

The present study has been prepared in the framework of the DAC project entitled “Assessment of the degree of expression of the functions and values of the transboundary Lake Doiran” which is funded by the Hellenic Ministry of Foreign Affairs within the framework of the Bilateral Development Aid Programme, (DAC).

*This document may be cited as follows:*

Katsavouni Sotiria and Svetozar Petkovski (editors). 2004. Lake Doiran-An overview of the current situation. Greek Biotope/Wetland Centre (EKBY), Society for the Investigation and Conservation of Biodiversity and the Sustainable Development of Natural Ecosystems (BIOECO).Thermi, 117 p.

## **PROJECT TEAM**

### **EKBY**

Manolis Anastasiadis

Lena Hatziordanou

Sotiria Katsavouni

Eleni Mihalatou

Dimitris Papadimos

### **BIOECO**

Svetozar Petkovski

Vesna Sidorovska

Darrell Smith

Vladimir Stavric

Vasil Anastasovski

Pene Penev

Josif Milevski

Aleksandar Trendafilov

Pece Ristevski

# C O N T E N T S

	p.
<b>LIST OF TABLES</b>	
<b>LIST OF FIGURES</b>	
<b>INTRODUCTION</b>	1
<b>1. GENERAL DESCRIPTION OF THE STUDY AREA</b>	2
<b>1.1. Location – Boundaries – Surface Area</b>	2
<b>1.2. Physical morphology</b>	3
<b>1.3. Protection status</b>	4
<b>2. NATURAL ENVIRONMENT</b>	7
<b>2.1. Abiotic characteristics</b>	7
<b>2.1.1. Climate</b>	7
2.1.1.1. Rainfall	8
2.1.1.2. Temperature	9
2.1.1.3. Relative humidity	10
2.1.1.4. Winds and wind speed	10
2.1.1.5. Sunlight	11
2.1.1.6. Evapotranspiration	12
2.1.1.7. Type of climate	13
<b>2.1.2. Geology - Geomorphology</b>	15
2.1.2.1. Geological features	15
2.1.2.2. Seismic activity and earthquake hazard	17
2.1.2.3. Summary of hydro-geological investigations	17
2.1.2.4. Permeable rock types and their hydro-geological characteristics - aquifers	18

2.1.2.5.	Groundwater monitoring and data collection	20
2.1.2.6.	Assessment of groundwater depletion and pollution problems	20
<b>2.1.3.</b>	<b>Hydrology</b>	21
2.1.3.1.	Water budget	21
2.1.3.1.1.	Characteristics of the Lake Doiran catchment area	21
2.1.3.1.2.	Physical features of Lake Doiran	22
2.1.3.1.3.	Historic seasonal water level variations	26
2.1.3.1.4.	Groundwater regime	30
2.1.3.1.5.	Mutual relationship between ground- and lacustrine waters	30
2.1.3.1.6.	Groundwater use	31
2.1.3.1.7.	Interaction between surface and groundwater and overall water balance	32
2.1.3.2.	Water quality	33
2.1.3.2.1.	Major chemical constituents	36
2.1.3.2.2.	Point-source pollutants	48
2.1.3.3.	Sediments of the lake	48
<b>2.1.4.</b>	<b>Soils</b>	50
<b>2.2.</b>	<b>Biotic characteristics</b>	53
<b>2.2.1.</b>	<b>Vegetation - Habitats</b>	55
<b>2.2.2.</b>	<b>Flora</b>	56
<b>2.2.3.</b>	<b>Fauna</b>	59
2.2.3.1.	Endemic taxa within Lake Doiran and vicinity	66
2.2.3.1.1.	Endemic taxa of Lake Doiran	66
2.2.3.1.2.	Endemic taxa of the Doiran Valley	68
2.2.3.2.	The zooplankton of Lake Doiran	69
2.2.3.3.	The benthos of Lake Doiran	70
<b>3.</b>	<b>AGRONOMIC AND SOCIO-ECONOMIC DATA IN THE STUDY AREA</b>	71

<b>3.1.</b>	<b>Population</b>	<b>71</b>
<b>3.2.</b>	<b>Land use – Ownership around the lake</b>	<b>75</b>
<b>3.3.</b>	<b>Crop farming</b>	<b>76</b>
<b>3.4.</b>	<b>Animal farming</b>	<b>77</b>
<b>3.5.</b>	<b>Fish yield</b>	<b>78</b>
<b>3.6.</b>	<b>Forestry</b>	<b>80</b>
<b>3.7.</b>	<b>Hunting</b>	<b>82</b>
<b>3.8.</b>	<b>Processing plans</b>	<b>82</b>
<b>3.9.</b>	<b>Tourism</b>	<b>83</b>
<b>3.9.1.</b>	<b>FYROM</b>	<b>83</b>
<b>3.9.2.</b>	<b>Greece</b>	<b>85</b>
<b>3.10</b>	<b>A project to restore the lake and serve its surrounding area</b>	<b>85</b>
	<b>LITERATURE CITED</b>	<b>87</b>
	<b>ANNEXES</b>	<b>99</b>
.	<b>Meteorological data</b>	<b>100</b>
.	<b>Water level in lake Doiran</b>	<b>109</b>
<b>III.</b>	<b>List of vertebrate species of special concern</b>	<b>112</b>

## LIST OF TABLES

		p.
<b>Table 2.1.</b>	Meteorological stations in the study area	8
<b>Table 2.2.</b>	Mean monthly temperature ( C) at weather stations of Doirani, Ano Theodoraki and Nov Doiran	10
<b>Table 2.3.</b>	Mean monthly relative humidity (%) at Nov Doiran (1961 - 1990)	10
<b>Table 2.4.</b>	Mean monthly wind speed (m/s) at Nov Doiran (1961 - 1990)	11
<b>Table 2.5.</b>	Sunshine duration, mean monthly cloudiness, number of sunny and cloudy days and solar radiation in Nov Doiran (1961-2000)	11
<b>Table 2.6.</b>	Potential evapotranspiration (Penmann-Monteith method)	12
<b>Table 2.7.</b>	Lang draught coefficient at Nov Doiran weather station	13
<b>Table 2.8.</b>	Climate type according to the Lang draught coefficient	13
<b>Table 2.9.</b>	Climate type determination at Nov Doiran weather station	14
<b>Table 2.10.</b>	Mean annual water deficit in Lake Doiran, based on the decrease trend of the water level	29
<b>Table 2.11.</b>	Summary of selected water chemistry data for Lake Doiran	35
<b>Table 2.12.</b>	Summary of selected sediment chemistry data for Lake Doiran	49
<b>Table 2.13.</b>	Physical and chemical properties of soils (upper 60 cm) in the Doiran Plain	52
<b>Table 3.1.</b>	Population density in the Municipality of Doirani and Mouries	73
<b>Table 3.2.</b>	Population distribution in age classes in Municipality of Doirani and Mouries	73
<b>Table 3.3.</b>	Land use distribution (ha) in Municipality of Doirani and Mouries	75
<b>Table 3.4.</b>	Land uses and area (ha) of the main cultivation types in Municipalities of Doirani, Mouries (Greece) and Star Doiran (FYROM)	76
<b>Table 3.5.</b>	Livestock in the study area (number of animals)	77
<b>Table 3.6.</b>	Livestock production	78
<b>Table 3.7.</b>	The fishing yield of Lake Doiran	79
<b>Table 3.8.</b>	Distribution of wooded area	81
<b>Table 3.9.</b>	Production of fuelwood at Belles and Myriophyto forests	82

## LIST OF FIGURES

	p.
<b>Figure 2.1.</b> Mean monthly precipitation (mm) at weather stations of Doirani, Ano Theodoraki, Evzoni, Megali Sterna and Nov Doiran	9
<b>Figure 2.2.</b> Rainfall-temperature variation at the weather station of Nov Doiran	14
<b>Figure 2.3</b> The catchment area of Lake Doiran	21
<b>Figure 2.4.</b> Digital elevation model of the Lake Doiran catchment	22
<b>Figure 2.5.</b> The hydrographic network of Lake Doiran catchment area	24
<b>Figure 2.6.</b> Correlation of the absolute altitude of the lake surface and the stored water volume	25
<b>Figure 2.7.</b> Correlation of the absolute altitude of the lake surface and the flooded area	26
<b>Figure 2.8.</b> Mean annual absolute altitude of water surface (m) of Doiran Lake for the period 1961 to 1983 (data from FYROM)	27
<b>Figure 2.9.</b> Mean annual absolute altitude of water surface (m) of Lake Doiran for the years 1984 to 2003 (data from Greece and FYROM)	28
<b>Figure 2.10.</b> Relationship between rainfall and water level in Lake Doiran (1952-2000)	34
<b>Figure 2.11.</b> pH values in Lake Doiran during 1984-2003	37
<b>Figure 2.12.</b> Conductivity variations in Lake Doiran during 1984-2003	38
<b>Figure 2.13.</b> Dissolved oxygen in the water column of Lake Doiran in the decade 1984-1995	40
<b>Figure 2.14.</b> Ammonia-nitrogen concentrations over the period 1986-1994	42
<b>Figure 2.15.</b> Nitrate (mg/l) concentration in Lake Doiran during 1987-2003	43
<b>Figure 2.16.</b> Nitrite (mg/l) concentration in Lake Doiran during 1986-1994	44
<b>Figure 2.17.</b> Pedologic Map of the Doiran Plain (adapted from Vilarov [1956])	51
<b>Figure 3.1.</b> Population variation of Doirani Municipality	71
<b>Figure 3.2.</b> Population variation in Mouries Municipality	72

## **INTRODUCTION**

Lake Doiran straddles the border of Greece and FYROM, being a relic of the large ancient lake Paionia. Two thirds of the open waters are in FYROM, whereas 2/3 of its catchment area are in Hellenic territory.

Lake Doiran is a significant natural asset and a valuable resource for communities around the lake.

The main objective of this study is to describe lake Doiran's biotic and abiotic features, by compiling all available data and information. It must be noted that this is the first joint report for the whole water body that has been produced. Its importance lies not only in the information included in the text, but also in the opportunity for collaboration it offers to its authors.

The study contains three chapters. All biotic and abiotic information is presented in the first two chapters. Socio-economic attributes are described in the third chapter.

The study is prepared in the frame of the project "Assessment of the degree of expression of the functions and values of the tranboundary Lake Doiran". The project is funded by the Hellenic Ministry of Foreign Affairs – HELLENIC AID and carried out by The Goulandris Natural History Museum – Greek Biotope/Wetland Centre (Greece) and the "Society for the Investigation and Conservation of Biodiversity and the Sustainable Development of Natural Ecosystems (BIOECO)" (FYROM).



---

## CHAPTER 1

---

### GENERAL DESCRIPTION OF THE STUDY AREA

#### 1.1. Location – Boundaries – Surface Area

Lake Doiran is situated on the Balkan Peninsula in South-eastern Europe (41°23' N 22°45' E). It is a relic of the ancient Lake Paionia which was formed by strong earthquakes and had covered 13,000 hectares (Gerakis et al 1996).

Both the drainage basin and the lake itself are separated by the international boundary between the Greece and FYROM. The national border crosses the lake in a north-south direction and continues along a small watercourse east of the village of Nikolich toward Belles/Belasitsa Mountain. The border reaches the crest of Belles/Belasitsa Mountain at 1,474 m<sup>1</sup> or 1,447 m<sup>2</sup> msl. From this point, the catchment area's boundary follows the mountain ridge toward the east to the mountain peak (1,874 m<sup>1</sup> or 1,820 m<sup>2</sup> msl). It then goes down the mountain slope toward the south and southeast, where it reaches the lowest point of the catchment area's boundary with the Strymon/Struma River Basin to the east. The boundary of the catchment area continues along the eastern crest of Krousia/Krusa Mountain and then, turning toward the southeast, it reaches the lake's outlet, the Doiranity/ Ayiak River. Continuing on, the catchment area boundary closely parallels the lake's western shoreline and then proceeds around Star and Nov Doiran, rising to an elevation of 720 m msl<sup>2</sup>. From here, the boundary continues northward to a point (1,474 m<sup>1</sup> or 1,447 m<sup>2</sup> msl) on the FYROM-Greek border.

Lake Doiran has a surface area of about 39.9 km<sup>2</sup> (or 42.0 km<sup>2</sup> according to the FYROM), of which approximately 3/5 is within FYROM and about 2/5 is within Greece (Map 1). The entire watershed of Lake Doiran comprises an area of about 276.3 km<sup>2</sup> (or 271.8 km<sup>2</sup> according to the FYROM). The study area covers the whole catchment of the lake (Map 1).

---

<sup>1</sup> According to the Piraeus tidal gauge in Piraeus harbor (PH)

<sup>2</sup> According to FYROM benchmarks and measurement standards, which relate to the old Yugoslavian reference point in Pula, Croatia (PC)

This system is different from the system used in Greece. The abbreviation, "msl," denotes mean sea level.

## 1.2. Physical morphology

Lake Doiran is located in the lowest part of the topographic depression bounded by Belles/Belasitsa Mountain on the north and Krousia/Krusa Mountain on the southeast. The lake was formed during the latest tectonic outbreaks of Quaternary that influenced the impervious rocks of Perirodopiki and Serbomacedonean Massif. The patterns of the supply and straining of the lake began to change at the early 20<sup>th</sup> century (Nicolaidis et.al. 2001).

Lake Doiran's only natural outlet, the Doiranitis River, is situated at the southern end of the lake, within the territory of Greece. Outflow is only possible, however, when the water level within the lake is high. This river was canalised in the nineteenth century in order to prevent water within the lake from reaching flood stage. In the 1950s, the main problem was control of high water levels and protection from shoreline flooding.

The Water Development Institute (WDI) of FYROM examined the morphology of the Lake Doiran drainage basin in 1960s and 1970s. In 1991, a bathymetric survey using an echo-sounder and a tachymetric survey of the shoreline were carried out in the FYROM portion of the lake. The results were published by the Water Development Institute (WDI) (1993). The information from this survey, combined with the data concerning the Greek portion of the lake bottom, has been digitised by the Ministry of Agriculture, Forestry and Water Management (Durnev and Lazarevski 2001).

According to this survey, the following points should be emphasised:

- Only a relatively small portion of the catchment area, around 50 km<sup>2</sup> or 18 %, is above an elevation of 500 m msl (PC reference point).
- The surface area of the Lake Doiran drainage basin does not increase significantly with lowering elevations. This indicates that the surface features at high elevations have steep slopes and create favourable conditions for the drainage of surface waters. This is especially true for the southern side of Belles/Belasitsa Mountain.

That portion of the catchment area below 500 m provides favourable conditions for slower drainage of surface water and increased infiltration of precipitation into the soil in places where the soil's hydro-geological composition allows.

The lake is very shallow, with the lake bottom being generally situated at an elevation of 138.0 m msl. In contrast to its former depth of 10 m, after the recent reduction of the water level, the current depth of the lake now stands at 3-4 m. This shallow depth increases the immediate danger for the lake.

### **1.3. Protection status**

Lake Doiran is under the protection of international and national legislation. It is designated as an Important Bird Area (IBA) for both Greece and the FYROM (codes GR023 and MK010 respectively). Greece has proposed to include its part in the European Union "Natura 2000" network as a Special Protection Area-SPA (GR1230003) (Dafis et al. 1996). In 2002, as an area of special conservation interest (ASCI), Lake Doiran was also included in the early stages of the establishment of the National Emerald Network within the FYROM.

Lake Doiran, being divided by an international border, is also subject to international agreements. Although a previous agreement (1956) between Greece and Yugoslavia exists regarding Lake Doiran, it is concerned primarily with regulating the maximum lake water level for flood protection purposes. In this agreement, the water level of the lake is to be maintained between 146 and 144.8 m msl (PH reference point) or 146.14 and 147.34 m msl (PC reference point).

In the FYROM, Lake Doiran was registered as a natural rarity based upon a decision (No. 06-691/1) adopted by the National Institute of Cultural Monuments, Skopje, as of 21 July 1970. In addition, in 1977, the Law on the Protection of lakes Ohrid, Prespa and Doiran ("Official Gazette of the SRM" No. 45/77) established lake Doiran as a Monument of Nature. According to this law and owing to their specific features and natural beauty; geological, geo-morphological, hydrological, hydro-biological, limnological and other scientific values; their cultural, aesthetic, educational, health, recreational, tourist and other economic significance; Lakes Ohrid, Prespa and Doiran, their waters, shores, springs and watercourses were declared Monuments of Nature of particular importance for society and were placed under special protection.

This legal act regulates the entire sphere of protection for the three lakes, including preservation of the lakes in their natural state, creation of the most favourable conditions for maintenance and development of their inhabiting species, prevention of activities which could affect their natural beauty and regulation of human activities impacting the lakes, in order to provide for their wise and sustainable use. The Law on the protection of Lakes Ohrid, Prespa and Doiran also regulates the regime of the lakes' protection, the determination of the maximum usable volumes of water within the lakes (for the purpose of preserving them in their natural states and providing biological balance for their ecosystems), the controlled use of waters within scientifically based limits, the adoption of specific programmes for lake protection, the provision of funds for lake protection, the keeping of professional and scientific documentation, the adjustment of spatial and urban plans to be in accordance with the law and the establishment of a Council for the protection of Lakes Ohrid, Prespa and Doiran (disbanded in 1988 on the basis of amendments and supplements to the law).

In 1987, on the basis of Article 5 of the Law on the Protection of Lakes Ohrid, Prespa and Doiran, a Programme for the protection of Lakes Ohrid, Prespa and Doiran was adopted. The programme specifies the measures and activities to be undertaken for the protection of the lakes; monitoring of the quality of waters, fauna and flora; additional required scientific research and professional reports; and financing. The Councils of the various Municipalities, as owners of these Monuments of Nature, have been delegated the responsibility to resolve issues related to the disposal of communal solid waste, use of boats and other vessels, transportation of harmful materials near the lakes, compliance of urbanised areas along the shoreline with basic protection principles, development of systems for protection of the lakes against wastewater and establishment of systems for monitoring lake quality.

Numerous general laws regarding the protection of the environment also exist. To date, no other specially protected areas in the vicinity of Lake Doiran have been proclaimed. Presently, in the FYROM national environmental legislation is being reviewed and steps are being taken to harmonise it with that of the EU.

In addition to the existing environmental protection measures, additional scientific research and professional reports have been envisioned for Lake Doiran, work which will complete the foundational knowledge required for Lake Doiran's comprehensive protection. These include:

- Study on the water balance of Lake Doiran, including its watershed, water use and maximum usable volume of water within the lake,
- Study on the status of the vegetative cover of the watershed of Lake Doiran and the presence of sediment and pollution loads from eroded areas,
- Study on the application of agrochemicals in the Lake Doiran watershed and their impacts on the biological, chemical and biochemical characteristics of the waters of the lake,
- Study on the impacts from regulated and non-regulated urban storm waters, industrial wastewater and outfalls which discharge into the lake.