was more open to environmental groups and the broader scientific community. The restoration paradigm proposed was modified favouring "softer" restoration principles instead of hard engineering solutions (Table 2). Funding for the Plan was approved by the Cohesion Fund in 12/2005. In the meantime the Mygdonian basin (including the Koronia subbasin) was designated as a National Wetland Park and a Management Body was set up to coordinate actors involved in its management (Kampa E., 2007).

Table 2: Some of the proposed measures of the revised Master Plan (Zalidis et al., 2004a).

Proposed restoration measures	Proposed works and action
Establishment of wetland and creation of deep water habitats	- Establishment of wetland of a surface of 376 ha with controlled periodic flooding, by constructing a dike on the western side of the lake. This will re-create degraded wetland habitats and contribute to non-point pollution control - Creation of deep water habitats by dredging part of the lake bottom (117 ha) for the reproduction, over-wintering and protection of fish, which in their turn will benefit fish-feeding bird species
Improvement of hydraulic characteristics and reversible operation of the ditch connecting lakes Koronia and Volvi	- Partial transfer to Koronia of 25% of the yearly water flow of two torrents, Scholariou and Lagadikion, normally mouthing into Lake Volvi – this way, the level of Koronia could reach its restoration goal within 6-7 years and the measure is not expected to significantly affect the water balance of Lake Volvi - Reversible operation and hydraulic modification of the ditch connecting Koronia and Volvi – this will strengthen the water potential of the lake and contribute to the progressive rise of the water level. It is not expected that the connection of the two lakes will decrease the water quality of Lake Volvi
Treatment and disposal of urban wastewater and industrial effluents to minimise the inflow of nutrients and toxics into Lake Koronia	- Extension of the UWWTP of Langadas with two additional units to receive and pre-treat effluents from domestic cesspits of small settlements and effluents from cesspits of small industries. Pre-treated effluents will then be further treated in the UWWTP of Langadas
	- System of maturation ponds, where the treated urban wastewater from the UWWTP of Langadas will be mixed with industrial effluents already treated by individual industries. Ponds serve for further treatment to reduce remaining COD and colour (mainly through sedimentation) before the discharge of wastewater and effluents into Lake Koronia
	- Construction of a pumping station for the UWTTP of Langadas and a separate sewerage and stormwater drainage system within the city of Langadas
	- Treatment of saltwater effluents of the dye industries in a central treatment unit and disposal into the sea
	- Construction of sewerage networks and wastewater treatment units (artificial wetlands) for settlements of Kolhiko, Drakontio, Lagyna, Kavalari (proposed measure of secondary priority)
Measures of horizontal support to the revised Master Plan	- Monitoring of management interventions and development of decision support system
	- Actions for public information, awareness and volunteer work
	- Contracting a project management consultant
Application of sustainable agricultural practices	- Agrienvironmetal programme of the Ministry of Agriculture
	- Regulations for the improvement of farming practices
	- Irrigation area stabilization
	- Farmer support measures (Centre for agrienvironmental information and development including office for informing farmers)

The Revised Plan proposes three scenarios for the quantitative and two others for the qualitative rehabilitation of Lake Koronia. Two of the scenarios regarding the quantitative rehabilitation of Lake Koronia are (Malamataris D., et al, 2017):

- *Streams diversion:* Sxolari and Lagkadikia streams drain a wide area in the northern and southern part of the Mygdonia catchment respectively and they outflow to an artificial ditch. Two spillways is proposed, to be constructed before the streams outflow to the ditch in order the 15% of the Sxolari stream discharge and the total discharge of Lagkadikia stream to outflow to lake Koronia.
- *Rehabilitation of the groundwater aquifer:* The wells surrounding the Mpogdanas stream are proposed to be removed and a public irrigation network to be established.

Effectiveness of the proposed measures

Although the revised MP is in place from 2004, to rehabilitate the Lake with many actions partly financed by EU funds, progress proved to be slow. At the recommendation of Environment Commissioner Janez Potočnik, the EC resorted to bring the case to the Court of Justice. Greece is referred to the European Court of Justice for its failure to protect Lake Koronia. It was recognised once more, that lake has been seriously affected by pollution and illegal water extraction, with serious consequences for local fauna and flora (EC Press Release, 2011).

Calculation of the historical (1970-1999) and future (2020-2049, 2070-2099) water balances of Lake Koronia shows negative values for the long-term future period (Table 3) (Malamataris D., et al, 2017). Thus, it seems that implementation of the technical measures that have been proposed in the revised Master Plan for the restoration of the Lake, proved to be inefficient. Climate change, are also expected to further deteriorate the already distributed water balance of the lake, so it is a parameter that it must be taken into account.

Table 3. Historical and future water balance of lake Koronia (Malamataris D., et al, 2017).

	1970-1999	2020-2049	2070-2099
Inflows to lake (hm^3/year)			
Precipitation	20.61	19.76	19.10
Runoff	7.49	11.24	10.48
Outflow from groundwater to lake	0.00	0.00	0.00
Outflows from lake (hm^3/year)			
Evaporation	29.51	30.14	32.39
Recharge to groundwater	0.00	0.00	0.00
Outflow from lake to River Derveni	0.00	0.82	0.61
Water balance (hm^3/year)	**-1.41**	**0.04**	**-3.42**

Suggestions

As the development model in the area of Mygdonia basin, is mainly based on agricultural activities, the restoration of the lake would need a brave shift towards new development activities that are based on the carrying capacity of the whole ecosystem. Solutions should be built taking advantage of the main strengths of the area such as the natural landscape, human resources and crops compatible with the climate and the soil (Malamataris D., et al, 2017).

For example:

- Cultivation of heat-tolerant and less water intensive crops and
- Improvements in irrigation techniques

Finally, monitoring of phytoplankton species richness, composition, blooms of toxic, invading and sediment “seed bank” species winners and available species pool should become a target in itself by the management authorities for its restoration (Moustaka-Gouni, M., 2012).

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