Shorezone Functionality

Prespa Lake

Implementing the EU Water Framework Directive in South-Eastern Europe

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Disclaimer

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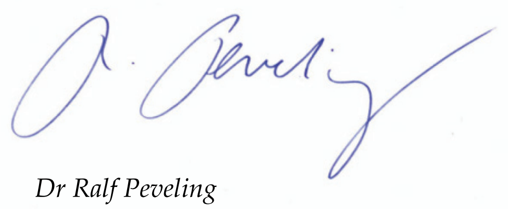
Foreword

The EU Water Framework Directive (WFD) sets a framework for the management of surface and ground waters within the territory of the Union, with the aim to preserve or achieve their good ecological and chemical status. Significant progress has been made in recent years by Albania, FYR of Macedonia[1] and Montenegro not only towards transposing the WFD into their national legislation but also implementing it in parts of their river basins, including the sub-basins of Lakes Prespa, Ohrid and Shkodra/Skadar.[2] As a result of this joint transboundary endeavour, the so-called initial characterization of the three lakes has been achieved in 2015, with support of German Development Cooperation and other development partners. The present document marks another important milestone in WFD implementation – the assessment of hydromorphological status. This comprises a mixture of hydrological and morphological assessments.

Whilst the biological, chemical and physico-chemical elements are concerned primarily with the quality of the aquatic environment, hydromorphology is concerned with its physical nature. It examines the physical size of the water body itself as well as the shore/riparian zone – depth variations, surface areas, substrate composition, water inflow, abstractions/discharges, outflow, residence time, water level etc. For classification purposes, a water body can only be considered to be of good or even high ecological status if there are no or very limited hydromorphological alterations from its reference status, and if lake shore functionality is not seriously diminished, e.g. by urban encroachment and the concomitant extension of impervious surfaces.

Within the EU, different methodologies have been applied to assess the hydromorphology of lakes. The approach pursued in the present study – the Shorezone Functionality Index (SFI) – was first developed in Italy and has in the meantime been adopted by several European countries. Even though the SFI has been developed primarily to inform water management, it is of more general importance to all kinds of spatial planning taking place within lake sub-basins, including physical and landscape planning and zoning designations for protected areas. Moreover, it provides a status quo baseline and benchmark against which to measure future developments. The SFI will, therefore, enable planners and developers to take informed decisions for the sake of the sustainable development of the lake areas, to which all riparian countries are committed.

The authors of the study are acknowledged not only for the quality of their work but also for demonstrating that, in water resources management, more comprehensive and meaningful results can be achieved through transboundary collaboration.



Dr Ralf Peveling
Program Manager CSBL

[1] Upon decision of the General Assembly of the United Nations in 1993, Macedonia is provisionally referred to as "The former Yugoslav Republic of Macedonia", pending settlement of the difference that had arisen over its name. For the ease of reading and without prejudice, henceforth the name Macedonia is used.

[2] The names Shkodra and Skadar are used together or interchangeably.

1 THE SHOREZONE FUNCTIONALITY INDEX

1.1 Introduction

Lakes are extremely important. They are a source of freshwater and provide resources such as fish and support services like water transportation, recreation and tourism.

Today, mitigating nutrient losses caused by anthropogenic nonpoint source pollution is particularly important for improving the water quality of a great number of the world's freshwater lakes. Relationships between land use and in-lake water quality have been observed, which means the whole drainage basin should be considered when managing nutrient loadings in lakes (Nielsen et al. 2012). For example, chemicals – nitrogen and phosphorus being prime examples – that are originally applied to the land for agricultural purposes can work their way into lake waters and, once present, will actively (and often negatively) affect the trophic-evolutionary processes of these waters (Premazzi and Chiaudani 1992; Chapman 1996).

The lake's riparian vegetation plays an important role as a buffer that helps to protect the aquatic ecosystem against degradation caused by human activities (Dosskey et al. 2010). Studies by Osborne and Kovacic (1993) have shown that the riparian zone can efficiently intercept nutrients emanating from nearby agricultural areas, diminishing by over 90% the nitrogen and phosphorus content of both the superficial and sub-superficial waters flowing into the water body (Figure 1).

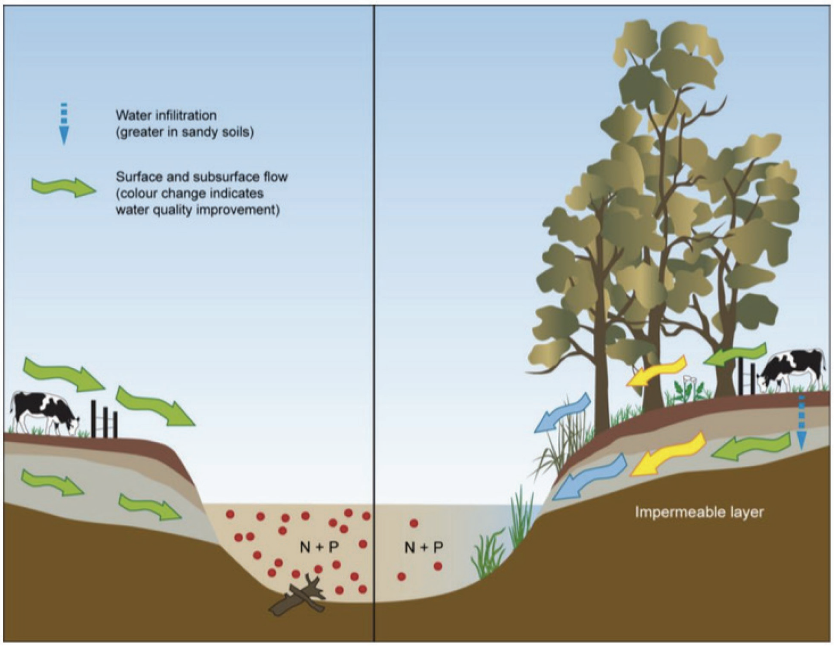


Figure 1. Nutrient interception by riparian vegetation (Dosskey et al. 2010)

The shorezone is a transition zone (ecotone) between a lake and its surrounding territory that can perform important ecosystem services, such as regulating nutrient inputs and protecting against nonpoint source pollution, ensuring the maintenance of ecological processes, providing food and habitat for organisms, and protecting the shoreline from erosion (Figure 2).

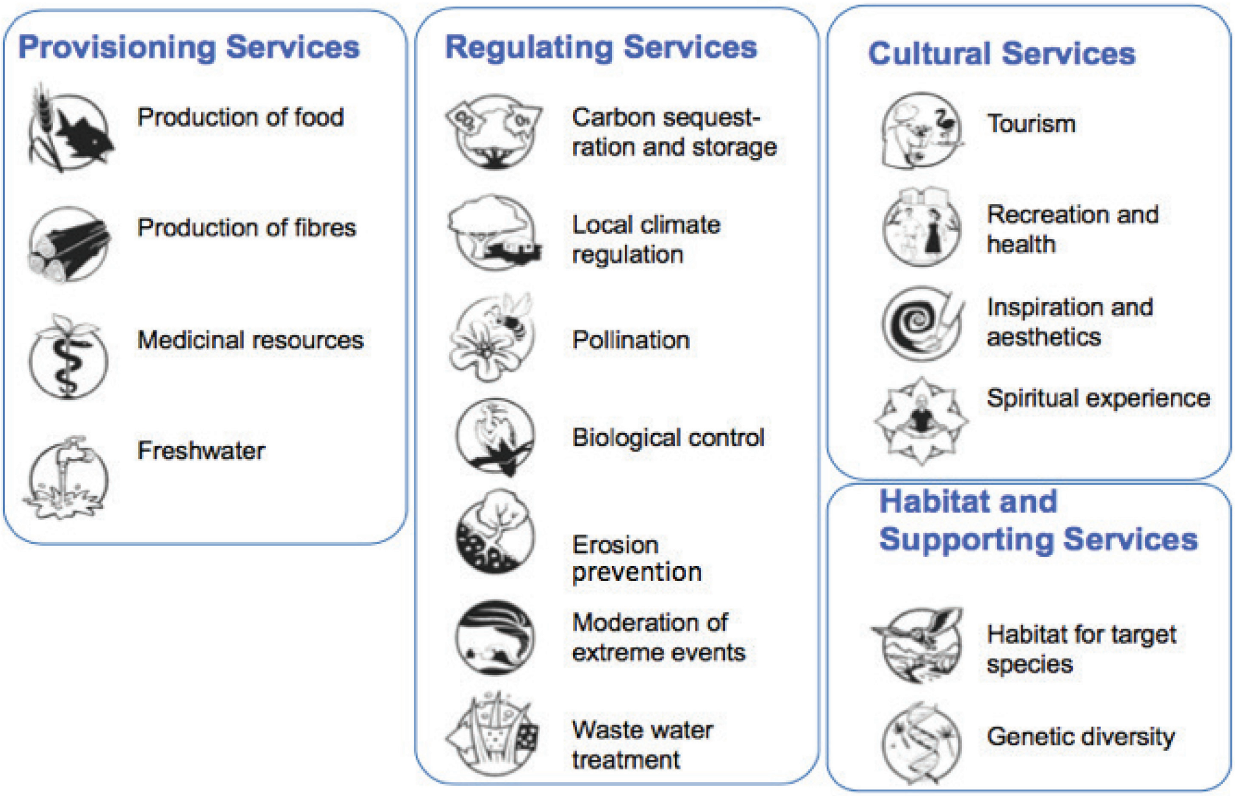


Figure 2. Examples of ecosystem services (TEBB 2012)

While the structure and extension of the shorezone are influenced by the area in question's topography and climate and the geological composition of its soil, the shorezone's water fluxes, nutrient and sediment inputs, and diffusion of animal and plant species are influenced by the lake's riparian vegetation. When unregulated lake-shore developments are built without sufficient planning authority oversight (a problem that particularly affects transboundary lakes), the functional shorezone can therefore be negatively affected.

1.2 The Shorezone Functionality Index

Understanding and evaluating the functions of the lake's shorezone provides the basis for creating a set of indicators that can be used to evaluate shorezone functionality, and it also supports and guides land planning policies and management choices. Furthermore, the need for a new index was also supported by the Water Framework Directive (WFD) 2000/60/CE, which, to determine ecological quality, requires that the evaluations of biological elements and the evaluation of hydromorphological elements be considered in conjunction.

The WFD defines the elements of quality (EQ) for classifying the ecological state of water bodies of any typology. Among the EQ to be determined are biological elements and hydromorphological elements that, for lakes, consist of the hydrological regime (quantity and dynamics of the water flow, and water percolation and residence time) and the lake's morphology (variations in depth, characteristics of the substrate, and shore structure) (CIS Wetlands Working Group 2003).

The Shorezone Functionality Index (SFI) was developed in Italy in 2004 by a working group of the Italian Agency for Environmental Protection and Technical Services (APAT), which was coordinated by the Provincial Agency for Environmental Protection (APPA) of the Autonomous Province of Trentino, Italy.

The SFI was originally created as the counterpart to the already existing Fluvial Functionality Index (Siligardi et al. 2007) and was tailored to Alpine lakes. Subsequently, it has been employed by (a) the European Alp Lakes Project to assess lakes in Italy's Lombardy region, (b) the European SILMAS project to assess the lakes along the Alpine Arch (Italy, Austria and Slovenia), (c) the European Eulakes Project, albeit in modified form, to assess the large lakes of central Europe (Austria, Italy, Hungary and Poland) and (d) the University of Villarica, Chile, to train professionals with the Environmental Ministry (Ministerio de Medio Ambiente).

When using the SFI, morphological, structural and biotic parameters are evaluated in the field from an ecological perspective: biotic and abiotic factors are used to evaluate the buffering capacity of riparian vegetation, the complexity and artificiality of the shoreline, anthropogenic uses of the surrounding territory, and the way inputs from the watershed enter the water body.

This semeiotic index is easily surveyed, evaluates the state of the environment and assists in identifying the causes of deterioration by looking beyond the waterbody itself to include all the surrounding territory and drainage basin topography. The index not only provides baseline information on the status of the lake, but can also be used to support decision-makers tasked with planning environments adjacent to lakes and with managing lake water resources.

1.3 Methodology

To develop an initial overall understanding of the status of the lake, the first step of the SFI process involves reviewing existing literature on the hydrogeomorphological (HGM) characteristics of the lake and its drainage basin and on the pressures and current issues affecting these features.

The whole length of the lake is then surveyed, with surveyors navigating alongside the shore to gather information on the ecological parameters (typology, width, continuity and/or interruption of the riparian vegetation), socio-economic parameters (land use, presence of infrastructure, etc.) and other abiotic parameters (steepness, concavity, shore artificiality, etc.).

Every time a change in one of these parameters is identified, a new form is completed and a new homogeneous shorezone is identified. In this way, the whole of the lake's shorezone is divided into different stretches with similar characteristics.

The data collected in the field is processed using the Shorezone Functionality Index software package (SFINX02) which determines the functionality value for each homogeneous stretch. There are five different categories of functionality, ranging from bad to high (Table 1), as suggested by the WFD 2000/60/CE.[3]

[3] Editors' note: Contrary to the WFD classification system, whereupon any ecological status less than high (i.e. good, moderate, poor and bad) is considered to be caused by human activity (and should be reversed to the extent possible if less than good), low shorezone functionality may result from either natural causes or human activity. Only in the latter case measures can and should be taken to improve functionality. Nonetheless, even shorezones whose natural functionality is low (and therefore cannot be enhanced) require measures such as sustainable land use practices in the hinterland to prevent pollutants from being discharged into the lake unimpededly.

Table 1. Functionality levels, category names and reference colours

Level	**Category**	**Colour**	**Water Framework Directive**
I	High	BLUE	Acceptable
II	Good	GREEN	
III	Moderate	YELLOW	Not acceptable except where it is caused by natural processes
IV	Poor	ORANGE	
V	Bad	RED	

Of all the parameters collected in the field, only nine are actually processed using the software: shore artificiality, vegetation cover, presence of interruption within the lake's shorezone, concavity of the shore profile, presence of reeds, presence of arboreal species, presence of road infrastructure, heterogeneity of arboreal vegetation, and presence of non-hygrophilous species. These parameters were selected based on the results of an artificial neural network analysis (ANN), carried out during the development of the index. The ANN showed that these parameters had the greatest influence over the results because of their numerical weight. The remaining parameters are still, however, very important for the report and can also be used to develop the index in future.

The nine parameters are configured as a classification tree (Figure 3a), which shows the level of functionality (described as a sum of the percentages of each functionality level) of each homogeneous stretch.

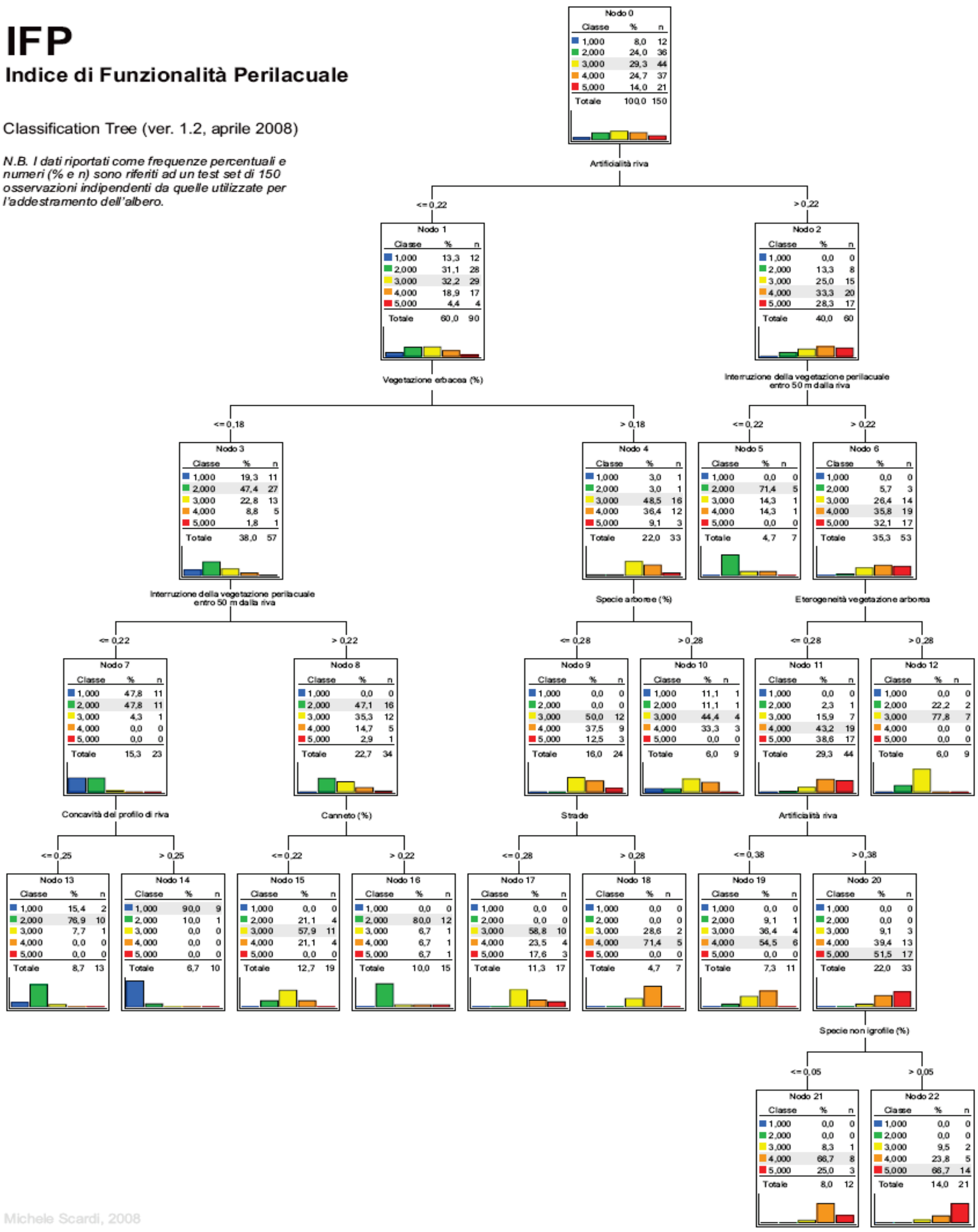


Figure 3a. The classification tree produced by the SFI software

Each node of the classification tree indicates for each homogeneous stretch the probability that it will fall into one of the five categories. Within each leaf, the higher probability percentage will determine the final level of functionality (Figure 3b).

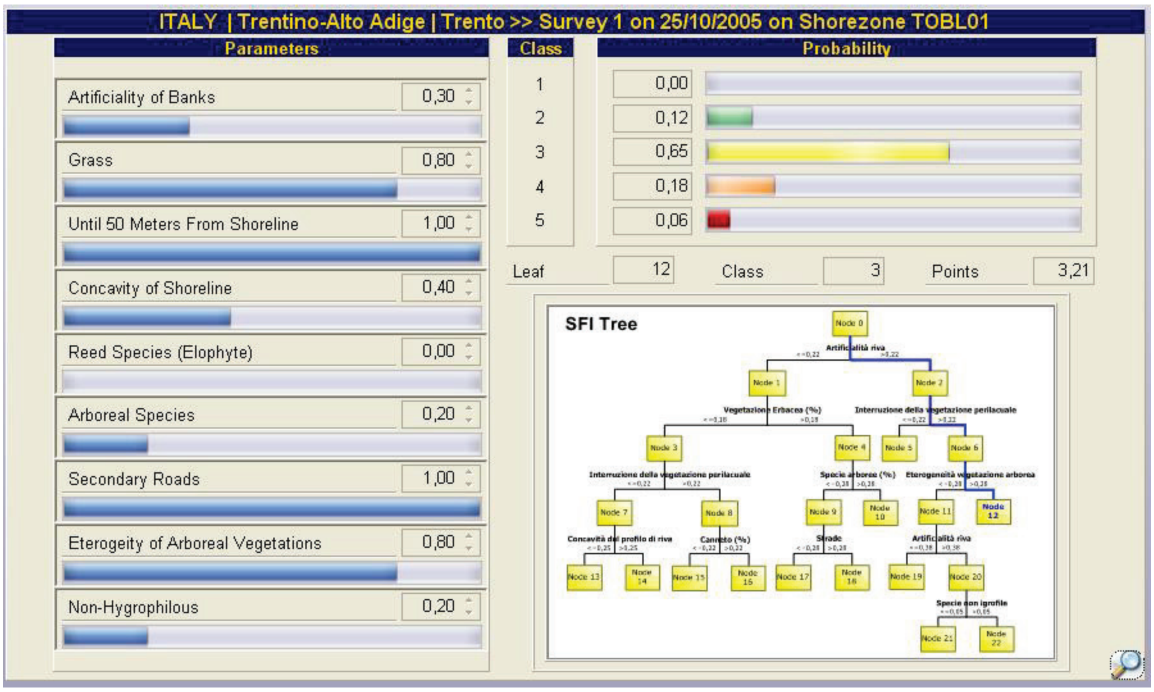


Figure 3b. Example of the results output by the SFINX02 software package for a given homogeneous stretch

The results and parameters are then transferred to a GIS platform, which makes it possible to create thematic maps of the parameters surveyed, to carry out spatial analyses, and to identify which locations are weaker or stronger and which are in greater need of or are more suited to restoration actions. The SFI maps are very important as they provide initial direct visualisations of the general status of the lake's shorezone – e.g. indicating the location of remaining areas of high functionality (blue colour) (Figures 4 to 6).

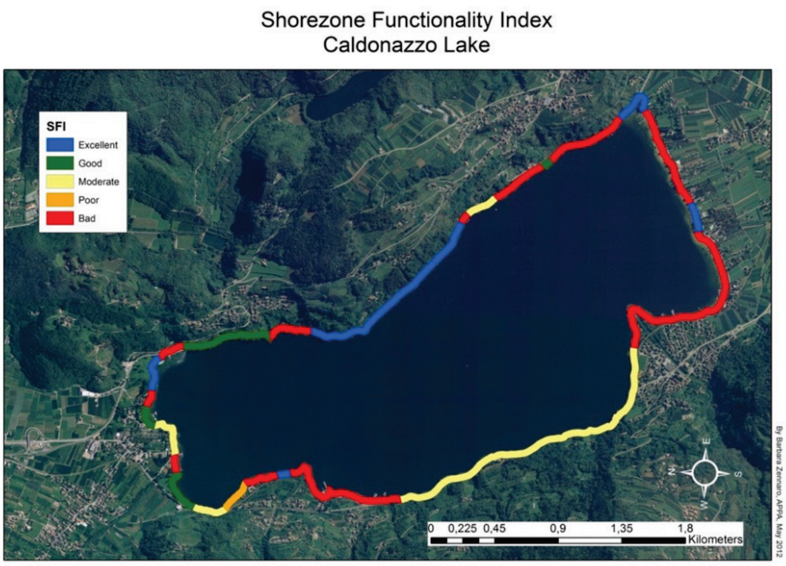


Figure 4. Map showing the Shorezone Functionality Index results for Caldonazzo Lake, Italy, which provides an initial direct visualisation of the status of the lake

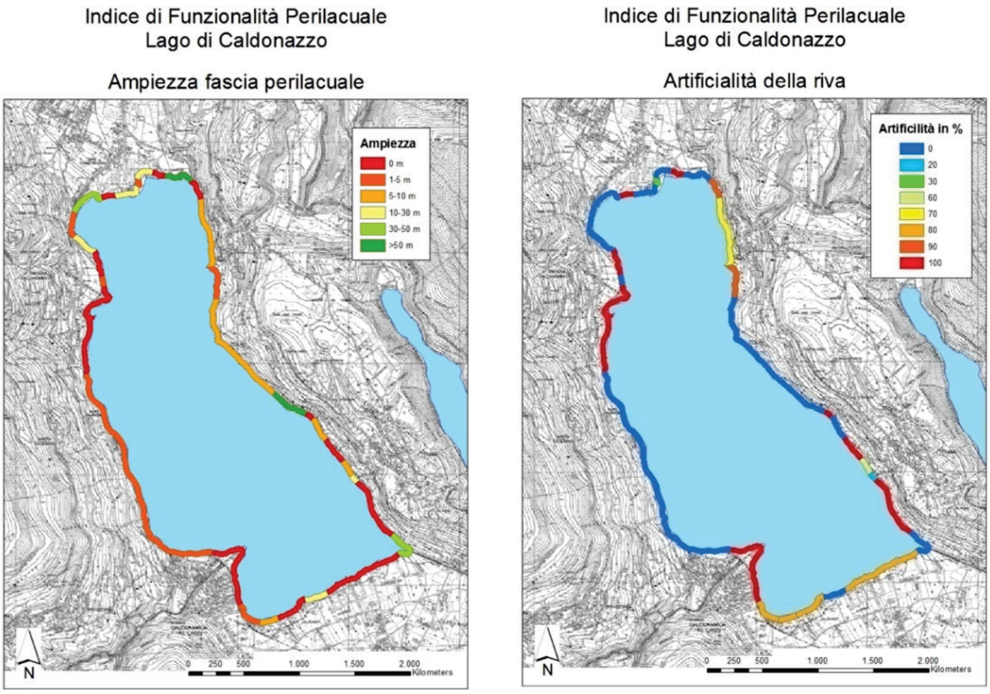


Figure 5. Thematic maps for Caldonazzo lake, with the left-hand map showing the width of the shorezone (red = 0 m, green = more than 40 m) and the right-hand map showing the artificiality of the shorezone (red = wholly artificial, blue = wholly natural)

It is important to keep in mind that the shore's naturality and functionality are two different concepts. Therefore, a location with a wholly natural shorezone may, in certain cases, have low levels of functionality (see also Footnote 3). For example, steep cliffs that descend directly into the water and have little or no riparian vegetation are often unable to perform any good ecological functions (Figure 6).

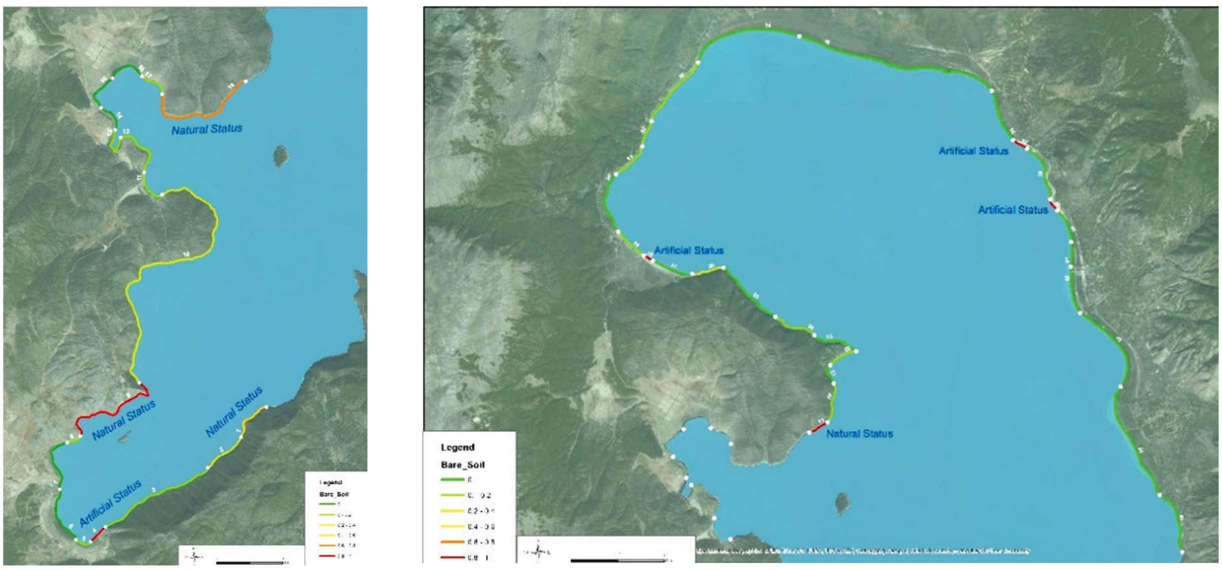


Figure 6. Percentage of "bare soil" at Lake Prespa, resulting in low shorezone functionality (i.e. moderate, poor or bad status). Bare soil may b e the result of natural (e.g., steep cliffs) or anthropogenic causes (e.g., artificial sandy beaches). Only in the latter case measures must be taken to restore or enhance its functionality to achieve at least good status.

1.4 The Shorezone Functionality Index as a management tool

The potential of the SFI method lies in its ability to produce a synthetic value for the shorezone functionality of a lake. With the SFI approach, it is possible to complete studies on the internal dynamics of a lake, which are often altered by productive activities, recreation and tourism. By basing a lake's shorezone management on the concept of its functionality, the human uses of the lake can be reconciled with its environmental protection, which facilitates ecologically sustainable urban and rural planning and watershed management. Lake managers and stakeholders can use these results to develop a sustainable ecosystem-based approach to watershed management (Figure 7).

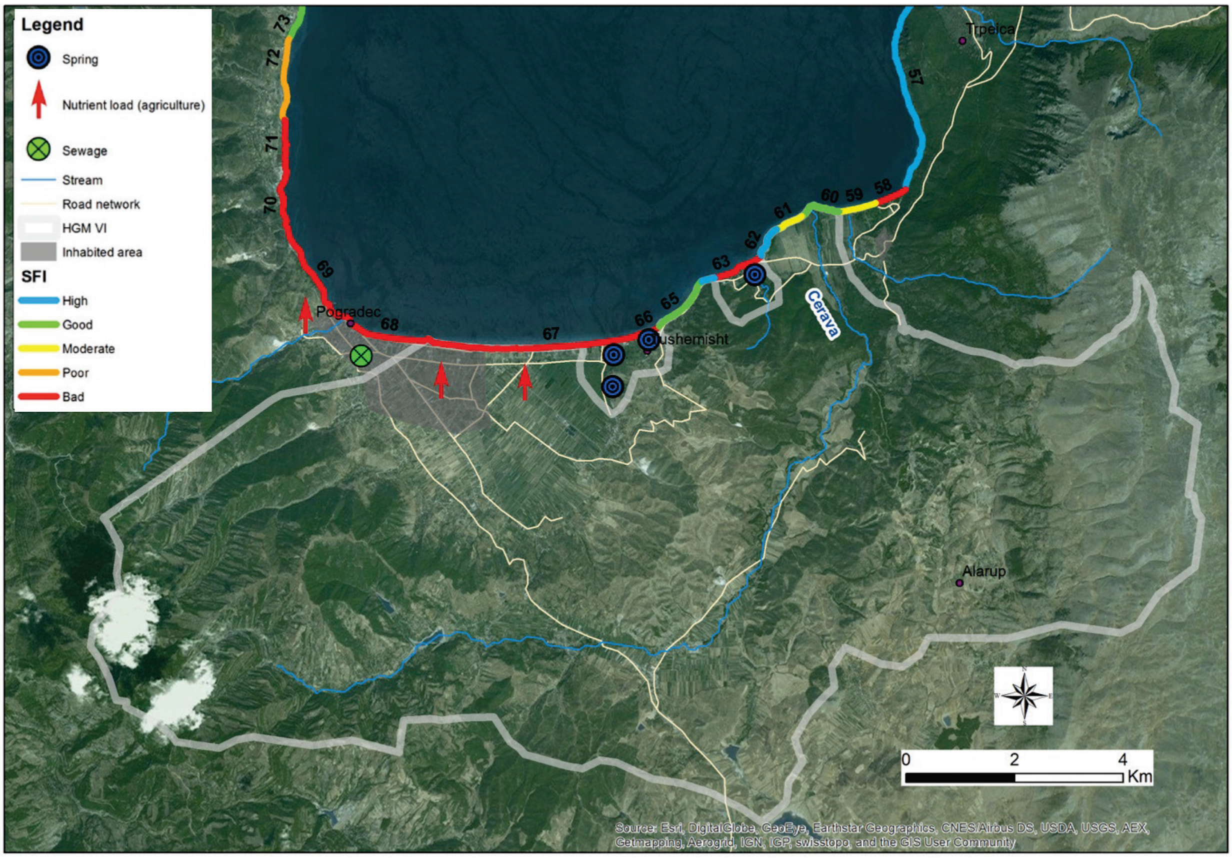


Figure 7. Example of an identified hydrogeomorphological (HGM) area at Ohrid Lake, Albania. The map shows the boundary of the HGM area (grey line), the presence of environmental stressors (i.e. the nutrient load from agriculture), hydrological factors (streams and springs), and the values produced when applying the Shorezone Functionality Index.

The results of the SFI, which are relatively economical and quick to obtain, provide an immediate general picture of the state of the shores around the lakes. This differs to earlier indices, which were only representative of specific points along the shore. The SFI results can also be used to easily identify the locations of and action needed in potential restoration sites (using the SFINX02 software, different scenarios can be modelled for a specific area and, by changing determinate parameters, it is possible to foresee the impacts public or private activities may have on the water body) as well as the locations of protected areas, sites of important economic value and so on.

The SFI responds to the current need, arising from the requirements of WFD 2000/60/CE, to develop new indices capable of assessing the hydromorphological elements of lake ecosystems, including riparian zones. Future SFI reports on the same lake can also be used to track changes in the shorezone over time. Under this project, a number of different output formats have been developed for end users – be they managers, local stakeholders or tourists – which include the SFI report, the SFI thematic maps and the SFI brochure.

The **SFI report** describes the status of the shores around the perimeter of a given lake, providing useful information on its level of functionality. Managers and stakeholders can then use this information to ensure the proper management of the lake's shores, to identify restoration sites and to test and determine which lines of action will make the restoration work a success. Alternatively, the report can simply be used as a baseline study for benchmarking future developments.[4]

The SFI report describes the lake and all the homogeneous stretches identified. The way in which it is written ensures that the results are comprehensible to readers who may not be familiar with the Index or the lake. It highlights the shorezone's weaknesses and strengths and indicates specific actions required to improve the lake's functionality. The report covers the following areas:

- The lake's location, origin and history
- Results, statistical analysis and management recommendations
- Application of the Shorezone Functionality Index (description of each homogeneous stretch with photos, SFI results and specific recommendations where applicable).

SFI thematic maps can be created for each parameter collected in the field. A shapefile containing this information is created for each lake and for each SFI study. When the results are imported into a GIS environment, geospatial and geostatistical analyses can be performed. For example, SFI studies carried out on a specific lake in two different years can be compared to extract information on changes in the shore functionality over time.

The **SFI brochure**, which is usually made available in both English and the local language, was developed as a way of communicating SFI results to the general public. The brochure briefly describes the methodology and the lake's main categories, and provides a summary of the statistical results and management suggestions.

[4] For similar reports on Lakes Ohrid and Shkodra/Skadar, see Blinkov et al. (2017) and Bajkovic et al. (2017), respectively.

2 MACRO PRESPA LAKE

2.1 Location, origin and drainage basin

Figure 8. Location of Prespa Lake in Europe

Prespa Lake is shared by Albania, Macedonia and Greece and lies in the karstic terrain of the south-eastern Dinaric Alps (Figure 8). In the delineation set out in the Water Framework Directive (WFD), the entire catchment basin of Prespa Lake falls within Ecoregion 6 – Hellenic Western Balkans (Figure 9).

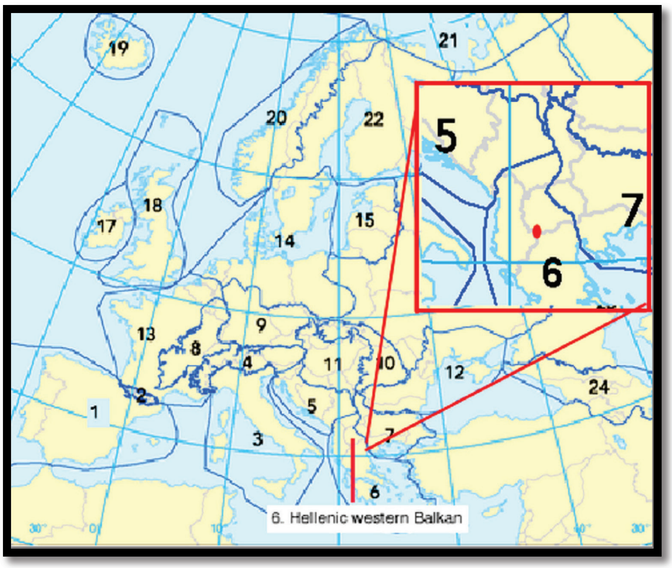


Figure 9. Position of Prespa Lake on the map of European ecoregions
(Ecoregion 6 – Hellenic Western Balkans)

Prespa Lake is a high-altitude lake system sitting approximately 850 metres above sea level (a.s.l.). The lake system consists of two interlinked lakes – Macro Prespa and Micro Prespa – that are separated by an isthmus. Between 1962 and 1975, water levels of both lakes were similar owing to a canal connecting the lakes at the outflow of Micro Prespa (Figure 10) (PLWMP-TR1 2010).

Figure 10. Macro and Micro Prespa lakes and the isthmus between them

Because Prespa Lake has a karstic substratum, a large amount of its water seeps into the soil, drains away through a network of underground fissures and supplies the springs located on the shores of Ohrid Lake (Blinkov et al. 2013; Figure 11).

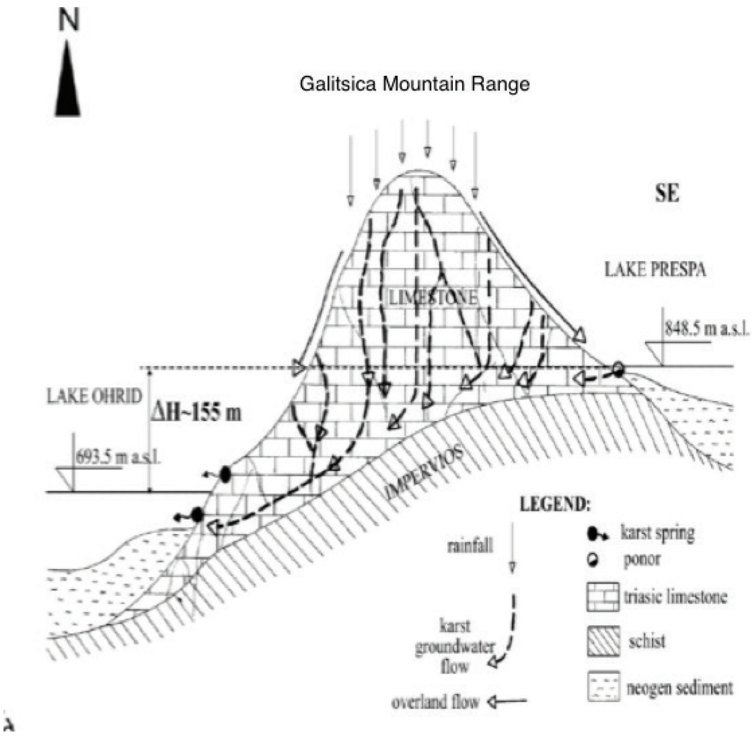


Figure 11. Flow of water from Prespa Lake to Ohrid Lake through the karst of Galitsica Mountain (Popovska and Bonacci 2007)

The Ohrid and Prespa sub-basins fall within the Drin River Basin. The Drin River originates on the northern shore of Ohrid Lake and flows northwards across Albania where, close to its mouth on the Adriatic Sea, its main distributaries joins with the Bojana/Buna River, which drains Skadar/Shkodra Lake (Figure 12).

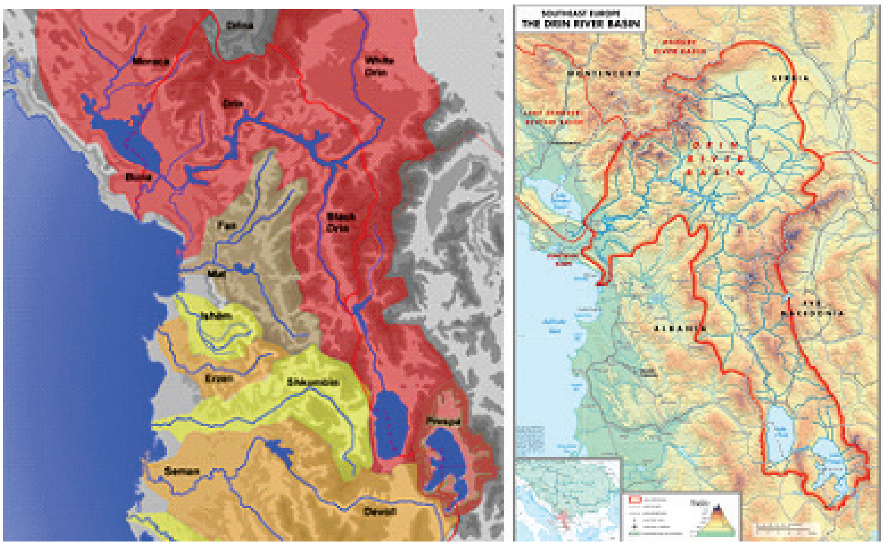


Figure 12. Location of Macro Prespa Lake within the Drin Basin (World Bank 2006)

The outstanding degree of biodiversity and the 'creeping biodiversity crises' of Ohrid and Prespa Lakes have not only prompted a multitude of biological and ecological studies; they have also promoted intensive interdisciplinary research combining geological, hydrological, sedimentological and climatic approaches that are seeking to understand the evolution of Lakes Ohrid and Prespa in general, and the climate dynamics and driving forces for their high degree of biodiversity in particular (Wagner and Wilke 2011).

2.1.1 Lake origin

Both Ohrid and Prespa Lakes are believed to have been formed during the Pliocene roughly two to three or possibly even five million years ago (Wagner and Wilke 2011; Trajanovski et al. 2010). These lakes therefore potentially qualify as ancient lakes. Some authors, however, define them as extant lakes that have existed continuously since before the Pleistocene, while others suggest continued existence since at least before the last glacial/interglacial cycle (>120,000 years; Albrecht and Wilke 2008; Gorthner 1994; Martens et al. 1997). In addition, Wagner and Wilke (2011) assert that it is not clear whether Prespa Lake experienced one or more desiccation phases during its long hydrological history. While there is no indication that the lake's water levels have dropped significantly at any point over the last 48,000 years or so, two studies do suggest that the lake's water level dropped considerably or even that it completely desiccated about 110,000 years ago. All that said, very few lakes exist in the world today with a similarly remote origin.

2.1.2 Drainage basin

Prespa Lake drainage basin is topographically surrounded by a ring of high mountains. On the western, southern and eastern sides the mountains are situated closer to the shore:

- to the east Mount Baba at 2,420 m and Mount Triclarion at 1,749 m;
- to the south Suva Gora at 1,480 m;
- to the west Mali i Thatë at 2,288 m and Mount Galitsica at 2,256 m.

Conversely, on the northern side there is a large basin (Figure 13) that separates the lake from the surrounding mountains (Mount Plakenska at 1,935 m).

Figure 13. Prespa Lake (Micro and Macro) drainage basin showing the ring of mountains enclosing it (World Bank 2006)

Basic dimensions of Macro Prespa Lake in 2016 – Study area

Because of strong oscillations in Prespa Lake's water level, its length, width, area, depth and volume vary significantly. As a result, the surface area of Macro Prespa ranges between 259.4 and 280.0 km^2 (Macedonia – 68.1%, Albania – 17.9% and Greece – 14.0%; Figure 14).

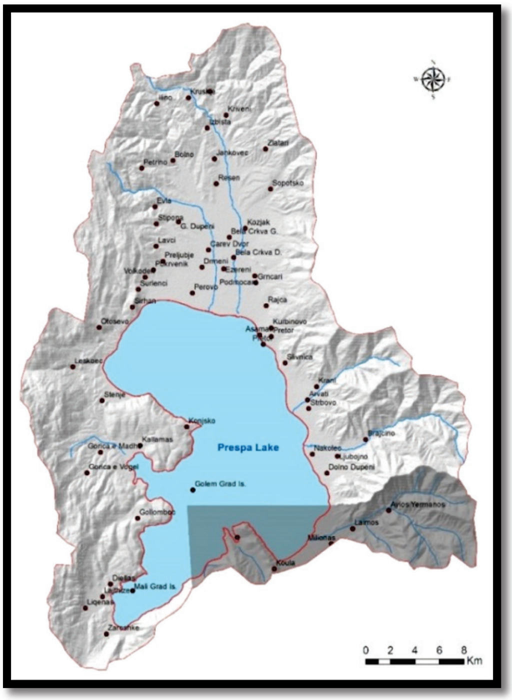


Figure 14. Macro Prespa basin (the section pertaining to Greece is shaded)

During the SFI mapping, undertaken in June 2016, the lake's water level was 844.8 m above sea level. The mapping and measurement of the Macro Prespa drainage basin was performed using topographic 1:25,000-scale maps, aerial photography with a one-metre resolution, and direct measurements recorded using GPS. The results are summarised in Table 2 (personal calculations; Mincev 2016).

Table 2. Characteristics of Prespa Lake drainage basin (June 2016; "– " means no data available)

Key: m a.s.l. = meters above sea level

	Total area of the drainage basin and lake surface area (km^2)	**Drainage basin area (km^2)**	**Lake surface area (km^2)**	**Minim. Height (m a.s.l.)**	**Maxim. Height (m a.s.l.)**	**Average Height (m a.s.l.)**	**Slope (%)**
Prespa basin (*Macro and Micro Prespa*)	1,370.6	1,060.9	309.6	844	2,420	1,207.4	26.2
Macedonia	767.4	589.2	178.2	844	2,420	1,118.4	21.4
Albania	268.3	218.3	50.0	844	2,288	1,207.4	26.2
Greece	334.9	253.5	81.4	844	2,331	1,132.6	24.4
Macro Prespa	*1,109.9*	*848.4*	*261.4*	*844*	*2,420*	*1,249.7*	*27.7*
Macedonia	767.4	589.2	178.2	844	2,420	1,218.7	26.0
Albania	211.8	166.1	45.6	844	2,288	1,268.2	30.4
Greece	130.7	93.1	37.6	844	2,331	1,425.8	35.1
Micro Prespa	260.7	212.5	48.2	844	2,156	841.1	26.1
Albania	56.5	52.1	4.4	844	1,480	–	–
Greece	204.2	160.4	43.8	844	2,156	–	–

The overall dimensions of Macro Prespa are as follows: length = 26.5 km, width = 14.6 km, length of shoreline = 106.04 km

2.2 General form of the lake

Tables 3 to 6 (SFI Form 1) summarise the lake's morphological, climatic and physical characteristics.

Table 3. General characteristics

	Indicator	Typology
GENERAL CHARACTERISTICS	Origin	tectonic
	Type	natural large
	Location	mountain
	Latitude (north)	41° 13′ 06″ to 40° 40′ 22″
	Longitude (east)	20° 49′ 41″ to 21° 15′ 20″
	Altitude of the lake	844.85 metres above sea level (2016)
	Average altitude of the catchment basin	1,249.78 metres above sea level
	Main geological type of the substrate	calcareous (west); magmatic and metamorphic (east); sedimentary (central part and south)

Table 4. Morphological characteristics

	Indicator	Typology
MORPHOLOGICAL	Catchment basin (watershed: WS)	848.4 km^2
	Shoreline length	Total: 106.04 km Macedonia: 47.52 km Albania: 36.77 km Greece: 19.77 km
	Lake surface area (LA)	261.4 km^2
	Volume	Macro Prespa = 3.6 km^3 (with water level at 844.85 m above sea level) Macro and Micro Prespa Lake range between 3.1 km^3 and 4.9 km^3
	Maximum depth	52.4 (2016) metres
	Average depth	16–18 metres
	Structure and substrate of the lake bed	muddy sediment

Table 5. Climatic characteristics

	Indicator	Typology
CLIMATIC	Precipitation	831 mm/year (modelling
	Average max. temperature in January	0.3°C
	Average max. temperature in July	21°C

Table 6. Other characteristics

	Indicator	Typology
O T H E R	Average residence time	11 years (author's own calculation) 11–20 years (drawing on various sources)
	Tributary/effluent capacity	10.6 m^3/s
	Spring/groundwater	15.5 m^3
	WS/LA relationship	4.48
	Water level changes	present
	Thermic cycle	dimictic
	Summer transparency (Secchi disk)	3–5 metres
	Trophic classification	mesotrophic to eutrophic

Climatic elements

Given the Prespa valley's proximity to the Adriatic and Aegean Seas, one would expect the area to be significantly influenced by the climate of the Mediterranean basin. However, because the Prespa valley is surrounded by high mountains, it has a highland climate, which is somewhat tempered by the presence of the lake, as this also influences the valley's climate. Given the impacts resulting from geographical and local factors and also the specific orographic conditions that influence the dynamic factors of the climate, three different types of climate exist across the watershed as a whole (PLWMP-TR1 2010):

- Warm sub-Mediterranean climate at altitudes of 600–900 m and cold sub-Mediterranean climate at altitudes of 900–1,100 m
- Sub-mountainous climate at altitudes of 1,100–1,300 m and mountainous sub-Mediterranean climate at altitudes of 1,300–1,650 m
- Sub-alpine climate at altitudes of 1,650–2,250 m and alpine climate at altitudes above 2,250 m

The Prespa basin's specific local climate is the product of its relief and altitude, the fluctuations of its lakes' water levels, and the influence of the nearby Mediterranean Sea. The valley's climate is predominantly warm-continental, making it well suited to agriculture and tourism. However, the influence of the Mediterranean climate is weak.

The following temperatures have been derived using the data recorded during the years 1952–95 (see also Table 7):

- Absolute minimum = -26.5°C (14 January 1968)
- Average temperature = 9.6°C
- Absolute maximum = 37.0°C (6 July 1988)

The Prespa valley is characterised by strong solar radiation, which averages from 1,400 to 2,600 hours per annum. In terms of wind and airflow, the local wind regime is determined by the lake because the valley's air heats up unevenly over the land and the lake, which increases the overall frequency of winds in the area. Fog in the Prespa area is rare, mainly because of the regular movement of air in the valley and the presence of large areas of lake water (PLWMP-TR1 2010).

Table 7. Main climatic parameters recorded at the Resen climatological station (PLWMP-TR1 2010)

Month	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**Annual**
Temperature in °C (recorded in 1952–95)													
Absolute min. temp.	-26.5	-21.0	-22.0	-8.5	1.7	0.0	3.2	3.0	-5.6	-8.0	-15.5	-21.5	-26.5
Average temp.	0.3	1.4	4.1	8.8	13.4	16.9	19.0	18.2	14.9	10.0	5.7	2.1	9.6
Max. temp.	18.8	20.0	22.8	26.2	30.5	35.4	37.0	34.0	31.4	27.5	22.5	17.5	37.0
Precipitation in mm (recorded in 1961–90)													
	68.8	77.1	55.3	53.3	62.4	35.9	27.0	26.5	49.0	75.0	97.4	77.2	705.0
Cloud cover (recorded in 1961–90)													
Cloud cover	6.4	6.1	6.1	5.3	5.0	3.7	2.2	2.1	3.2	5.1	6.6	6.6	4.8
Average monthly and annual relative air humidity (%) (recorded in 1961–90)													
Humidity	81	81	76	71	69	67	66	69	72	77	78	80	74
De Martonne aridity index (recorded in 1961–90)													
Aridity index	84.2	63.5	45.8	31.8	36.3	17.0	12.3	12.4	23.2	47.1	70.1	73.9	35.6

While numerous rain gauges are installed around the basin, no gauges are installed in the high-mountain areas. For this reason, isohyet and isothermal maps have been created using data from Macedonia's Administration for Hydrometeorological Affairs, and they indicate that mean annual rainfall in this region can reach over 1,000 mm. The maps were developed for the whole watershed in order to define mean temperature and precipitation levels (Figure 15).

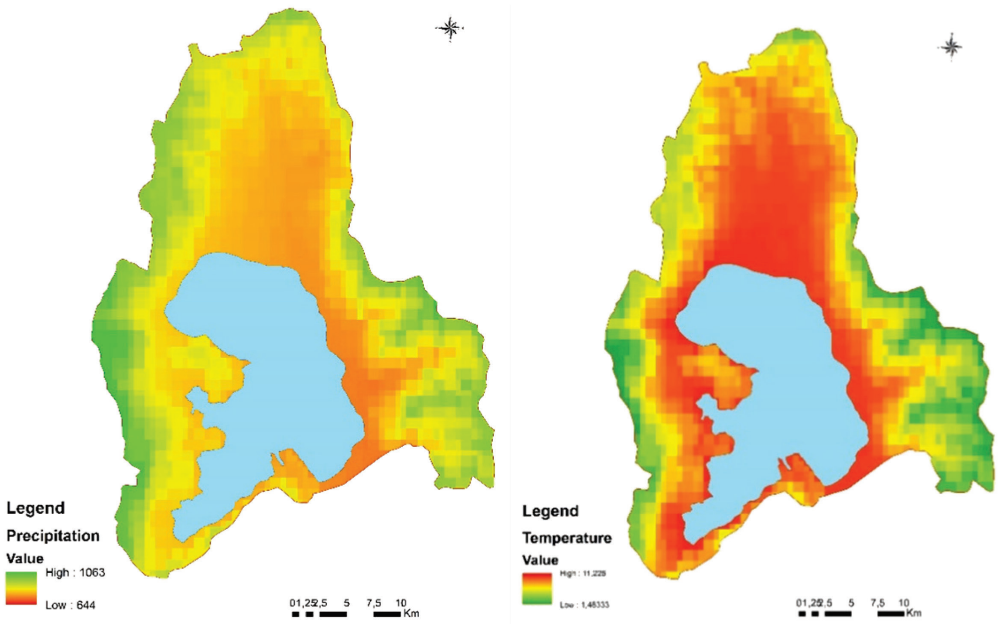


Figure 15. Isohyet and isothermal maps of the Macro Prespa watershed (author's own work; Mincev 2016)

As these maps show, the average temperature in the drainage basin is 8.02°C (range: 2.2°C to 10.45°C) and the average precipitation rate 831 mm (range: 722 mm to 1,063 mm).

Hydromorphological elements

Water level oscillation

Prespa Lake has a unique hydrological system. Its hydraulic connection with Ohrid Lake through the karstic massif of Galitsica Mountain constitutes the most important source of water for Ohrid Lake, contributing over 40% to its water balance. The latest research (Popov et al. 2009) shows that it takes only six hours for water to travel from Zavir (Zaveri) through the karstic system to Tushemisht, which means that any change in Prespa Lake's ecosystem would also have an immediate effect on Ohrid Lake.

Macro Prespa's water level significantly oscillates. A flood event in 1963 saw this lake reach 853.4 m above sea level, which corresponds to a lake surface area of approximately 280 km². The water level has decreased over time to a current elevation of 844.65 m above sea level, with the sharpest decline recorded between 1986 and 1991 (Popovska 2004). The lowest water levels observed in recent times occurred in summer 2002 when the elevation dropped to around 844.50 m above sea level.

Prespa Lake has no free surface outflow. Anovski et al.'s "*Study of Prespa Lake's hydrology using isotopes and other relevant techniques*" presents some results from environmental isotope measurements (Anovski et al. 2013). These results indicate that 52% of the mean discharge of the Tushemisht springs is recharged from Prespa Lake. The remaining 48% comes from precipitation infiltration through Mali i Thatë and Galitsica Mountains.

While fluctuations in the water levels of Micro Prespa Lake and Ohrid Lake are moderate, Macro Prespa in particular has experienced three sharp drops in water level in 1975–77 (1.2 m), 1987–90 (3.7 m) and 2000–2002 (2.2 m), respectively (Figure 16; Popovska 2004). The causes of this phenomenon are not yet fully understood.

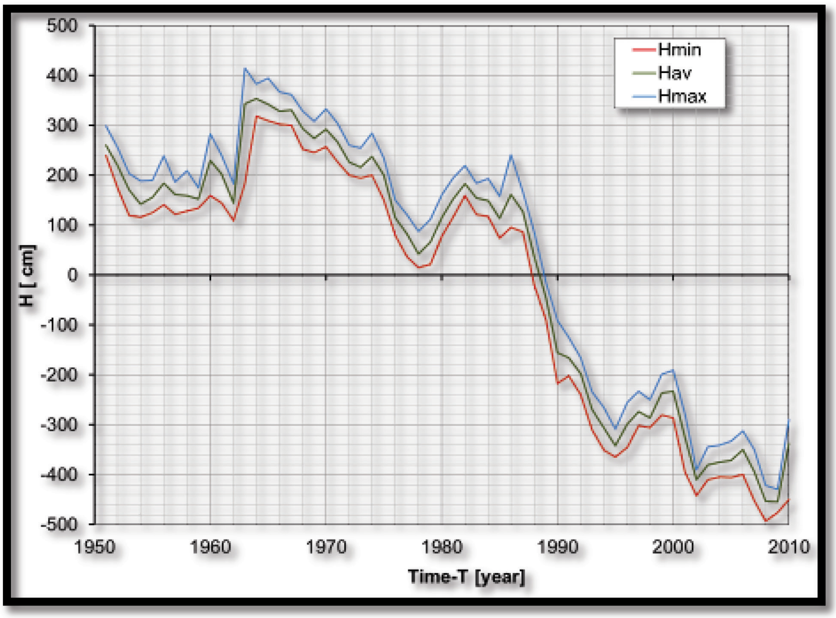


Figure 16. Water level of Macro Prespa Lake (PLWMP 2012, based on Popovska 2004)

The **hydrological monitoring system** comprises lake and river hydrological stations. Official measurements were first taken in April 1935 in the territory of present-day Macedonia, when a water level gauge was installed in the village of Stenje on the north-western shore of Macro Prespa Lake. The measurements were interrupted between 1941 and 1945 due to World War II. After July 1948, more stations were installed in Asamati, Nakolec and Pretor on the lake's eastern shore in Macedonia. Measurements have been continuously taken in Macedonia since 1945. Furthermore, water level gauging stations have been installed in Pustec in Albania (data from 1952 onwards) and in Psarades in Greece (data from 1969 onwards). The water level observations are based on the national geodetic system data of these three countries (Popovska 2004).

Main rivers

The main rivers in the area are Istočka Reka, Golema Reka, Kurbinska Reka, Kranska Reka, Brajcinska Reka and Agios Germanos (Table 8). From a hydrological point of view, there are several ephemeral streams that, in the past, have witnessed flash-flooding events and are thus considered as a hazard. The difference in altitude from the sources of these streams to their mouths is considerable (>1,000 m).

Table 8. Hydrological data for the main rivers (PLWMP-TR2a 2010)

River	**Watershed area** (km²)	**Length** (km)	**Discharge (Q) (m^3/s)**		
			Q min	Q avg	Q max
Istočka Reka	90.00	19.71	0.01	0.71	28.00
Golema Reka	174.00	28.70	0.02	1.10	41.10
Kurbinska Reka	8.64	6.07	0.007	0.13	5.88
Kranska Reka	38.05	11.35	0.01	0.57	28.42
Brajcinska Reka	73.96	18.30	0.08	1.17	57.94
Agios Germanos (Greece)	65.80	17.00	0.02	1.17	

The whole drainage basin comprising Macro and Micro Prespa Lakes can be subdivided into four main sub-basins or hydrogeomorphological (HGM) areas. The main rivers are located in the northern and western sub-basins. Specifically, the Istočka Reka and the Golema Reka are in the northern sub-basin and have a combined average discharge of 1.81 m^3/s (HGM area II), and the Kurbinska Reka, Kranska Reka, Brajcinska Reka and Agios Germanos rivers are located in the western sub-basin and have combined average discharge of 3.04 m^3/s (HGM area I) (Table 9).

Table 9. Main hydrological characteristics of the HGM areas in Prespa Lake's watershed

Sub-basin	**Area (km^2)**	**Mean annual run off (m^3/s)**	**Mean annual specific discharge ($l/s/km^2$)**
HGM area I – Western sub-basin	239.9	2.4	9.7
HGM area II – Northern sub-basin	364.0	4.6	14.2
HGM area III – Eastern sub-basin	244.4	3.6	13.4
HGM area IV – Southern sub-basin (pertaining to Micro Prespa)	233.0	2.5	11.4

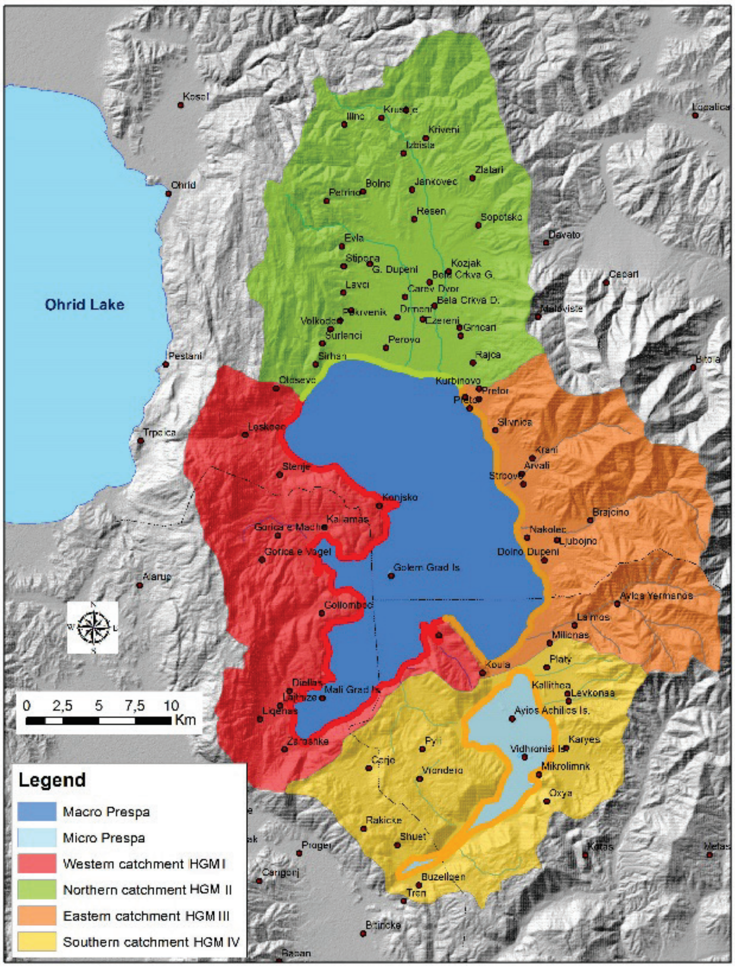


Figure 17. Main HGM areas for Macro and Micro Prespa Lakes

Water transparency

Krstic (2003) measured water transparency from June 2002 to May 2003 and, on an unofficial basis, continued to take measurements after this period. The highest levels of water transparency were observed in Macro Prespa lake in late autumn and winter (November and December), whereas the lowest levels occurred in summer (June and July). This typical cycle with minimum transparency in summer and maximum in winter is causally linked to the lake's biological activity. In summer, algae growing in the littoral zone turn the water green and reduce transparency to its minimum level. In autumn, as the amount of sunlight decreases, the algae die off and thus the highest levels of transparency are recorded. As algal growth depends directly on the concentration of nutrients present, transparency also serves as an indicator of the eutrophic state of that lake. Measurements in Prespa Lake show transparencies of 2.75 m (range: 1.55–5.60 m) in the pelagic area and 2.77 m (range: 1.20–5.50 m) in the littoral zone.

2.3 Development issues

2.3.1 History

Prespa Lake has been inhabited for many centuries. The Golem Grad area contains numerous archaeological remains from Neolithic, Hellenic, Roman, Byzantine and Ottoman times, and there are more than 130 archaeological sites around the lake. The Prespa area was a popular trading centre in Roman times, mainly because of its proximity to important roads such as the Via Egnatia.

Today, the lake is surrounded by many villages and towns, with the largest settlement being Resen in Macedonia. Other towns in the area are Agios Germanos, Laimos, Milionas, Platy, Kallithea, Lefkonas, Prespes, Oxia, Pyli and Psarades. The watershed is home to some 5,000 people in the Albanian sector; around 1,600 people in the Greek sector, who inhabit 12 villages there, and some 17,500 people in the Macedonian sector.

Thirty years ago, Prespa Lake was one of the region's most attractive tourist destinations. It provided constant and stable supplies of water for households and agriculture, and thus ensured the sustainable development of the region. However, after a period of unfavourable hydrological conditions, the system lost large quantities of its freshwater, leading within 25 years to a drop in the lake's water level of between eight and nine metres. This not only severely affected the lake's valuable shoreline habitats but also intensified major degradation processes. Because of its attractiveness, particularly in terms of its climate, clean air (for which the spas of Oteševo and Bolno were founded) and proximity to national parks, Prespa Lake experienced substantial growth in its tourism industry up to the early 1990s. However, the lake's decreasing water level and social changes in the region over that decade saw tourism decrease to the point that certain tourism facilities, especially those in Oteševo and Krani, were abandoned. In the last three to five years, however, Prespa's tourism industry has begun to pick up again.

2.3.2 Human pressure on the lake

Over recent years, the lake ecosystem has been affected by human pressure such as pollution (Figure 18), land and water use (Figure 19), as well as threats to rare and vulnerable animal and plant species. These pressures affect the lake ecosystem in many ways. One of the main adverse effects is eutrophication. High biomass of phytoplankton may cause anoxia and indiscriminate kills of fish and other animals (anoxic layers are already present at depths greater than 12 m). Likewise, blooms of toxin-producing algae may intoxicate numerous life forms, diminish biodiversity and alter the dynamics of the entire ecosystem.

The principal causes of eutrophication are nutrient and organic matter runoff from cropland, watershed erosion processes and sediment transport, and untreated wastewater and solid waste. It is only by controlling these anthropogenic inputs and actively managing the lake by extracting excess organic matter that its health can be improved and its resilience strengthened (PLWMP-TR2 2010). The pollution and eutrophication processes not only affect the region's valuable biodiversity but also its key sectors tourism, water and fishing, all of which are essential for the socio-economic wellbeing of local populations. All the aforementioned processes are believed to be responsible for the current negative demographic trends in the region (PLWMP-TR2 2010).

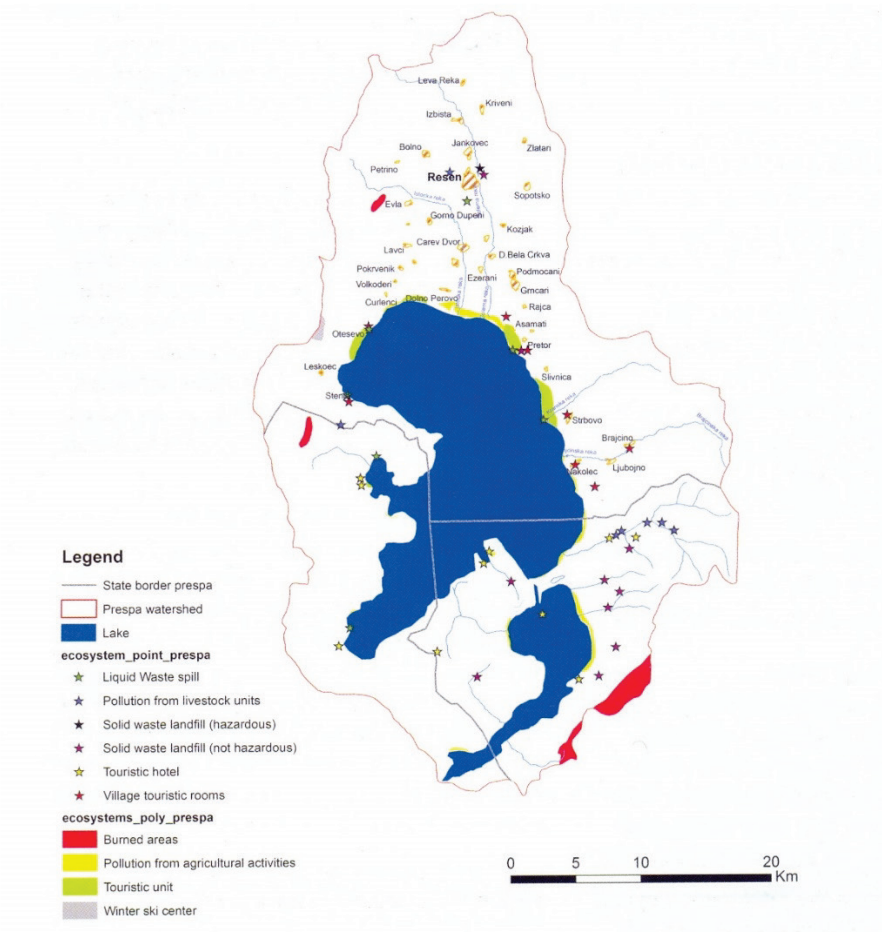


Figure 18. Sources of pollution in the Prespa watershed
(adapted from PLWMP 2012)

Prespa Lake watershed is, and has been for a considerable time, under significant pressure from pollution, which also results from the uncontrolled use of various pesticides and from materials used in industrial production. Even the upstream sections of rivers located in the basin’s high ground, which in normal situations are used as reference cases because they are usually barely or not affected by such pollution, are also under obvious pressure (Figure 20).

The surface water bodies in the Prespa Lake watershed have been and are subject to intense pressure due to irregular waste disposal and farming. Agricultural production affects terrestrial natural habitats and the aquatic environment in several ways. Crop growing diminishes the levels of nitrogen, phosphorus and other nutrients in the soil and provokes pest infestations. This is addressed by the application of fertiliser and pesticides which in turn may cause environmental problems including (pesticide) residues. Farming activities enhance the pressure on water bodies, especially watercourses and wetlands, and increase the nutrient load of the two Prespa Lakes because nutrients running off fields are not being naturally absorbed before they enter the basin’s water bodies (PLWMP 2012; Chapter 3 of the present report). Human pressures are, therefore, the root cause of the unsatisfactory ecological status of this area’s surface water and groundwater bodies.

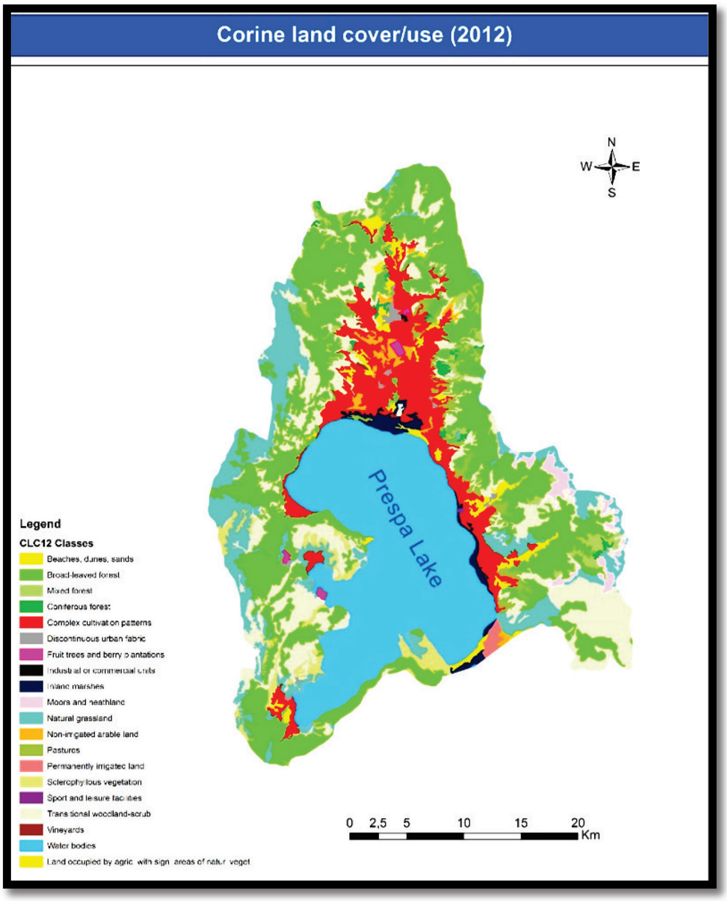


Figure 19. Corine land cover/use map for the Prespa watershed
(Corine dataset, 2012)

NB: Corine land cover/use data is based on measurements taken using Landsat satellite imagery with a resolution of 30 m, equivalent to scale 1:100,000. The total area employed differs slightly from that used by the GIS experts, whose more accurate maps and images.

Table 10. Corine land cover/use (Corine LCU Level III)

Corine LCU Class – Level III	Area (ha)	%
Beaches, dunes, sands	288.07	0.3
Broad-leaved forest	31,230.30	28.4
Complex cultivation patterns	10,550.80	9.6
Coniferous forest	586.25	0.5
Discontinuous urban fabric	509.95	0.5
Fruit trees and berry plantations	272.75	0.3
Industrial or commercial units	28.49	0.0
Inland marshes	1,372.71	1.3
Land principally occupied by agriculture, with significant areas of natural vegetation	1,895.73	1.7
Mixed forest	1,751.05	1.6
Moors and heathland	1,612.90	1.5
Natural grassland	9,899.74	9.0
Non-irrigated arable land	1,022.29	0.9
Pastures	1,679.25	1.5
Permanently irrigated land	331.30	0.3
Sclerophyllous vegetation	2,607.10	2.4

Corine LCU Class – Level III	Area (ha)	%
Sport and leisure facilities	26.14	0.0
Transitional woodland-scrub	17,611.80	16.0
Vineyards	35.92	0.0
Water bodies	26,558.00	24.2
Total	109,870.54	100.0

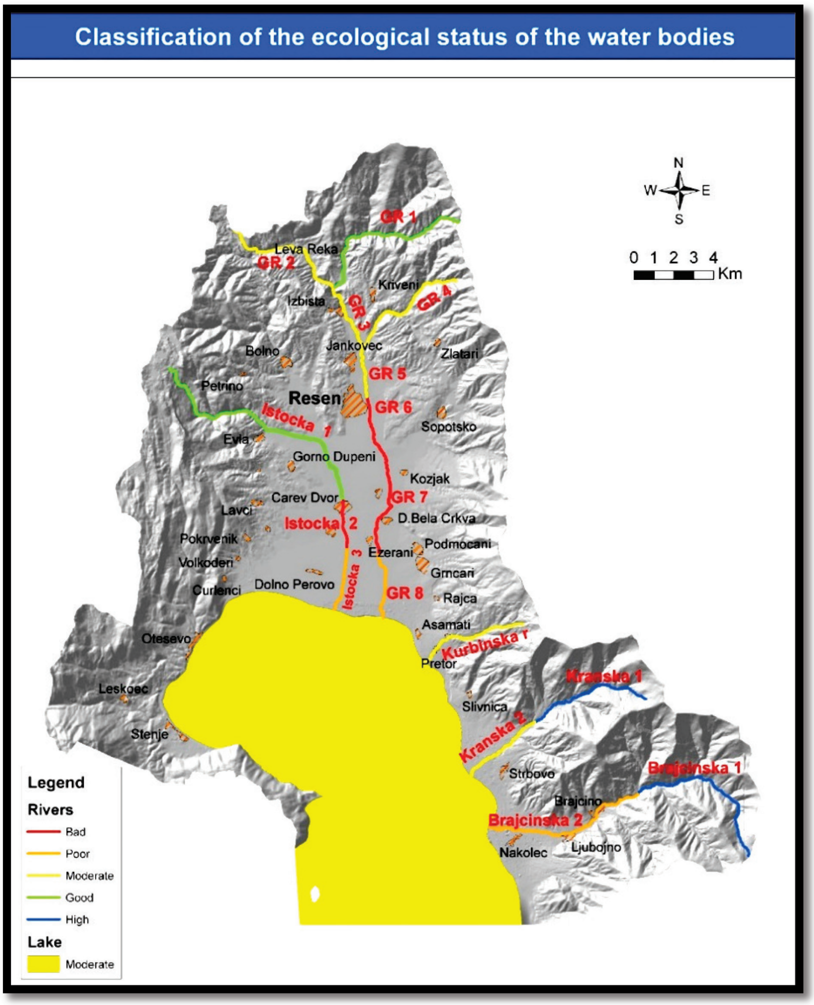


Figure 20. Map of the ecological status classifications of water bodies in the Macedonian section of the Prespa watershed (Prespa Lake Watershed Management Plan 2012)

2.3.3 Protection status

The Prespa basin has been identified as one of Europe's major transboundary 'ecological bricks' and as a biodiversity hotspot. Designated protected areas exist in each of the basin's three countries:

- Albania's Prespa National Park includes the drainage basin of both Macro and Micro Prespa Lakes and is subject to specific zoning.
- Pelister National Park in Macedonia is the oldest designated national park in the area (1948). Although the larger section of the park lies outside the basin, in 2008 its jurisdiction was expanded to cover the upper part of the Brajcinska River valley.

- Galitsica National Park includes most of the eastern side of the Macro Prespa basin in Macedonia and extends beyond the confines of the basin to the shores of Ohrid Lake.
- The Ezerani wetlands, formerly a strict nature reserve, became a designated nature park in 2011. They are located on the northern shore of Macro Prespa Lake and are a designated Ramsar site.
- Since 1971, in the Greek section of the Prespa basin, an area of 19,470ha has been designated as Prespa National Forest (PNF).

2.3.4 Ohrid-Prespa Transboundary Biosphere Reserve

This Reserve comprises a stretch of territory shared by Macedonia and the Republic of Albania, and in 2014 it was added to UNESCO's World Network of Biosphere Reserves (Figure 21). The Reserve is the first transboundary protected area in the Balkans. It was first established in February 2000 on the back of a joint declaration of the prime ministers of Albania, Greece and Macedonia, which was itself prompted by a proposal from the Society for the Protection of Prespa and WWF Greece. Given its geomorphology, rich ecology and biodiversity, the Prespa area is a unique natural area worldwide. It is a single catchment basin, which, if it is to be effectively protected, requires a joint management policy from the three states that share it. In accordance with the prime ministers' joint declaration, this collaboration has three broad aims to:

- safeguard the natural and cultural values of the Prespa basin with the participation of local communities,
- promote the economic and social welfare of its residents, and
- strengthen peace, friendship and collaboration among the three populations.

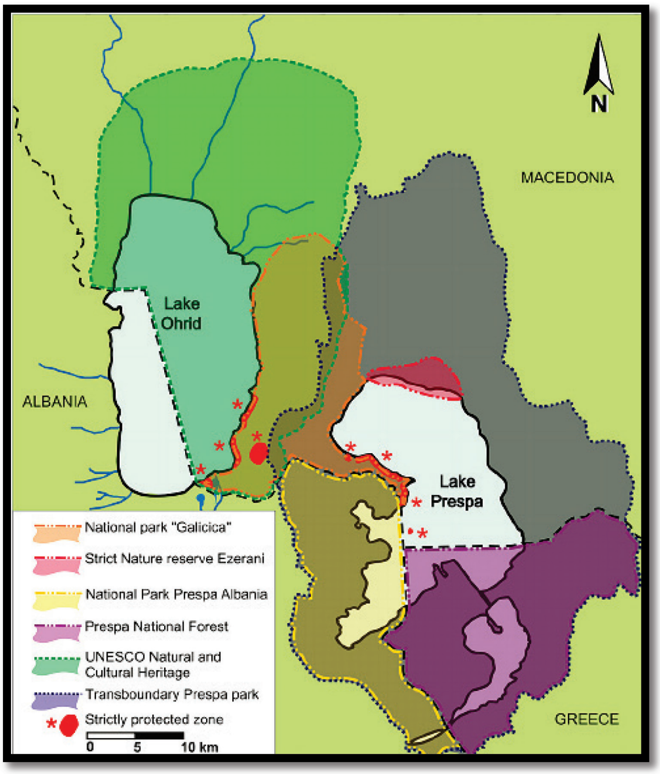


Figure 21. Map of protected areas in the Prespa basin (Kostoski et al. 2010)

2.4 Lake management

Prespa Lake's management is shared between Albania, Greece and Macedonia.

2.4.1 Lake management in Macedonia

Competences

The main national body competent for water is the Ministry of Environment and Physical Planning (MoEPP). Macedonia's Law on Waters regulates matters related to:

- "surface waters, including permanent and intermittent watercourses (…), **lakes**, reservoirs and springs; groundwaters, the riparian lands and wetlands;
- the management of waters, riparian lands and wetlands, which also includes water resource distribution, water protection and conservation, and protection against the harmful impact of waters;
- water management structures and services;
- the organisational arrangements and financing of water management; and
- the manner, conditions and procedures under which water can be used or discharged" (excerpt from Law on Waters, n°87, art. 1, 2008).

According to the Law on Waters of Macedonia, the shore belt of a lake or an impoundment is a 50-metre-wide zone that is measured from the line of the highest determined water level. Local municipalities are tasked with determining the riparian belt, whereas the MoEPP is tasked with evaluating efforts to this regard.

According to Article 131 on the Regulation and Maintenance of Surface Waters, among other things it is prohibited to remove sand, gravel and stones from the banks of water bodies, to cut trees or destroy vegetation on the banks, to dump waste material, etc. The state water-economy inspector (from the environmental inspectorate) is tasked with monitoring and, in cases where the laws are broken, ensuring the relevant penalties are applied to guilty parties.

Part of the western coast of Prespa Lake falls within Galitsica National Park. Therefore, according to the Law on Nature Protection, the national park's administration is also obliged to manage the riparian zone. Likewise, a section of Ohrid Lake's eastern coast falls within Galitsica National Park.

The management of lakeside land has, because of recent legal changes, been transferred to local municipal administrations (LMAs). While LMAs provide permits for urban equipment on the beaches and inspect the work of concessionaires, it is still the Ministry of Transport and Communications (MTC) that manages the issuing of **concessions** for these beaches.

According to the Law on Spatial and Urban Planning, LMAs are obliged to draw up new urban plans for their **urban** construction activities. The MTC then approves these plans – or not – in line with guidance or assent given by the MoEPP. Plans must be prepared as part of Strategic Environmental Assessments, which require the MoEPP's approval. As such, the MoEPP is able to postpone, request changes to or even stop a development that may threaten the lake and its shore.

Monitoring and research

With the UNDP's support, a unit for monitoring Prespa Lake's water quality in line with WFD requirements has been established at the municipal level.

Given the Ohrid-Prespa region's ecological importance, numerous studies have been carried out on its lakes and catchment areas. The Public Scientific Institution's Hydrobiological Institute was established in Ohrid in 1935 and was the first scientific institution in the Balkans. The Institute has undertaken a number of projects and programmes involving the monitoring of the lake's water quality. It also carried out numerous studies on the riparian zone. Likewise, the Biology Institute under the Faculty of Natural Sciences and Mathematics at the University of Saints Cyril and Methodius in Skopje carried out several studies in these areas.

GIZ's 2015 report *Initial Characterisation of Lakes Prespa, Ohrid and Shkodra/Skadar* includes detailed information on monitoring sites and the current status of the lake (Peveling et al. 2015).

Access to the shoreline

In general, the shoreline is state-owned. In cases where sections of the shoreline fall within a private plot and the development of this section is mooted, the state is entitled to preserve this shoreline by nationalising it. According to the Law on Waters, citizens are entitled to freely access the riparian belts of lakes, and the LMAs are duty-bound to ensure this access is maintained.

2.4.2 Lake management in the Republic of Albania

Competences

The competent national body for water quality monitoring is the Ministry of Environment (MoE), while the Ministry of Agriculture, Rural Development and Water Administration (MARDWA) is in charge of water administration.[5] The country's Law on Water regulates matters related to:

- surface waters, including watercourses, lakes, reservoirs, springs and groundwaters;
- riparian lands and wetlands, including water protection and conservation, and protection against the harmful impacts of water;
- water management structures and services;
- organisational arrangements and the financing of water management;
- the manner, conditions and procedures with which water can be used or discharged.

The main law covering lake management issues in Albania is the Law on the Integrated Management of Water Resources No. 111/2012, which is fully harmonised with WFD 2000/60/EC of the European Parliament. This Law aims to protect and improve water environments and water resources, ensuring their rational exploitation, fair distribution and protection from pollution, and it provides for the establishment of the central and local institutional frameworks required to implement national management and administration policies. According to this law, all of the Republic of Albania's water resources, including its lakes, are state owned and must be administered by state bodies. The main central authorities for the administration and management of water resources are the Council of Ministers, the National Water Council, MARDWA, MoE and the Technical Secretariat of the National Water Council.

[5] Reform of water administration ongoing at the time of publication of the present report

The **Council of Ministers** (CoM), through the Prime Minister's Office, adopts bylaws proposed by the National Water Council on water management and approves the composition and functioning of the Technical Secretariat of the National Water Council. The CoM also approves the composition of the National Water Council and regulates its operations, and it appoints a special commission for the management of transboundary waters. The CoM approves river basin management plans following their approval in principle by the National Water Council, and it approves the National Strategy for Water Resources Management.

The **National Water Council** is the central decision-making body responsible for the management of water resources. The National Water Council is the inter-ministerial body chaired by the Prime Minister.

The **Ministry of Environment**, in collaboration with line ministries, develops and implements policies, strategies, programmes and projects aimed at ensuring the integrated management of water resources and the quantitative and qualitative preservation and further consolidation of these resources. The **Ministry of Agriculture, Rural Development and Water Administration** is tasked with the main duties involved in managing the nation's water bodies.

At the local level, the authorities tasked with the management of water resources are the River Basin Councils and the River Basin Agencies. The Technical Secretariat of the National Water Council is the executive organ of this Council. River Basin Councils, which are responsible for managing water resources in given basins at the local level, report to the Technical Secretariat of the National Water Council. River Basin Agencies, which are set up in each watershed, are embedded in the central government structure.

Protected areas

Law No 9806 of 6 June 2002 on Protected Areas provides the legal basis for the management of protected areas in Albania. It provides the framework for the designation, conservation, administration, management and sustainable use of protected areas and their natural and biological resources. The law pays special attention to the management of water areas and other natural resources within protected areas. It also provides the legal basis for the organisation of administrative structures and management committees for certain categories of protected area. It also defines the procedures for setting up and operating the management committees.

Prespa National Park in Albania was officially gazetted in 1999 and inaugurated on 2 February 2000 by the then President of Albania. According to Law No 9806 on Protected Areas, all construction activities occurring within the park area are to be managed through a zoning system. In Prespa National Park there are currently 12 villages, which fall within one of three communes and are inhabited by a total of 5,634 people.

Monitoring and research

Monitoring is conducted to assess the effectiveness of park management. Water monitoring programmes are essential for assessing the main sources of pollution and eutrophication that are altering the current or potential ecological status of the lake ecosystem. Discharges from tributaries flowing into this ecosystem must also be monitored. A detailed monitoring plan for physical and chemical parameters is provided in the framework of the transboundary monitoring system for both Macro and Micro Prespa Lakes. Based on archival data of the Institute of Hydrometeorology, Tirana, a programme to monitor lake water levels is in place for both lakes (with water gauge measurements taken every two or three days). The monitoring of water quality and ecological status of water bodies on the Albanian side of the lake has been conducted since 1951 under the responsibility of different state institutions.

Currently, the Fishery Inspectorate is responsible for monitoring the lakes' fish stocks. The most recent (2013-2015) and comprehensive assessment of fish assemblages of Macro Prespa has been conducted with support of GIZ (Ilik-Boeva et al. 2017). State-owned forests and pastures are managed by central government, whereas the forests and pastures defined as common property are managed by the commune authorities. Urban areas also fall under the autonomous commune organisation for the national park territory.

Access to the shoreline

The lake's shoreline is state property. Should any part of the shoreline fall within a privately owned plot and should the owner of this plot decide to develop this section of shoreline, the state is empowered to nationalise the section to maintain access. According to Albanian law, access to the riparian belts of lakes is free. As such, local governments are obliged to ensure continued free access to these areas.

3. RESULTS AND RECOMMENDATIONS

3.1 Hydrogeomorphological areas

Three hydrogeomorphological (HGM) areas have been identified (Table 11 and Figure 22). They are characterised by different geological, hydrological and morphological features which either represent an advantage for or a limitation to the natural growth of a functional shorezone. Even in the absence of significant anthropogenic pressures, shorezone functionality may be low as a result of the nature of the HGM areas. The parts of HGMs I and III that fall within Greek territory have not been surveyed but were designated as HGM areas Ia and IIIa, respectively. HGM area IV comprises the drainage basin of Micro Prespa Lake.

Table 11. Key shoreline data for each HGM area

HGM areas	Drainage basin area (km²)	Shore length (km)	Stretch numbers
HGM I – Western sub-basin	239.9	64.2	1–32 + Greek shore
HGM II – Northern sub-basin	364.0	13.2	33–35
HGM III – Eastern sub-basin	244.4	28.6	36–45 + Greek shore
HGM IV – Southern sub-basin (pertaining to Micro Prespa)	233.0	n/a	n/a

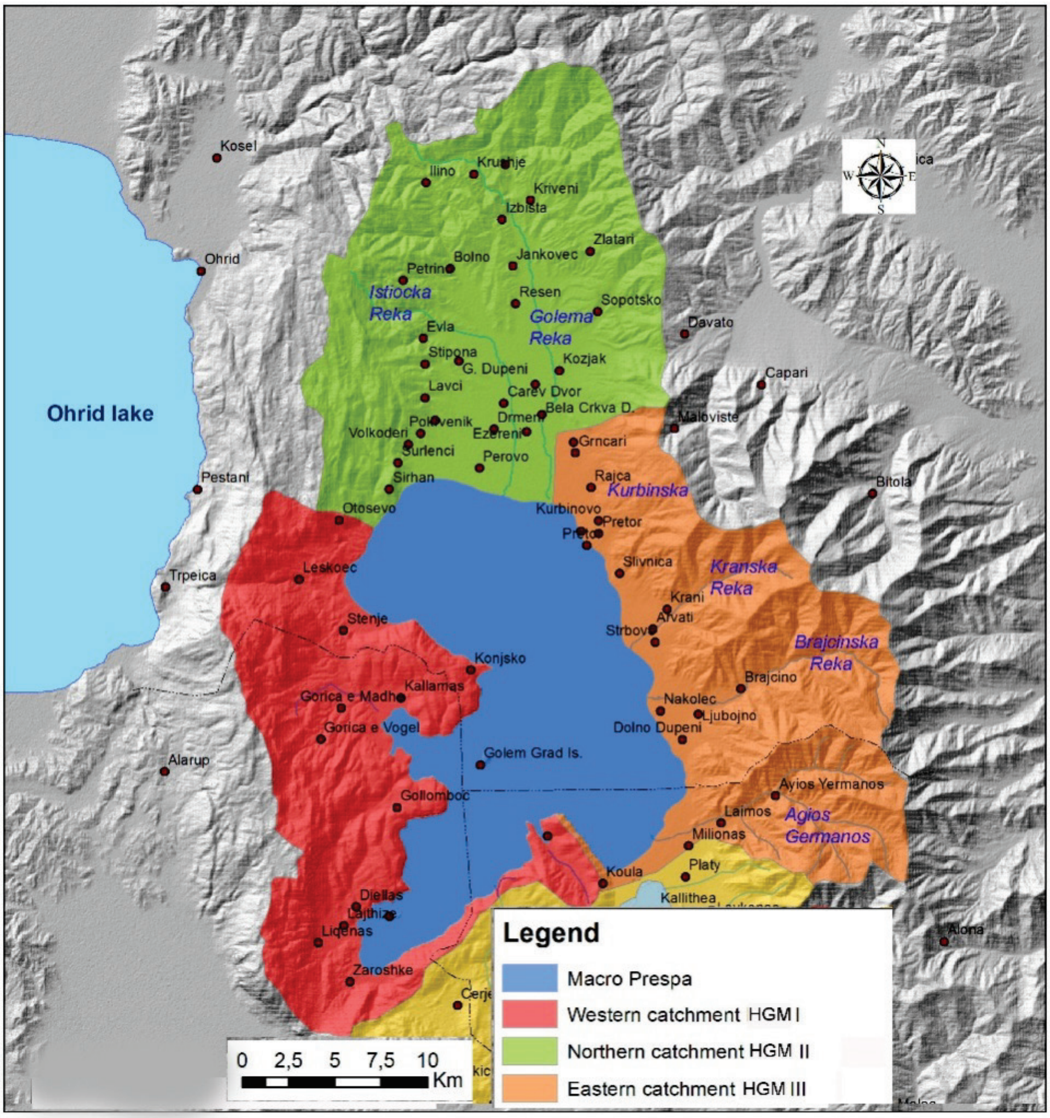


Figure 22. Main HGM areas for Macro Prespa Lake

3.1.1 HGM area I – Western sub-basin

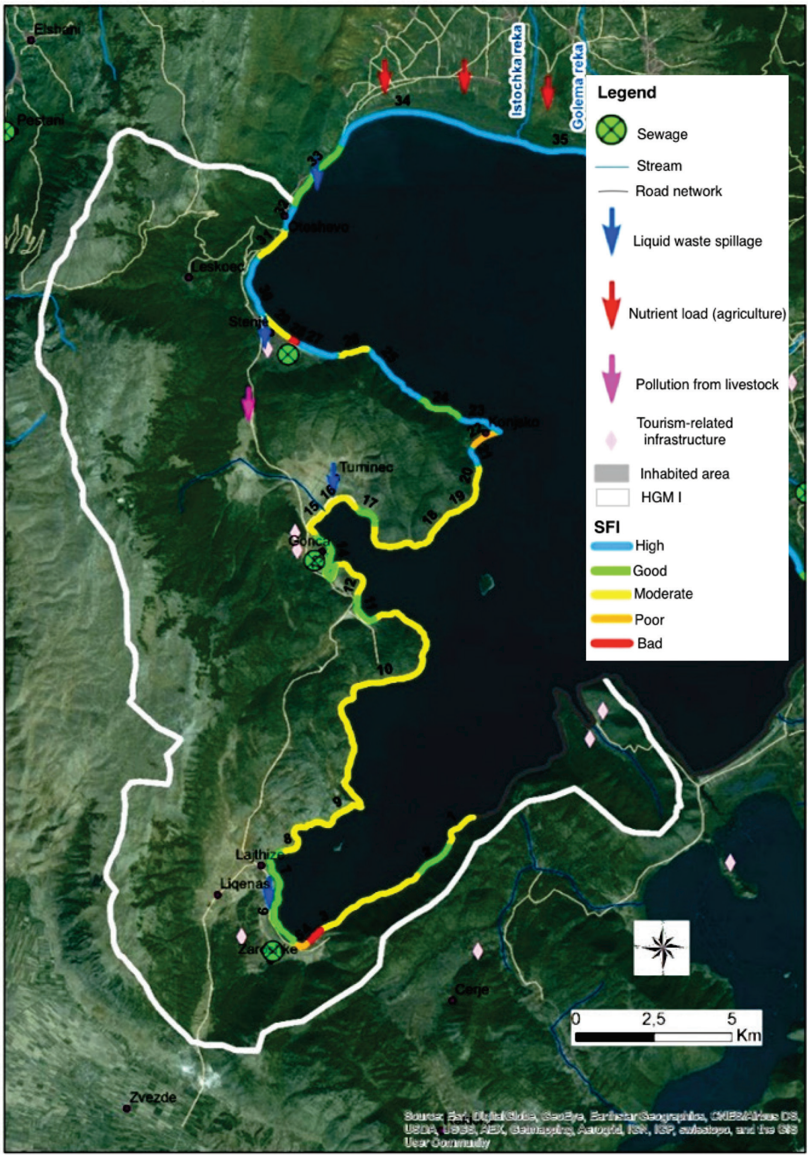


Figure 23. Main features of HGM area I and the SFI results for its shorezone

HGM area I is located on the western side of the lake (Figure 23). It starts in Greece, continues northwards through Albania and ends at the Macedonian village of Oteševo in the north-western section of the lake. This drainage basin has an area of 239.9 km^2.

HGM area I is characterised by the presence of a mountain range that separates Lakes Prespa and Ohrid and is mainly composed of permeable limestone. The range's highest peaks are Mali i Thatë (2,288 m) in the southern part and Galitsica (2,256 m) in the northern part. Because of the presence of mountains here, this area is characterised by steep slopes that descend directly into the lake.

The combined forces of nature and uncontrolled animal grazing in the Albanian section (southern part) of the Prespa basin have created a shoreline that, for the greater part, comprises cliffs that descend directly into the lake and which are covered with bare soil or limited shrub-type vegetation. The main shorezone typologies present here are typologies 3 (Figure 24, cliff with reeds) and 4 (Figure 25, just cliffs). Consequently, the functionality level in this area is, in general, naturally low (category 3 – moderate).

Shorezones with high naturality and low functionality are particularly vulnerable because they have limited resilience and reduced homeostatic capacity and are thus less able to buffer existing or potential pressures. On these shores, a minor stressor can, therefore, cause major environmental problems.

In HGM area I, human settlements are concentrated in the shorezone's few flat sections, which correspond with lake bays. Here the depth of the water favours the growth of a thick belt of reeds, which improves the overall shorezone functionality (shorezone typology 2 with good functionality).

Figure 24. Example of a typology 3 shorezone: cliff skirted by reeds

Figure 25. Example of a typology 4 shorezone: cliff

In the northern Macedonian section of HGM area I, the riparian vegetation grows further inland from the shoreline, which increases the width of its functional area. The shorezone here is typology 1 with category 1 (high) and 2 (good) functionalities.

HGM area I has the lowest mean annual runoff (2.4 m^3/s) and the lowest mean annual specific discharge (9.7 $l/s/km^2$) of the four HGM areas identified in the Prespa region. The main tributary here is the Jamata Paljistrata in Albania.

There are different water sinkholes in this part of the lake, where the water seeps down through the ground to Ohrid Lake. The best known sinkhole is the Zavir hole located in Albania.

The surrounding territory mainly comprises either broad-leaved forest, found on the Macedonian side and on the southern Albanian shore within the confines of Prespa National Park, or sclerophyllous vegetation (shrubs) on the western side in Albania where unrestricted grazing has substantially modified the environment (Corine land use map 2012; authors' own observations 2016). Category 5 (bad) stretches are limited to those areas where the level of human pressure is higher, such as in the few small villages present along the shore that are often set among small agricultural fields and pasture. Some villages also contain small tourism facilities.

The whole of HGM area I falls under the protection of either Prespa National Park, Albania, or Galitsica National Park, Macedonia.

3.1.2 HGM area II – Northern sub-basin

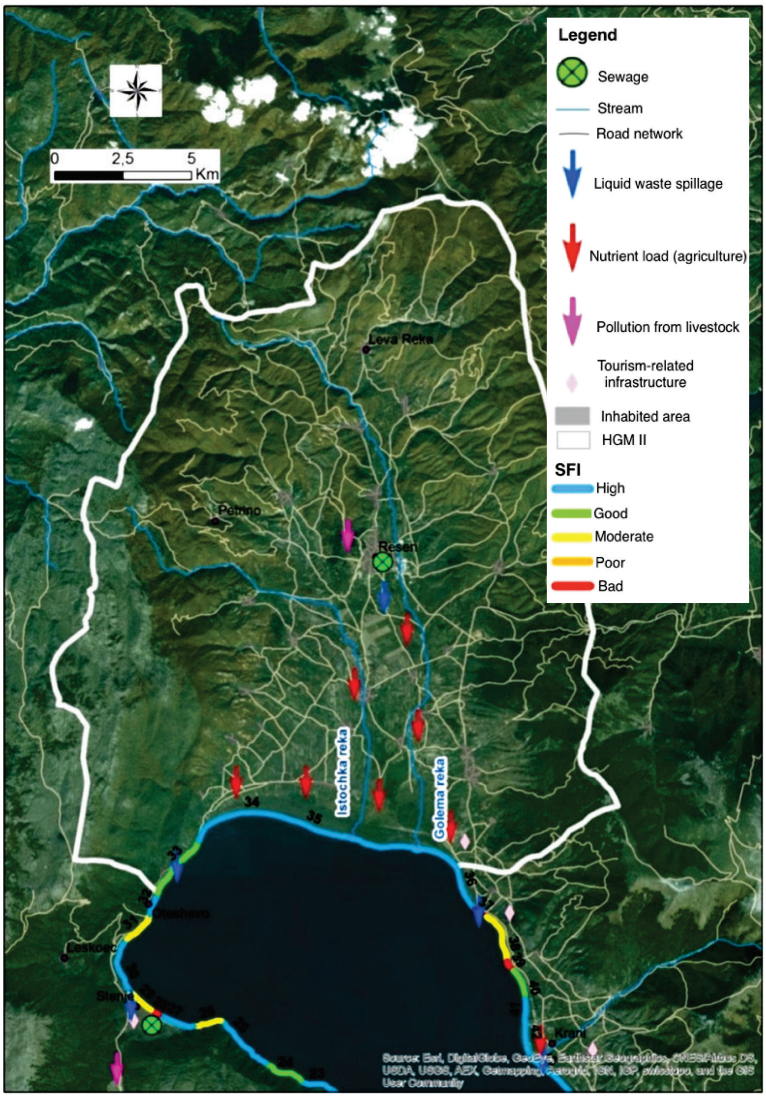


Figure 26. Main features of HGM area II and the SFI results for its shorezone

With a catchment area of 364 km^2 and a mean annual runoff of 4.6 m^3/s, HGM area II has the greatest impact on the lake. The area comprises a wide valley floor, which is heavily farmed, and contains numerous human settlements (Figure 26). Its main land-use typologies are discontinuous urban areas, orchards and berry plantations (in the northernmost section), non-irrigated arable land, and inland marshes towards the shore that fall within the Ezerani wetland nature park (CORINE Land Cover 2012).

The mountains located in the northern part of the basin are formed of impermeable granite rock and their highest peaks are Mount Plakenska (1,935 m) and Mount Bigla (1,656 m). The Istočka Reka and Golema Reka Rivers, with average discharges of 0.71 and 1.10 m^3/s, respectively, are the main rivers flowing into the lake. They import nutrients and other sources of pollution from the surrounding territory and therefore represent the biggest threat to the lake's water quality. The ecological status of these rivers, although good at their sources, progressively worsens as they move towards the lake (Figure 27).

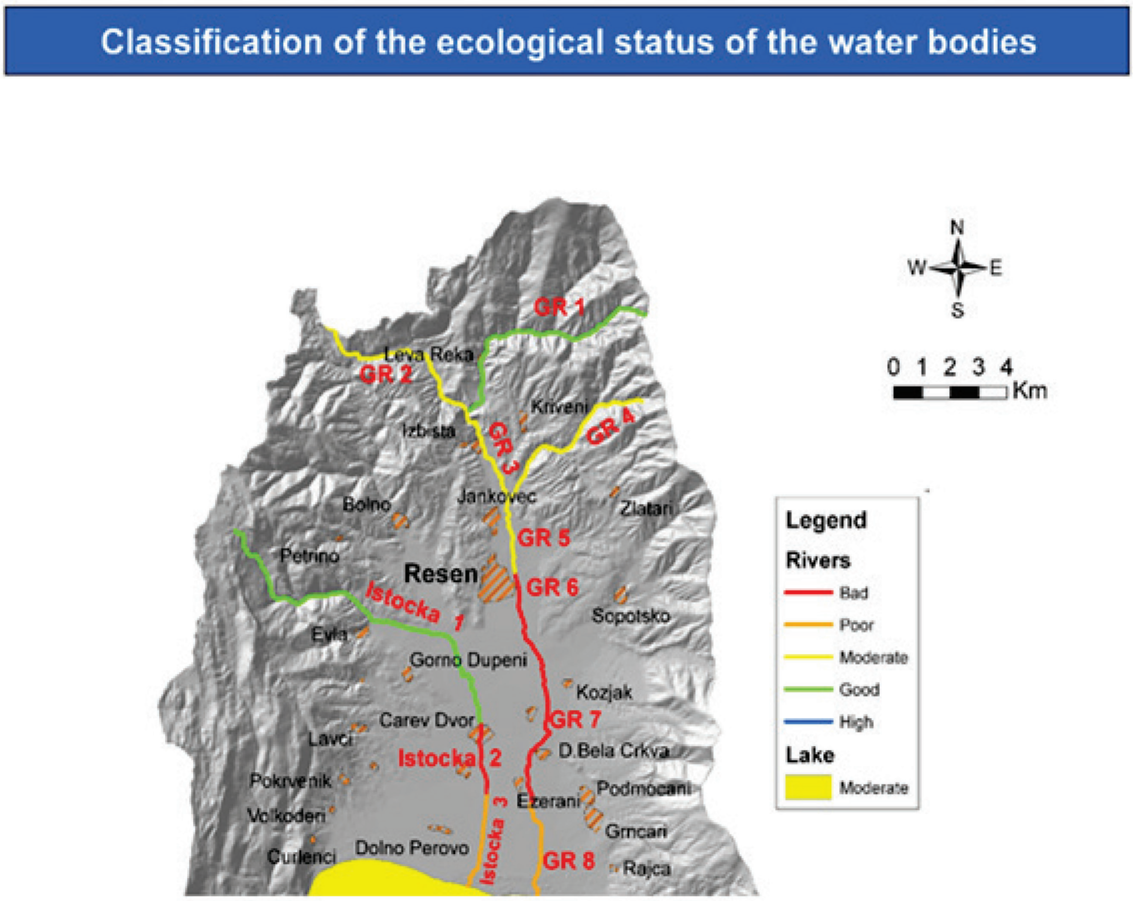


Figure 27. Map of the ecological status classifications of water bodies in HGM area II
(Prespa Lake Watershed Management Plan 2012)

Because these rivers channel the pollutants running off surrounding land into the lake, it is extremely important to monitor these rivers' water quality to ensure that the health of the lake is maintained. Another important factor for water quality in this area is the protected wetland area of Ezerani Nature Park, which was previously a Strict Nature Reserve but is now an IUCN IV Habitat/Species Management Area. The Ezerani wetlands, located near the mouths of the Istočka Reka and Golema Reka rivers, naturally filter out some of this pollution.

Given the flatness of the terrain in HGM area II, reeds can grow out into the lake for hundreds of metres, which substantially increases the overall width of the functional shorezone (Figure 28).

On the western side of HGM area II, adjacent to a wide belt of reeds, are agricultural fields that run almost all the way up to the shoreline. The shorezone on the eastern side, around the mouths of the Istočka Reka and Golema Reka rivers, is part of the Ezerani wetlands, which are rich in reeds as well as different species of riparian trees.

The presence of riparian vegetation here is very important as, by removing excess nutrients and aiding sediment deposition, it serves to filter out some of the pollutants carried by the two main rivers that would otherwise end up in the lake.

Figure 28. Example of a typology 2 shorezone: reeds only

Groundwater surveillance monitoring has been conducted as part of the Prespa Lake Watershed Management Plan (2012) for the period 2011–17. It showed that groundwater quality for irrigation purposes ranged between high and moderate. Bacteriological contamination was detected in all the monitored wells and pesticides in most of them. Major seasonal drawdown of the groundwater level was detected in a number of wells, although a comprehensive monitoring network would need to be put in place to corroborate these findings (PLWMP 2012).

3.1.3 HGM area III – Eastern sub-basin

HGM area III runs along the eastern side of Prespa Lake and, given the continuity in morphology and riparian vegetation, extends into the Greek section of the lake (Figure 30). However, for the purposes of this study, the fieldwork survey ended at the border between Macedonia and Greece.

HGM area III is characterised by a small area of flat terrain (wider than that found on the western side of the lake in HGM area I) which is mainly used for farming (Figure 29). It is skirted to the east by the impermeable granite Baba Mountains, which contain the highest peak in the Prespa watershed, Veternica (2,420 m; Figure 30).

HGM area III covers an area of 344.4 km^2, comprising the lake tributaries of the Kurbinska, Kranska and Brajcinska Reka (all of which fall in the Macedonian section of the sub-basin) as well as the Agios Germanos River in Greece. Combined, these tributaries contribute a mean annual discharge of 4.6 m^3/s.

Figure 29. View of the Prespa Lake shorezone in HGM III

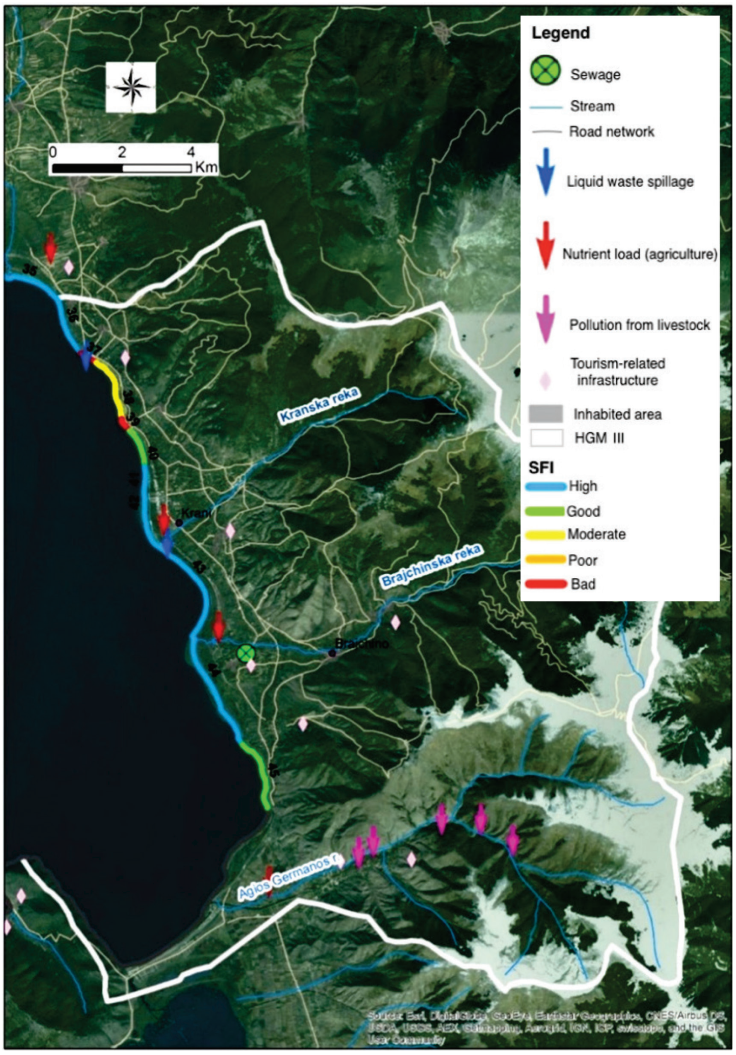


Figure 30. Main features of HGM area III and the SFI results for its shorezone

While agricultural fields and sparse urbanisation are present throughout the surrounding territory (i.e. the terrain up to 200 metres from the shoreline), the shorezone area is often natural and contains wide reed belts (Figure 31). The shorezone functionality is therefore naturally high, but decreases in locations where human pressure is higher.

Figure 31. Example of a typology 1 shorezone: established riparian trees and belt of reeds

Figure 32 shows the correlation between the width of the shorezone (red line = 0 m; dark green = >50 m) and the composition of the functional shorezone (red = bare soil; orange = grass; yellow = reeds; light green = shrubs; dark green = riparian trees). The presence of reeds is therefore an important component of this area's ecology.

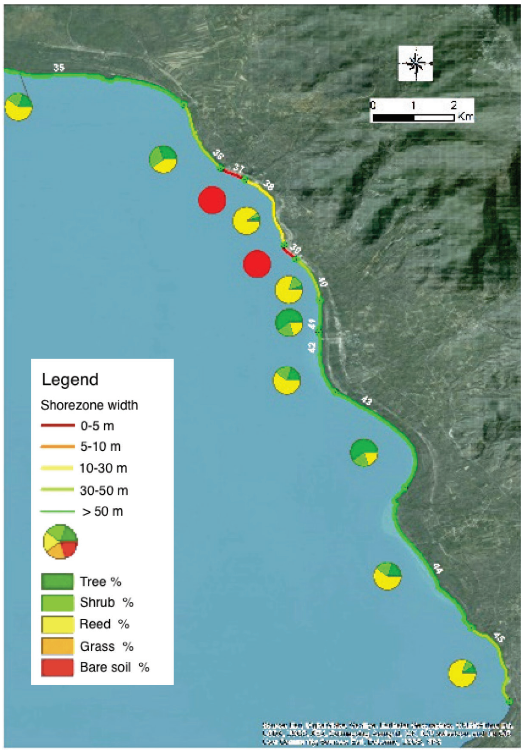


Figure 32. Composition of the functional shorezone

The main shorezone typology present in this area is typology 1 (Figure 32). The two sites in this area where functionality is absent contain beaches (0 m functional shorezone, 100% bare soil; Figure 33).

Figure 33. Example of a typology 5 shorezone: bare soil/beach with high artificiality and no functionality

While the upper sections of the rivers in HGM area III have been evaluated with a high ecological status, their downstream sections are strongly affected by human activities (including domestic sewage and diffuse agriculture-related pollution) and are thus classified with a medium or poor ecological status according to the WFD classification of ecological status of surface water bodies (Prespa Lake Watershed Management Plan 2012; Figure 34).

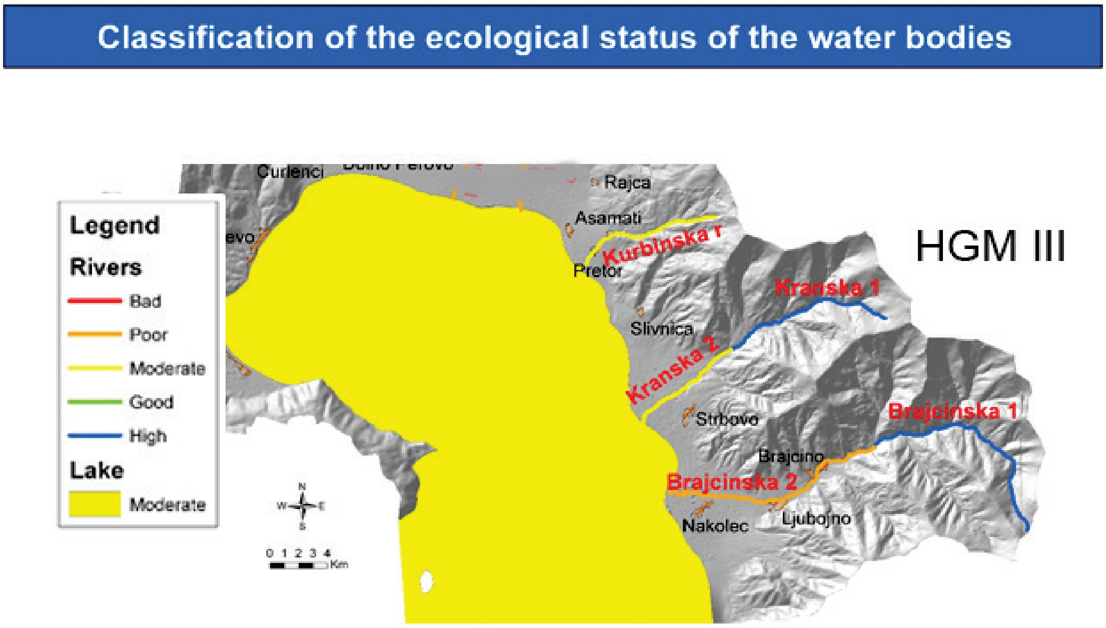


Figure 34. Map of the ecological status classifications of water bodies in HGM area III (Prespa Lake Watershed Management Plan 2012)

3.1.4 HGM areas Ia and IIIa

The parts of HGM areas I and III that are located in Greece have been designated as Ia and IIIa, respectively (Figure 35). As Ia and IIIa fall outside the territories of this study's target countries, they have not been surveyed.

Figure 35. View of the approximate lake shorezone (HGM areas Ia and IIIa) that falls within Greek territory

3.1.5 HGM area IV – Southern sub-basin

HGM area IV comprises an area of 233 km^2 of land around Micro Prespa Lake. The mountains in this area, similar to the western mountain range, are mainly formed of permeable limestone, and the whole area is part of Greece's Prespa National Forest.

Until 2000, a canal fed water from Albania's Devoll River into Micro Prespa during winter, which was then abstracted over summer. The water input from the Devoll offset the water extracted from the lake for Albania's Korça irrigation scheme, keeping the Micro Prespa's water level at an average of about 851 m above sea level. However, the Devoll inflow carried an estimated volume of 1.2 m^3/s of solid matter which resulted in significant sedimentation. The feeding and extraction was therefore stopped in 2001 and the Macro and Micro Prespa Lakes now remain separated.

3.2 Main shorezone typologies

At Macro Prespa Lake, there are five recurrent shorezone typologies, which are determined by the different parameters they display. The typologies correlate in part to the natural topography of the land surrounding the lake (e.g. steep cliffs or plains) and in part to the degree of human pressure exerted on the lake. In these typologies, the presence/absence of reeds greatly influences the width of the shorezone and therefore influences its functionality.

3.2.1 Typology 1: wide belt of riparian vegetation

Typology 1 is characterised by a belt of riparian vegetation (shrubs and trees), accompanied by reeds in the littoral zone, covering an area more than 50 metres wide (Figure 36). It provides a high value of complexity and functionality (SFI = 1). It is typically found in HGM area II, mainly on the eastern side of the Ezerani wetlands, and in HGM areas I and III in places where there is no human disturbance.

This typology of shorezone falls into the high category for functionality.

Figure 36. Established riparian trees and belt of reeds

3.2.2 Typology 2: wide belt of reeds only

In typology 2 the belt of reeds of different width runs adjacent to land that is heavily impacted by human activity. In general, this means that the land has been used for either grazing or crop growing and that its terrestrial riparian vegetation is either totally absent or present in small pockets that do not provide any ecological services.

This typology is generally found in flat bay-side areas in HGM area I and in the western section of the Ezerani wetlands in HGM area II that is populated by reeds and contains extensive apple orchards.

Figure 37. Wide belt of reeds along the western side of the Ezerani wetlands

Typology 2 shorezone falls into either the high or the good category for functionality, depending on the width of the shorezone.

3.2.3 Typology 3: cliffs followed by reeds

HGM area I extends from the Greek border to the Macedonian town of Stenje. The slope of the mountain-side terrain continues into the lake, which means that reeds and aquatic vegetation are either limited to the first few meters close to the shore or absent. At certain points along the shoreline, there are small flat areas where shrubs can grow on the land and reeds in the littoral zone. These thin belts of functional vegetation provide some functionality and are thus classified as category 2 (good).

Figure 38. Cliffs with reeds

3.2.4 Typology 4: cliffs without reeds

In this shorezone typology, which is typically found in HGM area I (mainly in the Albanian and in a small section of the Macedonian part), the slope of the mountain side descends almost vertically into the lake. As a result, the littoral zone is not suitable for the growth of reeds and most of the shore, therefore, appears bare and is colonised by only a few shrubs (Figure 39).

Despite the naturalness of this typology, its functionality – i.e. its capacity to function as a buffer zone for pollutants coming from the surrounding territory and/or as habitat for wildlife – is extremely low. Therefore, this typology is classified as category 3 (moderate).

Figure 39. Cliff with bare rock

3.2.5 Typology 5: bare soil, high anthropogenic impact

This shorezone typology occurs in areas strongly impacted by human activity. As Prespa Lake has no established urban settlements along its perimeter, these typologies are only found in sites containing artificial beaches, which lack any functional riparian vegetation and reeds (Figure 40). Typology 5 stretches are therefore classified as category 5 (bad).

Figure 40. Bare soil/beach with high artificiality and no functionality

3.3 Shorezone Functionality Index results

3.3.1 Macro Prespa Lake as a whole

Macro Prespa Lake's whole shoreline is 106.4 km. However, as the study only considered the Albanian (36.8 km) and Macedonian (47.6 km) shorelines, and not the Greek shores (19.8 km), only 84.4 km of the total perimeter were surveyed. During the fieldwork, 45 homogeneous stretches were identified (Figures 41 and 42, Table 12). The stretches are each distinguished by a unique set of characteristics.

Figure 41. Shorezone Functionality Index for the Albanian and Macedonian sides of Macro Prespa Lake

Table 12. Total number, length and percentage of length of sections with various SFI values (all territories)

SFI value	No. of stretches identified	Total km	Percentage
1 – high	13	30.7	29.0
2 – good	11	16.5	15.6
3 – moderate	15	33.6	31.7
4 – poor	2	1.5	1.4
5 – bad	4	2.0	1.9
Not surveyed (Greece)	n/a	21.7	20.4
TOTAL	45	106.0	100.0

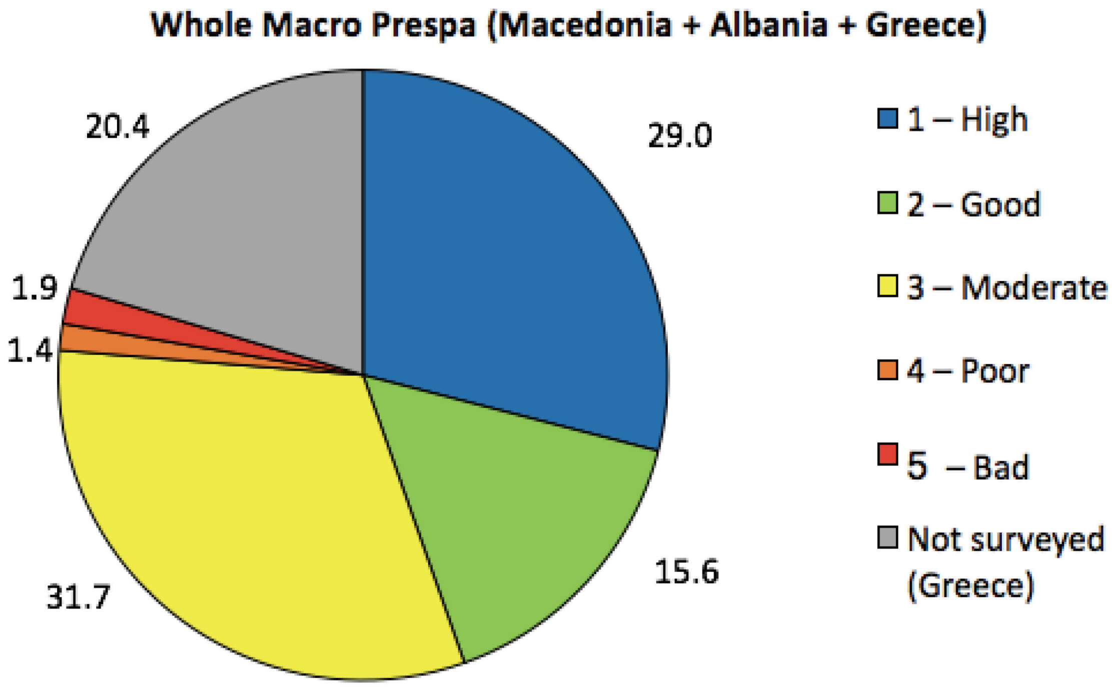


Figure 42. Shorezone Functionality Index percentages for Macro Prespa Lake as a whole (including the Greek part)

SFI results for only the surveyed shorezone on the Albanian and Macedonian side of Macro Prespa Lake are given in Table 13.

Table 13. Total number, length and percentage of length of sections with various SFI values (Macedonian and Albanian territories combined)

SFI value	No. of stretches identified	Total km	Percentage
1 – high	13	30.7	36.4
2 – good	11	16.5	19.6
3 – moderate	15	33.6	39.8
4 – poor	2	1.5	1.8
5 – bad	4	2.0	2.4
TOTAL	45	84.6	100.0

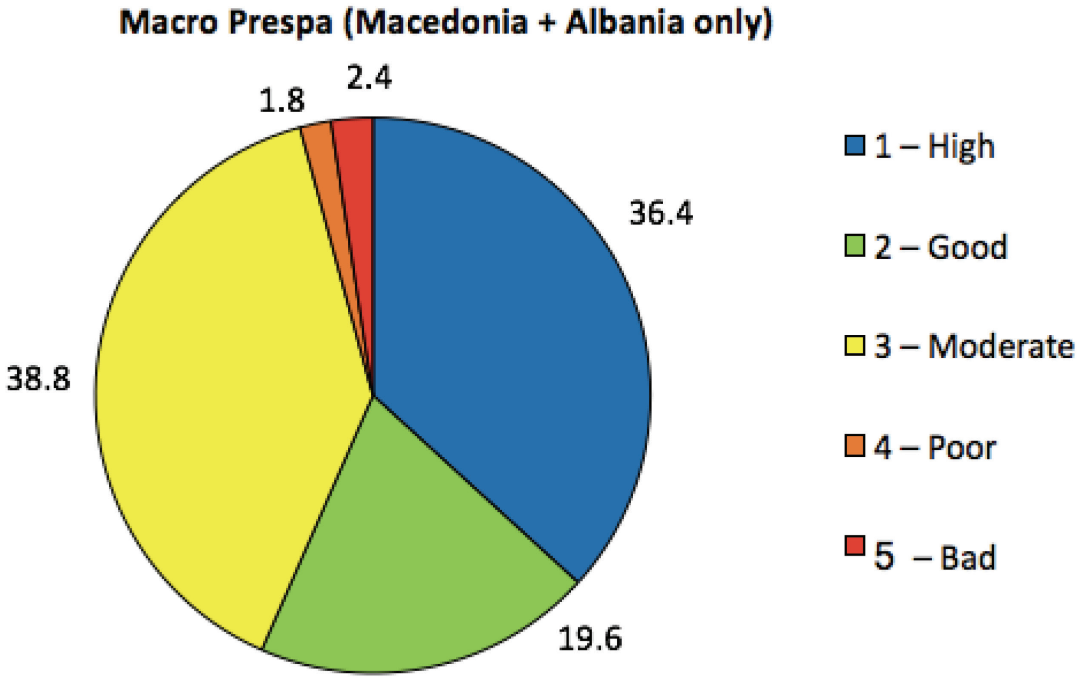


Figure 43. Macro Prespa Lake's SFI value percentages (Macedonian and Albanian territories combined)

SFI category 1 – high

All stretches falling into the high functionality category are located in Macedonia (64.7% of the total perimeter of the Macedonian side of Macro Prespa Lake) where the shorezone's topography is flatter and reeds and riparian trees can form larger belts of functional shorezone. This is the case for all of HGM area I and for isolated stretches of HGM areas II and III. This category corresponds to situations of high naturalness and the absence of human pressures.

This typology does not appear in Albania due to natural conditions (rocky cliffs falling into the lake) and anthropogenic factors (heavy grazing close to the shore and cultivation right up to the shoreline) that shape its shorezones.

SFI category 2 – good

The good category is found in isolated stretches at points around the whole perimeter of Macro Prespa Lake (HGM areas I and III). In these areas, human disturbance – mainly in the form of agriculture and unrestricted grazing – is the main factor limiting the width of the riparian vegetation.

SFI category 3 – moderate

Stretches falling into SFI category 3 (moderate) are located mainly in HGM area I and comprise 71.4% of the total Albanian shoreline of Macro Prespa Lake. Here, the stretches have a **high level of naturality** but are comprised of rocky cliffs that abut the lake. This topography is a key factor limiting the area where a functional shorezone can develop. These stretches are particularly vulnerable because they have limited resilience and reduced homeostatic capacity and are thus less able to buffer existing or potential pressures. In these stretches, a minor stressor can, therefore, cause major environmental problems (Siligardi et al. 2010).

Conversely, in the category 5 stretches on the Macedonian side of Macro Prespa, the main factor limiting the width of the functional shorezone is the higher level of anthropogenic pressure exerted there (Figure 44).

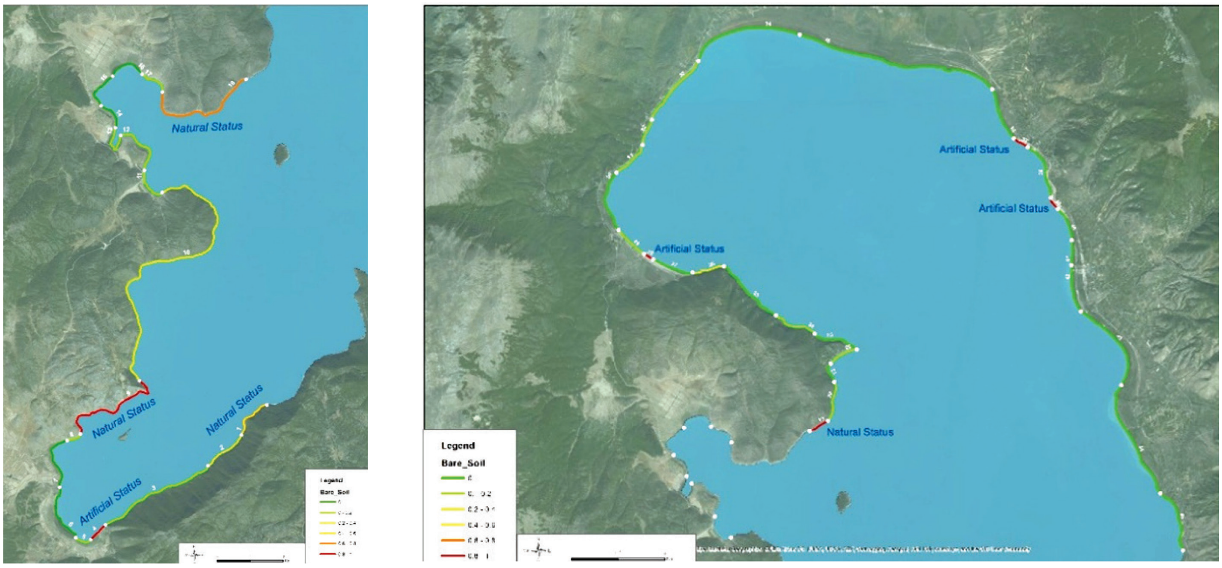


Figure 44. Artificial and natural status shores that correlate with stretches containing a high percentage of bare soil (between 80% and 100%)

SFI category 4 – poor

Only two small stretches, together totalling 1.5 km of the shoreline, fall into this category. They are both located on the Macedonian side of HGM area I. Here, most of the disturbance is the result of human activity, which has involved modifying the territory and removing the riparian vegetation in order to open up access to the lake.

SFI category 5 – bad

Only four stretches, together totalling 2 km, fall into this category. They are located in HGM areas I and III (Albania and Macedonia). These stretches correspond to areas containing tourist beaches where riparian vegetation is absent and sand and bare soil predominate.

3.3.2 Shorezone land use

Information on the type of anthropogenic use of Macro Prespa's shorezone (from the shoreline to 50 metres inland) and the surrounding territory (from the shoreline to 200 metres inland) was also collected during the survey (Figure 45).

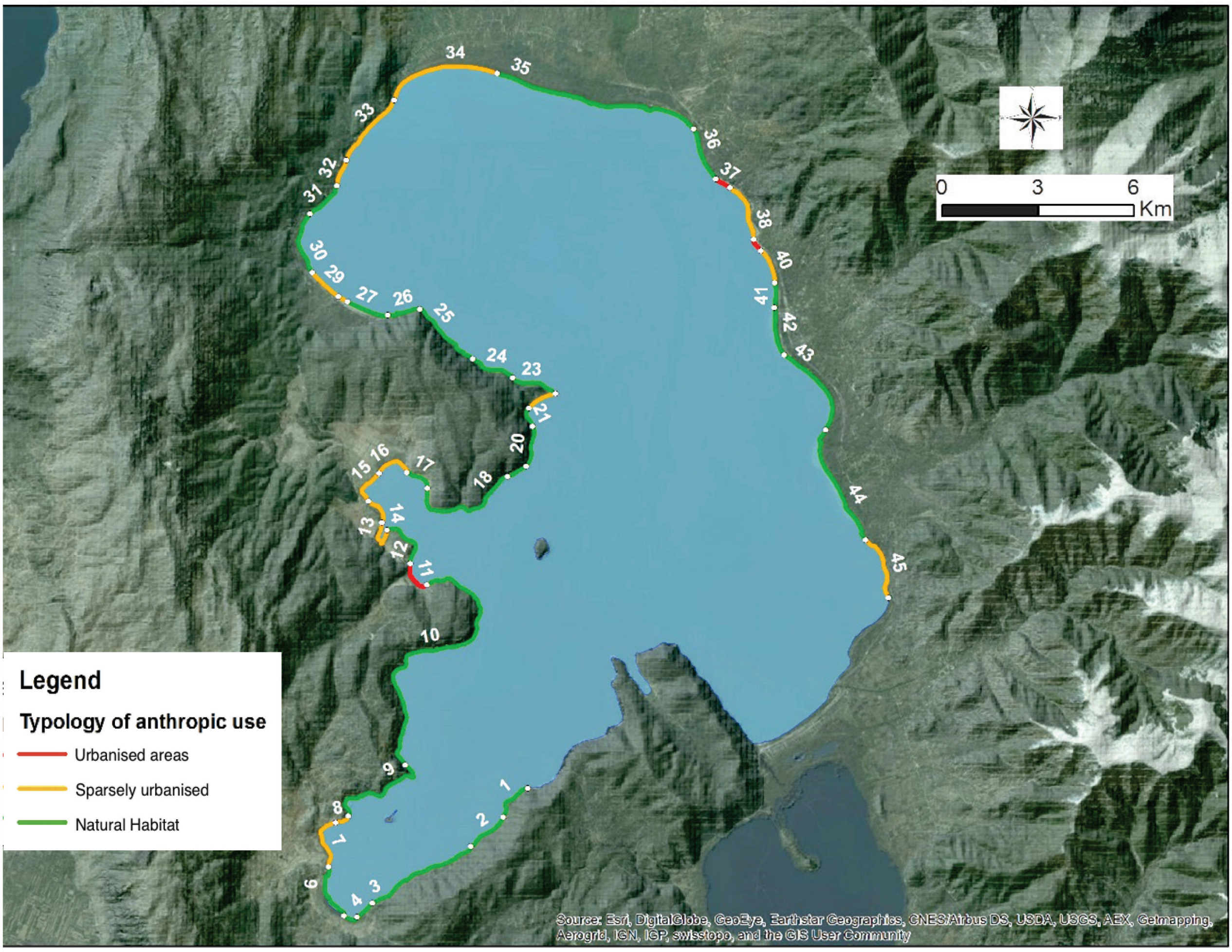


Figure 45. Anthropogenic use of the shorezone (0 to 50 metres inland from the shoreline)

Urbanised areas situated directly in the shorezone (0 to 50 metres inland from the shoreline) are very rare along the perimeter of line. Sparse urbanisation and cultivated fields (orange colour) are found in the vicinity of settlements and roads running alongside the shore. Sections of shore were classified as natural habitat (green line) when anthropogenic disturbances were absent. By comparing shorezone use (Figure 45) and shorezone functionality (Figure 41) it is easy to identify those stretches where functionality is naturally low (i.e. not the result of human activity).

It should be noted that this parameter looks at the overall status of homogeneous stretches identified, and that the value corresponds to the most prevalent typology in that stretch. If a one-kilometre-long homogeneous stretch contains a small urbanised area and this settlement does not impact on its surrounding environment, it will be assessed using the 'presence of interruption' parameter. An interruption is any intervention or work that in any way can reduce, affect, or limit the functionality of the vegetation in the lake shore zone, for example house gardens, vegetable plots, parking areas or other infrastructures.

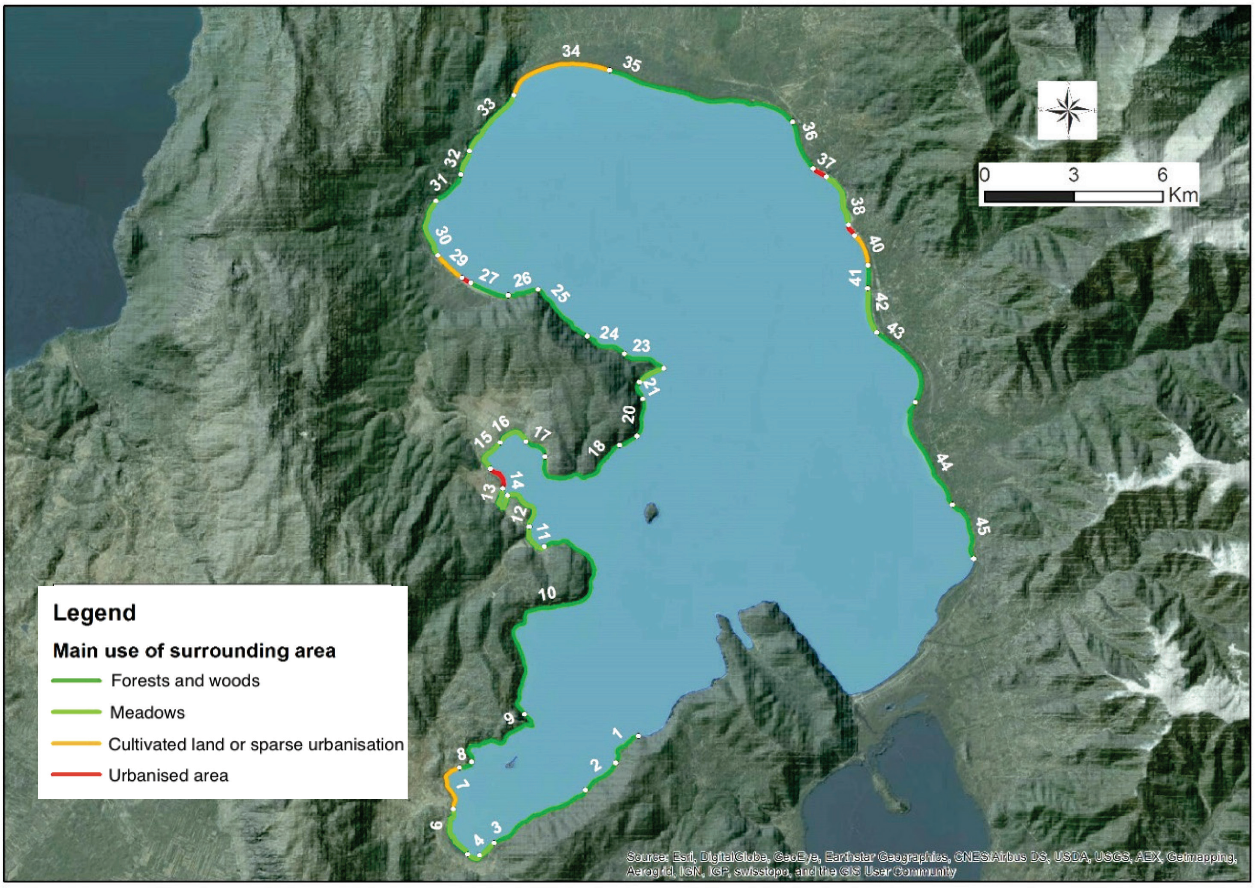


Figure 46. Anthropogenic use of the surrounding territory (0 to 200 metres inland from the shoreline)

Figure 46 depicts the prevalent human activities in an area running from the shoreline to 200 metres inland. It also indirectly indicates any repercussions on the shorezone's functionality occurring as a result of the modification of the surrounding soil that can increase the input of nutrients, organic matter and pollutants or change the natural permeability of the soil.

The dominant human use present in each identified homogeneous stretch is adopted as the use for that stretch.

Areas categorised as natural occur in national park areas, whereas the meadow category identifies areas where human presence has modified the environment but anthropogenic pressure is not overly significant (small-scale livestock farms and crop growing). The orange line represents areas where cultivation is more intensive and fertiliser is more likely to be used, and also where tourist campsites are present.

Only the tourist beaches fall into the urbanised area category, which therefore constitutes a very small percentage of the total surveyed perimeter of Macro Prespa Lake.

Reeds are not always present in Macro Prespa's littoral zone. However, where they do appear, they increase the width of the functional shorezone and its overall functionality. Figure 47 shows the correlation between the functional width of the shorezone (red line = 0 to 5 m; orange = 5 to 10 m; yellow = 10 to 30 m; light green = 30 to 50 m; dark green = more than 50 m) and the structure of the shorezone. The pie charts next to the shore describe the composition, as a percentage, of the following categories: dark green = arboreal riparian vegetation; light green = shrub riparian vegetation; yellow = reeds; orange = grass; red = bare soil (rock or beach).

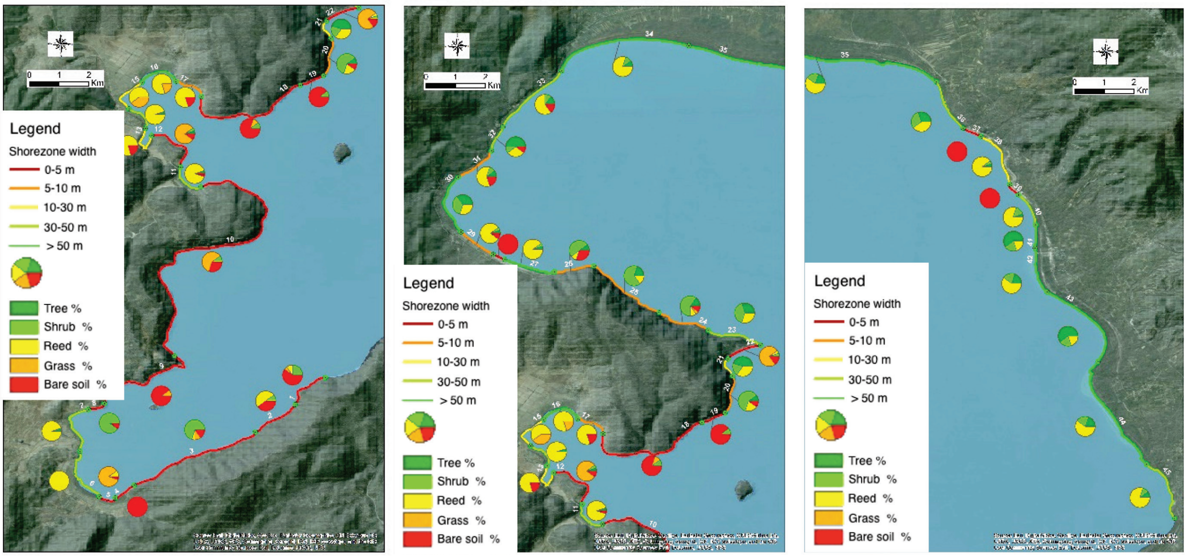


Figure 47. Shorezone structure – composition and width of stretches

3.3.3 SFI results for Macedonia

In the Macedonian section of Macro Prespa Lake's shorezone, 27 stretches with a total length of 47.5 were identified (Table 14). Four length classifications were also applied to these stretches: (1) shorter than 1,000 m, (2) between 1,000 and 2,000 m, (3) between 2,000 and 3,000 m and (4)greater than 3,000 m. The shortest stretch (no 10, the beach at Stenje village) is 337.30 metres long, while the longest (no 17, between Dolno Perovo and Asamati) extends 7,074.16 metres.

Table 14. Total number, length and percentage of length of sections with various SFI values (Macedonian territory)

SFI value	No. of stretches identified	Total km	Percentage
1 – high	13	30.7	64.6
2 – good	4	7.2	15.2
3 – moderate	6	7.3	15.4
4 – poor	1	1.0	2.0
5 – bad	3	1.3	2.8
TOTAL	27	47.5	100.0

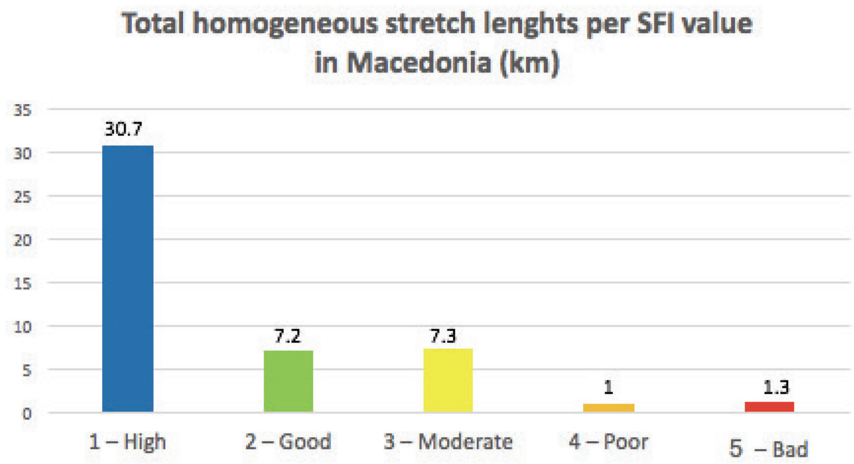


Figure 48. Total length (in metres) of homogenous stretches per SFI value on the Macedonian side of Macro Prespa

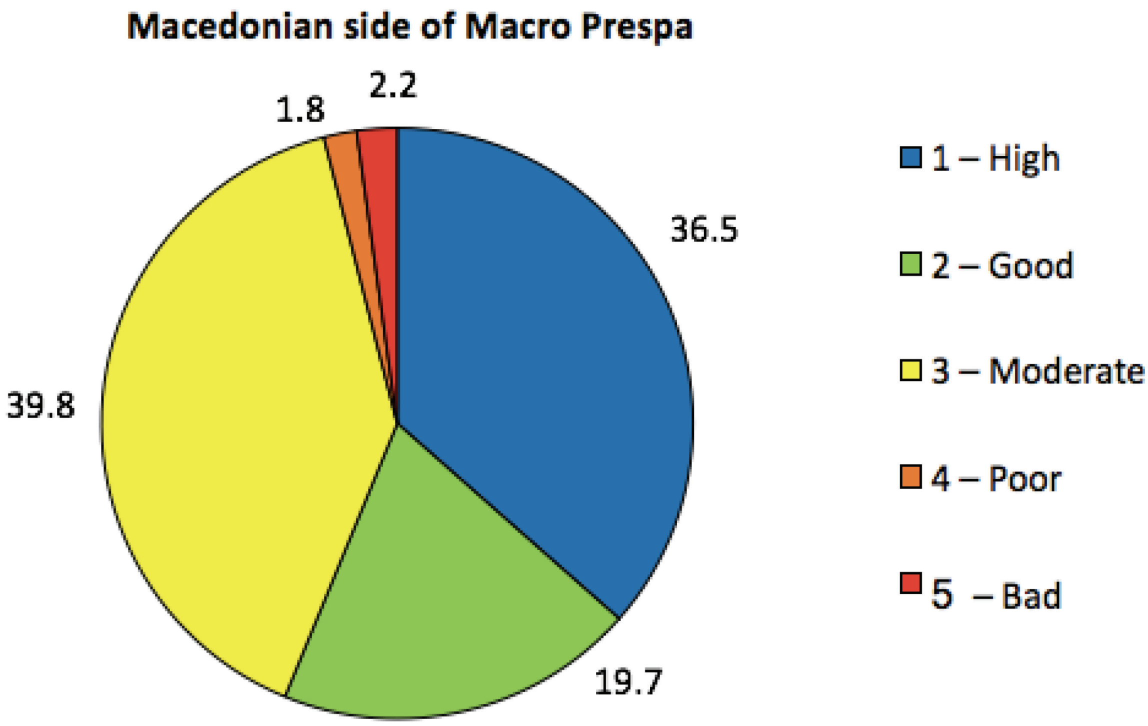


Figure 49. Percentages of the SFI values for the Macedonian side of Macro Prespa Lake

Classification of stretches according to their status

SFI category 1 – high

In Macedonia, 13 stretches, together totalling 30.7 km (or 64.7% of the Macedonian shore), fall into the high category (Figure 48). Three of these are up to one kilometre long, seven are between one and two kilometres, two are between two and three kilometres, and three are longer than three kilometres. The average length of category 1 stretches is 2.1 km. Six of these stretches are located on the west coast, two on the north coast, and the remainder on the east coast. Seven stretches lie in areas of flatter shoreline and eight occupy fairly hilly areas. Interestingly, eight stretches are affected by very high anthropogenic pressures in their surrounding territory, while the other seven experience very low levels of human impact.

The stretches usually contain well-developed belts of vegetation that contribute to their functionality, and their reed belts are characterised by great structural stability. With the exception of three or four stretches, the reed belt is continuous, and in some places it is exceptionally wide (in the Ezerani wetlands area more than 400 metres)[6]. The belt of riparian vegetation is usually well developed in category 1 stretches (particularly stretches 21, 23, 25, 35, 36 and 41) but also tends to show a certain level of structural distortion (usually a greater or lesser level of interruption, dominance of shrubs, occurrence of exotic species, etc.).

[6] Editors' note: Reed grasses can have detrimental or beneficial effects on ecosystems. At Lake Micro Prespa, for example, high nutrient input and water abstraction lead to the encroachment of reeds which now cover the entire Albanian part of the lake, thereby degrading its (former) ecological status. At Lake Macro Prespa, reeds are also common but more widely dispersed. Contrary to Micro Prespa, reeds are considered as beneficial because they add structural diversity, provide important spawning and breeding habitats for fish and birds, respectively, and reduce nutrient load.

SFI category 2 – good

Four stretches, together totalling 7.2 km (or 15.1% of the Macedonian shore), fall into the good category. The average length of these category 2 stretches is 2.1 km. The stretches on the west coast experience moderate levels of anthropogenic influence (in only one stretch is this influence absent), and the stretches on the east coast experience a fairly high level of anthropogenic pressure (from the combined impacts of agriculture and tourism). The riparian vegetation in category 2 stretches suffers from different degrees of structural disturbances (for example, limited width of functional vegetation, interruption of riparian vegetation). These disturbances are responsible for the decreased overall functionality.

Well-developed, continuous belts were recorded in only one stretch (no 30, between Stenje village and the Carina Resort). The other stretches contain regular interruptions.

SFI category 3 – moderate

Six stretches, together totalling 7.3 km or 11.7% of the Macedonian shore, fall into the moderate category. One is one kilometre long, two are between one and two kilometres long, and one is between two and three kilometres long. The average length of category 3 stretches is 1.4 km. They are all located on hilly land along the west coast that experiences minimal levels of human influence. The vegetation – both riparian and reeds – shows different degrees of disturbance. Interruptions in the functional shorezone are much more pronounced than in the two preceding categories and the percentage of bare land is much higher. The riparian vegetation mainly comprises bushes and shrubs.

SFI category 4 – poor

Only one stretch (no 22, 960 metres long) falls into the poor category. Anthropogenic pressure is the main reason for the disturbance identified here: the terrain has been heavily modified and the riparian vegetation removed to provide people with better access to the lake.

SFI category 5 – bad

Three stretches, together totalling 1.3 km or 2.7% of the Macedonian shore, fall into the bad category. All of them are shorter than one kilometre and their average length is 0.4 km. These stretches are small sections of lake shore that have been converted for use as beaches. One is located on the west coast (Stenje) and the other two lie on the east coast (Pretor and Slivnitsa). In these stretches, (natural) riparian vegetation is completely absent, as it has been removed to make way for tourism-related developments.

Conclusions

- The large majority of the Macedonian shorezone of Macro Prespa Lake has a high level of shorezone functionality.
- The stretches falling into the high category make up 64.7% of the overall Macedonian shoreline. They are fairly evenly distributed around the shores of HGM areas I, II and III, especially where the terrain is flatter.
- Counter-intuitively, category 1 stretches in HGM area II are found in areas where human pressure (pollution) is most intense.
- Category 5 stretches (bad) occupy the smallest area of the Macedonian shoreline: just 2.8%. The reason these stretches are categorised as bad is directly related to anthropogenic pressures and urbanisation. Future plans to further extend urban areas should avoid deteriorating shorezones that are ecologically important.

- The number and length of the stretches is primarily determined by the topography: shores comprising flat terrain generally form longer homogenous stretches, whereas shores associated with more complex reliefs lead to definition of smaller stretches.

3.3.4 SFI results for Albania

In all, 18 stretches with a total length of nearly 37 km were identified along the Albanian shorezone of Macro Prespa Lake (Table 15).

Table 15. Total number, length and percentage of length of sections with various SFI values (Albanian territory)

SFI value	No. of stretches identified	Total km	Percentage
1 – high	0	0.0	0.0
2 – good	7	9.4	25.5
3 – moderate	9	26.2	71.4
4 – poor	1	0.5	1.4
5 – bad	1	0.6	1.7
TOTAL	18	36.7	100.0

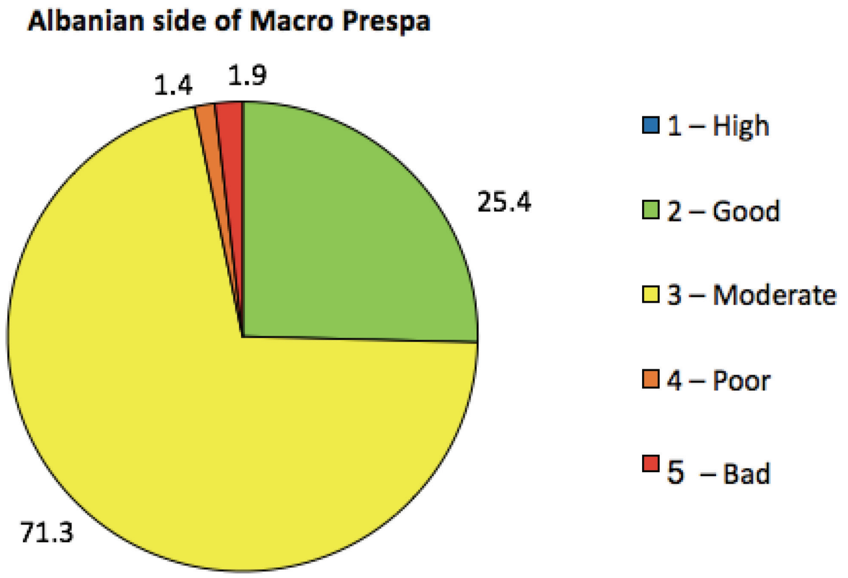


Figure 50. Percentages of the SFI values for the Albanian side of Macro Prespa Lake

SFI category 1 – high

No stretches in Albania fall into this category.

SFI category 2 – good

Seven stretches, totalling 9.4 km or 25.5% of the Albanian shore, fall into this category. Generally, these stretches contain a wide belt of reeds, but their riparian vegetation displays a certain level of structural disturbance.

Category 2 stretches are found at points all around Albania's shoreline and the reason they have been so classified is due:

- in four cases to different levels of human pressure – in stretches 11 and 14 there is limited farming activity and in stretches 6 and 7 there are tourism-related developments;
- in three cases to natural conditions – stretches 2, 13 and 17 experience almost no human impact but their shores are naturally rocky.

SFI category 3 – moderate

Most of the Albanian stretches (nos. 1, 3, 8, 9, 10, 12, 15, 16 and 18) are classified as moderate. The length of the shoreline of these nine stretches totals 26.2 km or 71.4% of the overall Albanian shore. One stretch is around half a kilometre long, four are between one and two kilometres, and three reach nearly four kilometres. The remaining stretch is exceptionally long at almost ten kilometres. Most of these stretches (1, 3, 8, 9, 10 and 18) experience almost no human influence, and two even more natural stretches (3 and 8) fall within protected areas of the lakeshore. However, despite a high level of naturality these stretches have moderate functionality, mainly because they comprise cliffs and hills near the shore which limit the space where vegetation belts can grow. Some stretches comprise pebble beaches which are almost void of riparian vegetation.

These cases typify the kind of shorezone that is natural but not necessarily functional. Shores with high naturality and low SFI values are particularly vulnerable because they have limited resilience and reduced homeostatic capacity and are thus less able to cope with pressures as and when they arise. In these stretches, minimal stresses can therefore generate further environmental problems (Siligardi et al. 2010).

Fortunately, on the Albanian side of Macro Prespa Lake these stretches mainly occur in areas where the surrounding territory remains undeveloped and human pressure is therefore absent. Stretches 15 and 16 are, however, affected by moderate levels of anthropogenic impact, displaying discontinuous reed belts and, due to cultivation, almost no riparian vegetation on the shore. The riparian vegetation in stretch 12 is disturbed by presumably unrestricted grazing.

SFI category 4 – poor

Only one stretch (5) falls into category 4. It is half a kilometre long and lies adjacent to the only category 5 (bad) stretch on the Albanian side of Macro Prespa Lake. The poor level of functionality in this stretch is mainly due to human activity, which has seen the removal of areas of naturally occurring reed belt and turned shore areas over to cattle grazing.

SFI category 5 – bad

Only one stretch (4), comprising pebble beach, falls into category 5. It is 0.6 km long and lies adjacent to the only category 4 stretch on the Albanian side of Macro Prespa Lake. Locals regularly remove shrubs growing along the back of this beach to open up access to the lake. The surrounding territory is covered with non-hygrophilous shrubs.

Conclusions

- In general, the Albanian section of Macro Prespa Lake has a moderate level of shorezone functionality.

- The stretches falling into the moderate category make up most of the overall Albanian (71%). Their functionality is diminished by the composition of the shore, which consists of rocky hills and pebble beaches.
- Most of the remaining stretches fall within the good category (25% of the Albanian shoreline). In these cases, anthropogenic factors such as crop growing, cattle grazing and/or tourism play a significant role in reducing shorezone functionality.
- Poor and bad levels of functionality were recorded in only two stretches of the Albanian shoreline, and these are the direct result of anthropogenic pressure.

3.4 Management recommendations

3.4.1 Common recommendations

Restoration and/or protection

- Given their ability to filter out pollutants and excess nutrients and to provide important habitat for fish reproduction, reed belts should be preserved.
- Shorezones near to cultivated fields, pastures and human settlements should be restored with functional riparian vegetation (covering a zone at least 30 metres inland from the shoreline) to improve their capacity for nutrient removal and to provide other valuable ecosystem services to humans and wildlife.

Planning and further research

- Sub-basin management plans from Albania, Macedonia and Greece should be enhanced.[7]
- Ecotourism that recognizes the ecological value of the lake and its surroundings should be prioritised.
- To address the issue of pollution deriving from its tributaries (e.g. nutrients from apple orchards), it is recommended to perform a Fluvial Functionality Index assessment on each of them: the Istočka Reka, Golema Reka, Kranska Reka and Kurbinska Reka.

3.4.2 Recommendations for Macedonia

Restoration and/or protection

- The main pathways of pollution of Macro Prespa Lake are its tributaries. For this reason, it is essential to:
  - fully implement measures to improve water quality proposed in the Prespa Lake Watershed Management Plan and
  - conduct a Fluvial Functionality Index (FFI) assessment of the four main rivers in the basin (Istočka Reka, Golema Reka, Kranska Reka and Kurbinska Reka), as these transport substantial amounts of nutrients and pesticides from apple orchards located along their courses.

[7] Editors' note: As an EU member, only Greece has developed a River Basin Management Plan in full compliance with the WFD. Macedonia has elaborated the Prespa Lake Watershed Management Plan (PLWMP 2012) and Albania and Macedonia the Initial Characterization of their territories of the Macro Prespa sub-basin (Peveling et al. 2015)

3.4.3 Recommendations for Albania

Category 3 (moderate) shorezone functionality predominates in Albania due to the natural topography of the terrain, which mostly comprises rocky cliffs. Prespa National Park therefore plays a very important role on the Albanian side of the lake, as it places limits on the amount of human pressure that can be exerted in these areas, where the natural landscape is highly vulnerable.

Anthropogenic factors identified as limiting shorezone functionality include crop growing and unrestricted grazing around the villages situated on the shore.

Restoration and/or protection

- The areas of forest remaining around the lake should be preserved and protected from unregulated grazing.
- As reeds can filter out nutrients running off the land and also provide important sites for fish reproduction, existing reed belts should be maintained (Ilik-Boeva et al. 2017).
- In the bay areas of the lake where human stressors are greater in number and more intense, it is possible to achieve high functionality shorezones by fencing off an area stretching at least 30 metres inland from the shoreline. This will provide terrestrial animals with valuable habitat and improve current functionality levels of the shorezone.
- Actions must be taken to preserve habitats of rare species. For fish, these should include:
  - protection of spawning sites (reed belts) and
  - improvement of habitat monitoring.
- In the area between the villages of Zaroshke and Kallamas (HGM area I), most of the riparian trees have been removed, and their natural regrowth is prevented by unrestricted grazing. The few remaining stands of trees (Figure 51) should therefore be fenced off to reduce any disturbance. Also, other sites located between these stands suitable for tree planting and/or protection should be identified.
- Areas should be restored using species that are native to the area, such as willow and poplar. These species are good providers of habitat and improve the functionality of the shorezone.

Figure 51. Presence (green line) and absence (orange line) of trees along the Albanian shore, with areas that should be protected and fenced off to deter grazing circled in red

Planning and further research

The Prespa region has great potential for tourism. Many pelicans and cormorants were observed during the fieldwork, and Prespa National Park has already installed an interesting network of nature trails. Some tourism-related infrastructure is already in place (Figure 52) and a number of local mountain guides have been trained. With the area primed to welcome ecotourism, marketing campaigns are now required to promote Prespa Lake as a destination.

Infrastructure

Tourism-related infrastructure can be improved without affecting the current functionality of the lake's shorezone. The region should target tourists who are keen on ecotourism experiences and who will enjoy the lake's wealth of birdlife. All tourist facilities should be planned in a way that ensures the proper disposal of additional waste generated as a result of increasing visitor numbers.

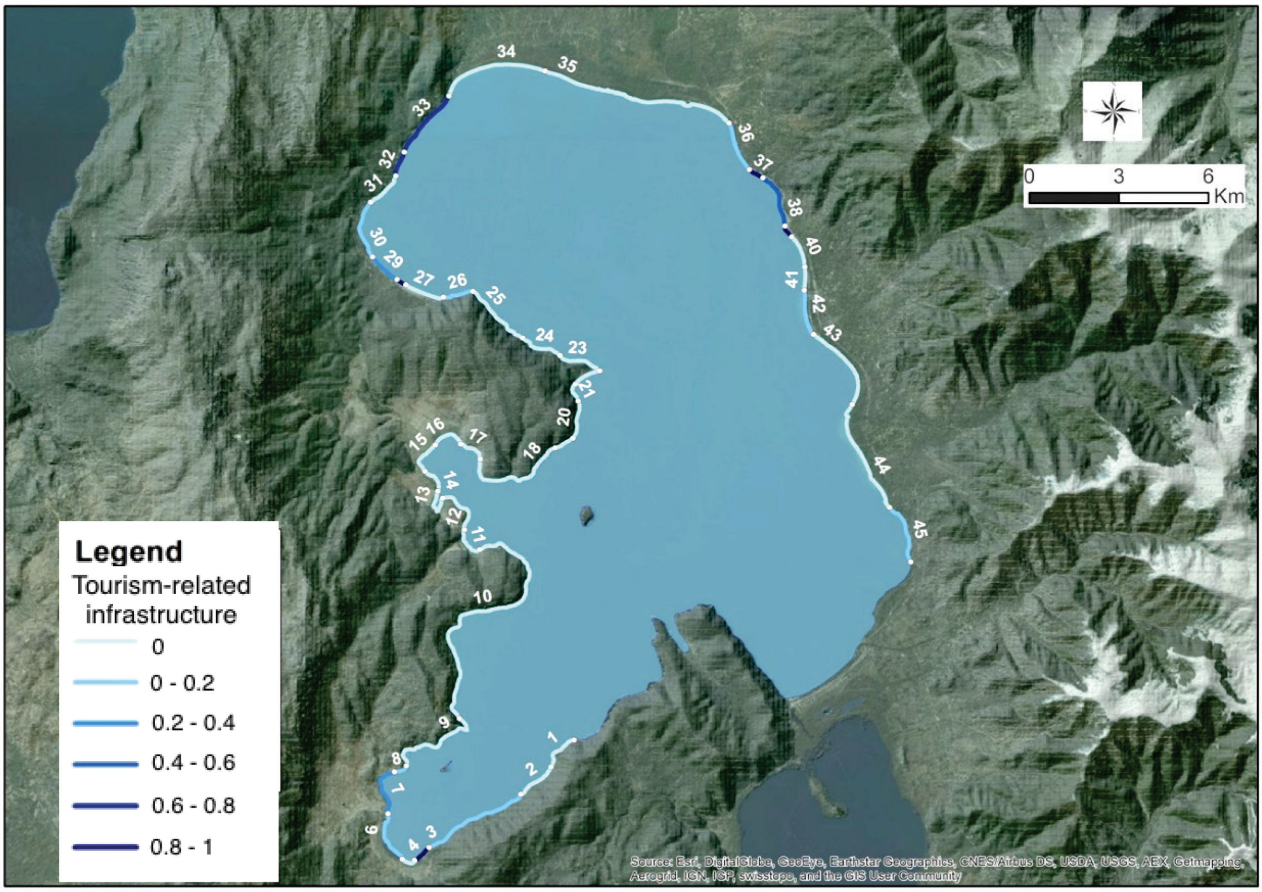


Figure 52. Tourism-related infrastructure (Range: 0 = none to 1 = 100% along entire stretch)
(0.1 = hiking trail; 0.2 = single hotel; 0.5 = pedestrian/cycle path alongside lake; 1 = beach or tourism infrastructure)

4 SFI APPLICATION FOR MACRO PRESPA LAKE

The SFI was established according to the methodology described in *Lake Shorezone Functionality Index (SFI) – A tool for the definition of ecological quality as indicated by Directive 2000/60/CE* (Siligardi et al. 2010).

The fieldwork was supervised by the SFI expert Barbara Zennaro who, for the first few days of the fieldwork, focused on the intercalibration of the different teams (including the Montenegrin team for Lake Skadar/Shkodra) to ensure the highest possible levels of consistency between the work undertaken on the Albanian and Macedonian sides of the lake.

SFI assessments in Macedonia were carried out on 10 and 12 June 2016 by Dr Ivan Blinkov (Hydromorphology), Svetislav Krstic (Hydrobiology), Mitko Kostadinovski (Botany), Dr Renata Kustereska (Botany) and Ivan Mincev (GIS). SFI assessments in Albania were carried out on 13 June 2016 by Klodian Zaimi (Hydromorphology), Orjeta Jaupaj (Botany), Dhimiter Peci (Botany) and Valbona Simixhiu (GIS).

The survey of the lake was carried out by boat. Both the Albanian and Macedonian teams were equipped with maps, a GPS-enabled camera and a tablet installed with relevant applications. An individual SFI sheet was completed for each identified stretch, and pictures and coordinates of the stretch were taken. Subsequently, the data captured in the evaluation sheets were entered into the SFI software package and the SFI category calculated.

Only the Albanian and Macedonian shores of Macro Prespa Lake were evaluated. The Macedonian and the Albanian shore was divided into 27 and 18 homogeneous stretches, respectively, with each of these stretches determined mainly by the different levels of human pressure exerted and the presence of exotic and/or hygrophilous species.

For each homogenous stretch, an ID card was prepared containing the following information:

- Field form number
- Length of homogeneous stretch
- Delineation
- SFI result
- Personal evaluation
- Description of stretch
- Notes
- Map with location
- Representative photo
- SFI classification tree (produced using the software).

4.1 Homogeneous stretches 1 – 45

Individual homogenous stretch descriptions are supplied in digital form on a USB flat card (see pouch in back cover).

5 References

Academy of Science of Albania, *Hidrologjia e Shqipërisë,* 1985.

Anovski T., Popov V., Amataj S., Anovska-Jovcheva E., Jovchev Z., Stojmenovska I., Anovski K. and Milevski J., *Study of Prespa Lake's hydrology using isotopes and other relevant techniques.* Transactions on Ecology and the Environment, Vol 160, 2012.

Bajkovic I., Hadžiablahović S., Cakovic D., Medenica B., Zaimi K., Elbasani O., Peci D., Simixhiu V., Zennaro B., Shorezone Functionality Skadar/Shkodra Lake – Implementing the EU Water Framework Directive in South-Eastern Europe. Technical Report. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn, Eschborn. Pegi Sh.P.K. Book Publishers, Tirana, 2017, 83 pp.

Blinkov I. (on behalf of GTI Geotehnicki Inzenering Team), *Prespa Lake Watershed Management Plan – Project Achievements*. Presentation at the Bilateral Meeting between the Ministry of Environment and Physical Planning of the former Yugoslav Republic of Macedonia and the Ministry of Environment and Water of Bulgaria on the Topic of Water Management, Skopje, 12–13 September 2013.

Blinkov I., Elbasani O., Kostadinovski M., Krstic S., Kusterevska R., Mincev I., Peci D., Simixhiu V., Zaimi K., Zennaro B., Shorezone Functionality Ohrid Lake – Implementing the EU Water Framework Directive in South-Eastern Europe. Technical Report. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn, Eschborn. Pegi Sh.P.K. Book Publishers, Tirana, 2017, 84 pp.

Chapman D., *Water quality assessment*, E & FN Spon, London, 1996.

CIS Wetlands Working Group, *Horizontal Guidance Document on the Role of Wetlands in the Water Framework Directive*, 7 October 2003, p. 63.

Demiraj E. and Muçaj L., *Climate variability and expected climate change over Prespa zone (Towards integrated conservation and sustainable development of transboundary Macro and Micro Prespa lakes – PPNEA)*, Korça, Albania, 1997, p. 10.

Dosskey M.G., Vidon P., Gurwick N.P., Allan C.J., Duval T.P. and Lowrance R., '*The role of riparian vegetation in protecting and improving chemical water quality in streams*', Journal of the American Water Resources Association, 46, 2010, pp. 261–277.

Ilik-Boeva, D., Shumka, S., Spirkovski, Z., Talevski, T., Trajcevski, B., Ritterbusch, D., Brämick, U., Pietrock, M. and Peveling, R. 2017. *Fish and Fisheries Prespa Lake – Implementing the EU Water Framework Directive in South-Eastern Europe.* Technical Report. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2015. Bonn, Eschborn. Pegi Sh.P.K. Book Publishers, Tirana. 120 pp.

Imeri A., Mullaj A., Gjeta E., Kalajnxhiu A., Kupe L., Shehu J. and Dodona E., '*Preliminary results from the study of flora and vegetation of Ohrid Lake',* Natura Montenegrina, Podgorica, 9(3), 2010, pp. 253–264.

Kostoski G., Albrecht C., Trajanovski S. and Wilke T., *'A freshwater biodiversity hotspot under pressure – Assessing threats and identifying conservation needs for ancient Lake Ohrid'*, Biogeosciences, 7, 2010, pp. 3999–4015.

Krstic S., *Biomonitoring of the Eutrophication of Prespa Lake,* Research Project, 2003.

Law *on Waters* – Official Gazzete of the Republic of Macedonia nro. 87 from 15.07.2008, Article 1.

Nielsen A., Trolle D., Søndergaard M., Lauridsen T.L., Bjerring R., Olesen J.E. and Jeppesen E. *'Watershed land use effects on lake water quality in Denmark'*, Ecol. Appl. 22(4), 2012, pp. 1187–1200.

Mersinllari M., *General Data on Vegetation of Ohrid and Prespa Watershed Area*, Proceedings of International Symposium, Korça, Albania, 1997, pp. 147–155.

National Environment Agency, *Biodiversity Strategy and Action Plan – Albania*, Albania, 1999.

Osborne L.L. and Kovacic D.A., *'Riparian vegetated buffer strips in water quality restoration and stream management'*, Freshwater Biology, 29, 1993, pp. 243–257.

Peveling R., Brämick U., Densky H., Parr B., Pietrock M., Adhami E., Bacu A., Beqiraj S., Djuranovic Z., Djuraskovic P., Gusheska D., Hadziablahovic S., Ilik-Boeva D., Ivanovski A., Kashta L., Koc E., Kostoski G., Lokoska L., Mirta Y., Mrdak D., Palluqi A., Pambuku A., Patceva S., Pavicevic A., Perunicic J., Rakaj M., Rakocevic J., Saliaga V., Veljanoska-Sarafiloska E., Spirkovski Z., Shumka S., Talevska M., Talevski T., Tasevska O., Trajanovska S. and Trajanovski S., *Initial Characterization of Lakes Prespa, Ohrid and Shkodra/ Skadar – Implementing the EU Water Framework Directive in South-Eastern Europe,* Technical Report. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2015. Bonn, Eschborn. Pegi Sh.P.K. Book Publishers, Tirana, 2015, 99 pp.

Popovska C., *Hydrology of Ohrid and Prespa Lake,* Macedonian Academy of Sciences and Arts and the Academy of Sciences of Albania, Regional International Conference on Prespa and Ohrid Lakes, Struga and Pogradec, 28–29 October 2013.

Popovska, C., *KfW Feasibility Study, Project Preparation & Development of the Transboundary Prespa Park Project, Part V Hydrology Report*, 2004.

Popovska C., Geshovska V., Jovanovski M., Donevska K., Tanaskovic V., Veljanovska-Sarafilovska E., Blinkov I., Peshevski I. and Minchev I., *Hydrogeological study for the Prespa Lake Watershed,* Faculty of Civil Engineering, Ss. Cyril and Methodius University, Skopje, 2015.

PLWMP-TR1: Blinkov I., Conevski T., Krstic S., Cukaliev O., Ristovski I., Mincev I., Dinev G., Dimov M., Bojkovska R., Talevski T., Talevska M., Stamenkovic-Slaveska V., Kaevski I. and Spirovska S., *Prespa Lake Watershed Management Plan – Technical Report 1. Data collection and analyses of existing conditions*, 2010.

PLWMP-TR2: Blinkov I., Krstic S., Conevski T., Stavric V., Cukaliev O., Ristovski I., Mincev I., Dinev G., Dimov M., Milevski J., Bojkovska R., Talevski T., Talevska M., Stamenkovic-Slaveska V., Kaevski I., Spirovska S., Soreva I. and Blinkova M., *Prespa Lake Watershed Management Plan Technical Report 2 - Identification of the major watershed management issues in Prespa Lake Watershed, Main Text,* 2010.

PLWMP-TR2a: Blinkov I., Krstic S., Cukaliev O., Ristovski I., Mincev I., Dinev G., Dimov M., Bojkovska R., Talevski T., Talevska M., Stamenkovic-Slaveska V. Kaevski I., Spirovska S., Soreva I. and Blinkova M., *Prespa Lake Watershed Management Plan Technical Report 2 - Identification of the major watershed management issues in Prespa Lake Watershed, Annex,* 2010.

PLWMP: Conevski T., Krstic S., Blinkov I., Stavric V., Longholt J., Cukaliev O., Petrovska M., Ristovski I., Mincev I., Dinev G., Dimov M., Bojkovska R., Taleski T., Talevska M., Stamenkovic-Slaveska V., Stafilov T., Kaevski I., Spirovska S., Krango N., Soreva I. and Blinkova M., *Prespa Lake Watershed Management Plan* 2011–2017, Ministry of Environment and Physical Planning of the former Yugoslav Republic of Macedonia and the United Nations Development Programme, 2012.

Popov V., Anovska E., Arsov M., Amataj S., Kolaneci M., Stamos A., Arsov L., Anovski T., Kiri E. and Gelaj A. (2009). *Study of the Prespa-Ohrid lake system using tracer experiments and the lake's water balance.* Water Resources Management V. Wit Press, pp. 75–84.

Premazzi G. and Chiaudani G., *Ecological quality of surface waters – Quality assessment schemes for European Community lakes*, Environmental Institute, University of Milan, ECSC-EEC_EAEC, Brussels and Luxembourg, 1992.

Roth B.M., Kaplan I.C., Sass G.G., Johnson P.T., Marburg A.E., Yannarell A.C., Havlicek T. D., Willis T.V., Turner M.G.and Carpenter S.R. '*Linking terrestrial and aquatic ecosystem: the role of woody habitat in lake food webs*.' Ecological Modelling, 203, 2007, pp. 439–452.

Siligardi M., Avolio F., Baldaccini G., Bernabei S., Bucci M., Cappelletti C., Ciutti F., Floris F., Francescini A., Mancini L., Minciardi M., Monauni C., Negri P., Pineschi G., Pozzi S., Rossi G., Spaggiari R., Tamburro C. and Zanetti M., *IFF 2007 – Indice di funzionalità fluviale*, Manuale APAT, 2007.

Siligardi M., Bernabei S., Cappelletti C., Ciutti F., Dallafior V., Dalmiglio A., Fabiani C., Mancini L., Monauni C., Pozzi S., Scardi M., Tancioni L. and Zennaro B., *Lake shorezone Functionality Index*, APPA manual, 2010.

Wagner B.W. and Wilke T., *'Evolutionary and geological history of the Balkan lakes Ohrid and Prespa'*, Biogeosciences, 8, 2011, pp. 995–998.

6 Appendix

6.1 Glossary of terms

Shoreline

The area that includes the littoral (maximum depth of one metre) and riparian zones, and extends inland up to 50 metres from the shoreline, with the exception of interruptions or particular lake morphology that may limit its width – see Figure 68 (Siligardi et al. 2010).

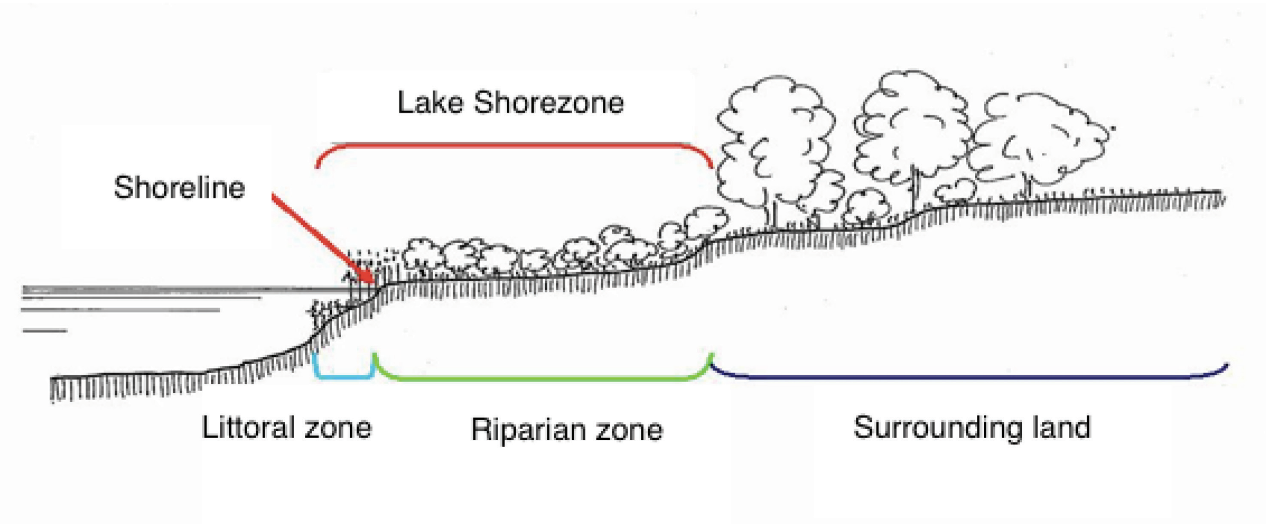


Figure 1. Structure of the lake shorezone

Riparian zone

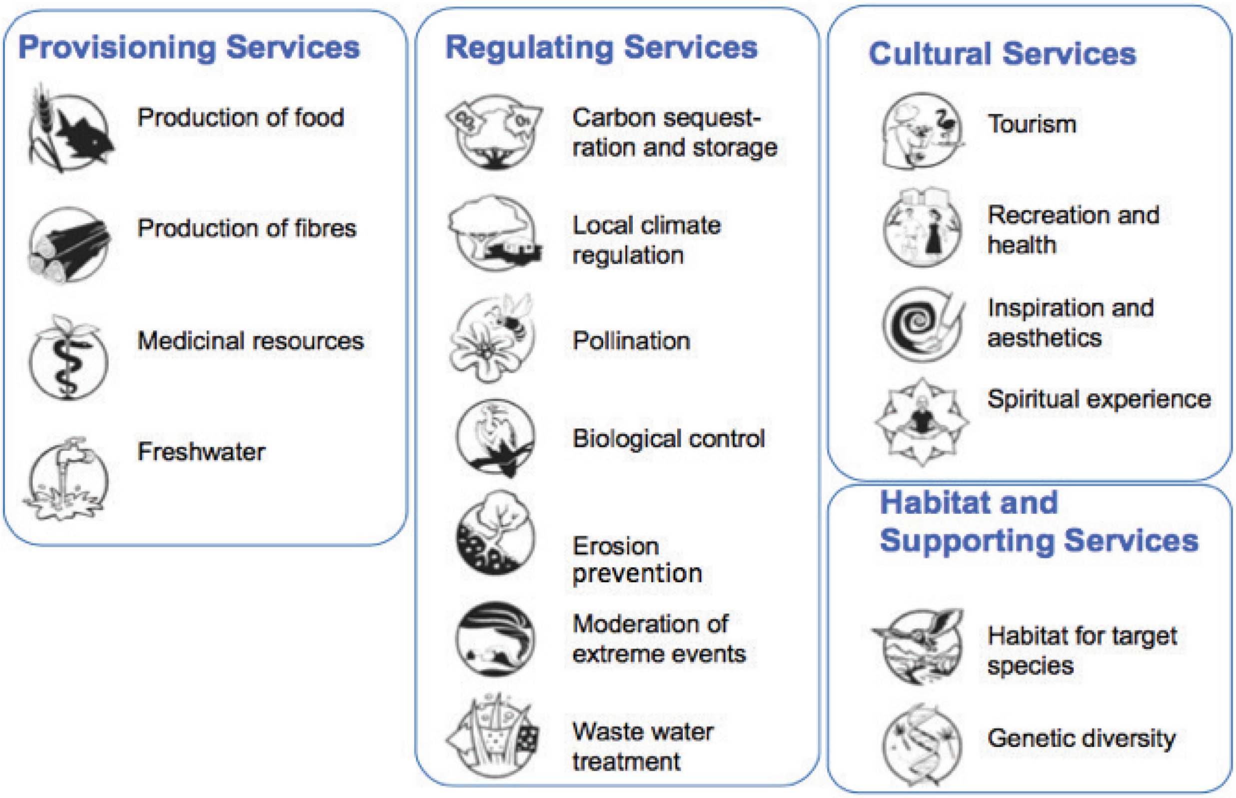
This is the area immediately adjacent to a body of water, which functions as a transition zone between the lake and its surrounding territory. It is important because it regulates inputs (nutrients and sediments), which improves lake water quality by (a) filtering the runoff from the catchment area and removing pollutants (the vegetation in the riparian zone can remove up to 90% of the nutrients passing through) and (b) aiding sedimentation (the vegetation slows the water flowing into the lake).The riparian zone also provides habitat for aquatic and terrestrial animals, including food, shade (temperature control), shelters, and areas for hunting and breeding, and it promotes bank stabilisation and thus protects the shoreline from erosion.

Littoral zone

This is the submerged section of the lake alongside the shore that generally coincides with the area where submerged macrophytes are present. This area often hosts many aquatic and non-aquatic animals. Many fish species choose this area for egg deposition and development (Rooth et al. 2007) and it is an important area for nutrient cycling. It also protects the shoreline from erosion and, by reducing wave action, promotes good water clarity.

Ecosystem services

These are the functions of the ecosystem that contribute either directly or indirectly to the wellbeing of society. They are divided into provisioning services (e.g. production of food or fibres), regulating services (e.g. erosion prevention, wastewater treatment), cultural services (e.g. tourism), and habitat and supporting services (e.g. habitats for target species) (TEEB 2012).



Drainage basin (also drainage area, catchment basin/area, watershed)

This is an area of land where all water derived from rain or melting/ice converges on a single point at a lower elevation, where the surface water then joins another body of water such as a river, lake, reservoir, estuary, wetland, sea or ocean.

Drainage basins are an important factor in an area's ecology because, as water flows over the ground and along rivers towards the outlet of the basin, it can pick up nutrients, sediment and pollutants. These can impact on ecological processes along the way and can also affect the water of the receiving source.

The modern use of artificial fertilisers containing nitrogen, phosphorus and potassium has been shown to affect the mouths of drainage basins. The minerals are carried by the drainage basin to its mouth and can accumulate there, disturbing the natural mineral balance. This can cause eutrophication where plant growth is accelerated by the additional material.

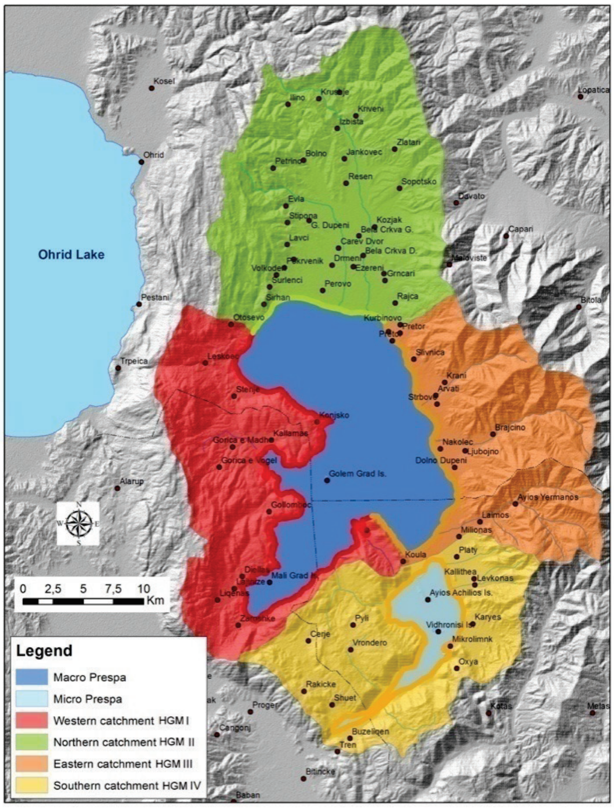
Drin River Basin

The area of land where all surface water converges on the Drin River as it works its way towards the Mediterranean Sea. The Drin originates in the drainage basin of Prespa Lake (Greece, Albania and Macedonia), the waters of which feed into Ohrid Lake (Albania and Macedonia). The latter then feeds into the Black Drin River, which traverses Albania, entering the White Drin River Basin to form the Drin River. The waters of the Drin River Basin subsequently join the waters coming from the Skadar/Shkodra Lake drainage basin (that stretches across Albanian and Montenegrin territory), which then pass downriver and finally debouch into the Adriatic Sea.

Hydromorphological (HGM) area

An area with specific hydrological, geological and morphological characteristics that differentiate it from nearby areas. HGM parameters considered in this study include topography (drainage slopes that affect runoff, and the presence of reeds in the littoral zone), bedrock type (the presence of soft or hard rock, which affects water percolation), soil types and vegetation presence (which affect runoff/percolation and the concentration of nutrients from natural/anthropogenic sources).

HGM areas around Prespa Lake



Average residence time

The average time that water spends in a particular lake, from the time it enters the lake to the time it exits.

Thermic cycle

How often lake-bottom and surface waters mix within a year.

6.2 List of GIS shapefiles

No	Description of dataset	Scale	Year produced	GIS format	File format
1	SFI stretches point	1:10,000	2016	shapefile (shp)	Point vector format with attribute database
2	SFI stretches line	1:10,000	2016	shapefile (shp)	Line vector format with attribute database of SFI software
3	Hydrogeomorph-ological areas	1:25,000	2016	shapefile (shp)	Polygon vector format with attribute database
4	Stream network	1:25,000	2015	shapefile (shp)	Line vector format with attribute database
5	Stream catchments	1:25,000	2015	shapefile (shp)	Polygon vector format with attribute database
6	Springs	1:25,000	1990, updated 2016	shapefile (shp)	Point vector format with attribute database
7	Settlements	1:25,000	2016	shapefile (shp)	Point vector format with attribute database
8	Nutrient load	1:25,000	2016	shapefile (shp)	Point vector format with attribute database
9	Road network	1:100,000/ 1:25,000	1995, updated 2016	shapefile (shp)	Line vector format with attribute database
10	Sewage	1:100,000/ 1:25,000	2016	shapefile (shp)	Point vector format with attribute database
11	Topographical maps	1:25,000	2004	TIFF (GeoTIFF)	Raster format
12	Digital Elevation Model (DEM SRTM)	30 megapixels	2014	TIFF (GeoTIFF)	Raster format

6.3 Parameters assessed in the field and included in the SFI stretch shapefiles

Each row represents a column in the GIS database and each box represents a question. Note that some questions require a single answer so the box has only one row (e.g. width), whereas other questions seek to collect a range of information (e.g. composition of lake shorezone), so the box has multiple rows.

<table>
<tr><th>Name</th><th>Parameter</th><th>Category</th><th>Significance</th><th>Comments</th><th>Area considered</th></tr>
<tr><td>Stretch_N</td><td>Stretch ID</td><td>-</td><td>-</td><td>Stretch ID as collected in the field</td><td></td></tr>
<tr><td>Length</td><td>length</td><td></td><td></td><td>Calculated a posteriori</td><td></td></tr>
<tr><td>SFI</td><td></td><td>1 to 5</td><td></td><td>SFI result</td><td></td></tr>
<tr><td>Width</td><td>Width of functional lake shorezone (LS)</td><td>0 to 5</td><td>0 = 0 m
1 = 1–5 m
2 = 5–10 m
3 = 10–30 m
4 = 30–50 m
5 = >50 m</td><td>Includes both littoral and riparian zone up to 50 metres inland</td><td>LS</td></tr>
<tr><td>Tree_%</td><td>Presence of trees within LS</td><td>%</td><td rowspan="5">0 = none
1 = 100% of LS
0.x = inter-mediate values (e.g., 0.2 = 20% presence)
Values add up to 1 (100%)</td><td></td><td>LS</td></tr>
<tr><td>Shrub_%</td><td>Presence of shrubs within LS</td><td>%</td><td></td><td>LS</td></tr>
<tr><td>Reed_%</td><td>Presence of reeds within LS</td><td>%</td><td>Water lilies, water chestnut and other vegetation with floating leaves not considered (see description of individual stretch)</td><td>LS</td></tr>
<tr><td>Grass_%</td><td>Presence of (natural) grasses within LS</td><td>%</td><td>Grass beneath vertical projection of trees not considered</td><td>LS</td></tr>
<tr><td>Bare Soil_%</td><td>Presence of bare soil within LS</td><td>%</td><td>Rocks, beaches, impermeable walls and fertilised managed gardens considered as bare soil</td><td>LS</td></tr>
<tr><td>Hygroph</td><td>Hygrophilous species</td><td>%</td><td rowspan="2">0 = none
1 = 100% of LS
Values add up to 1 (100%)</td><td></td><td>LS</td></tr>
<tr><td>No_Hygroph</td><td>Non-hygro-philous species</td><td>%</td><td>Bare soil and exotic species fall into this category</td><td>LS</td></tr>
</table>

Exotic_Sp	Exotic species	%	0 = none 1 = 100% of LS 0.x = intermediate values		RIP
Heteroge	Heterogeneity of arboreal and riparian vegetation	0 to 1	See table below*	Manual, p. 45	RIP
Cont_tree	Continuity of arboreal and shrub vegetation	0 = absent 0.5 = dis-continuous 1 = con-tinuous	0.5 when interruption >10%	Identify longitudinal interruptions (artificial or rocks/bare soil)	RIP
Cont_reeds	Continuity of wet reed zone	0 = absent 0.5 = dis-continuous 1 = con-tinuous	0.5 when interruption >10%		LIT
Cont_dryRe	Continuity of dry reed zone	0 = absent 0.5 = dis-continuous 1 = con-tinuous	0.5 when interruption >10%		RIP
Interrupti	Interruption	0 to 1	0 = none 0.1–0.9 = inter-mediate 1 = along whole stretch	Linear (e.g. beach is a continuous interruption) or scattered (e.g. fields within 50-metre area)	50
Use_0_50m	Typology of anthropogenic use of LS	0/0.5/1	0 = natural habitat 0.5 = sparse urbanisation/ meadows 1 = urbanised area	The most prevalent typology considered	50
Use_0_200m	Surrounding territory	0 to 3	0 = natural habitat 1 = meadow/small cultivation 2 = intensive	The most prevalent category considered	200

			cultivation/sparse urbanisation 3 = urbanised		
Infr_Roads	Infrastructure: provincial/state roads	0 to 1	0 = none 0.1–0.9 = present only in parts of stretch 1 = along whole stretch		200
Infr_train	Infrastructure: railroads	0 to 1			200
Infr_park	Infrastructure: parking	0 to 1			200
Infr_touri	Tourism-related infrastructure	0 to 1			200
Slope	Average slope	0 to 5	0 = flat 1 = noticeable 2 = obvious 3 = significant 4 = strong 5 = extreme	(e.g., extreme or strong could be cliffs)	50
Consistenc	Consistency	0/1	0 = consistent 1 = not consistent	To evaluate superficial vs hyporheic flow	50 + LIT
Concavit	Shore profile: concavity	0 to 1	0 = none 0.1–0.9 = inter-mediate 1 = along whole stretch	See examples in the manual, p. 61	SHO
Convexit	Shore profile: convexity	0 to 1			SHO
Complexit	Complexity	0 to 1	0 = none 0.1–0.9 = inter-mediate 1 = along whole stretch	Evaluates the presence of ecological niches 0 = e.g. impermeable walling	SHO or SHO LIT where applicable
Artificia_	Artificiality	0 to 1	0 = none 0.1–0.9 = inter-mediate 1 = along whole stretch		SHO
Run_Off	Runoff	0 to 1	0 = diverging	0.5 = parallel to the shore	200

			0.1–0.9 = inter-mediate 1 = converging		
PersonalEv	Expert judgment	1 to 5	1 = high 2 = good 3 = moderate 4 = poor 5 = bad	Surveyor evaluates overall functionality of shorezone, results of which are used in the future development and control of the methodology; NB: discrepancies with calculated values may indicate errors in data collection or entry	LS
Surveyors				Surveyors that carried out survey	
DateSurvey				Date the survey was carried out	
Shore_Type		1 to 6	1 = wide belt of riparian vegetation 2 = narrow belt of riparian vegetation 3 = thin layer of shrubs 4 = Reeds followed by bare soil/crops 5 = bare soil/grass/high anthropogenic impact 6 = artificial shore	Categories identified a posteriori	SHO
Floating		0 to 2	0 = absent 1 = present 2 = no information	Information extracted from description of stretches a posteriori	
Comments				Various info extracted from description of stretches a posteriori	
Oak		0 to 2	0 = absent 1 = present 2 = no information	Information on the presence of oak trees extracted from description of stretches a posteriori	

* Heterogeneity of arboreal and riparian vegetation

0	Native trees and shrubs are absent, or exotic species are prevalent
0.1	Native trees and shrubs cover more than 2/3 of the total tree/shrub area, but only 1 species is dominant, e.g. pine tree
0.2	Native trees and shrubs are prevalent, but only 1 species is dominant
0.3–0.4	Native trees and shrubs cover more than 2/3 of the total tree/shrub area, and there are at least 2 or 3 species equally present
0.5	Native trees and shrubs cover more than 2/3 of the total tree/shrub area, and there are more than 3 species equally present
0.6	Native **riparian** trees and shrubs cover more than 2/3 of the total tree/shrub area, but 1 species only is dominant
0.7–0.9	Native **riparian** trees and shrubs cover more than 2/3 of the total tree/shrub area, and at least 2 or 3 species are equally present
1	Native **riparian** trees and shrubs cover more than 2/3 of the total tree/shrub area, and more than 3 species are equally present

KEY

LS = lake shorezone (both riparian and littoral)

RIP = riparian only (terrestrial)

LIT = littoral only (aquatic)

50 = area between shoreline to a line 50 metres inland

SHO = shoreline (i.e. the point of contact between the land and the lake)

200 = area between shoreline to a line 200 metres inland

SHO LIT = lakeward boundary of reed belt

6.4 Example of an SFI field form

For more information on this form, please refer to the following manual, available free of charge on the APPA Trento website: Siligardi, M. et al., *Lake shorezone Functionality Index, APPA manual*, 2010

Date	Form no
Lake	
Delimitation of stretch	
Photos no	
Surveyors	
Lake shorezone	
1. Width of lake shorezone	
0 m	0
1–5m	1
5–10m	2
10–30m	3
30–50m	4
>50m	5
2. Characterisation of lake shorezone vegetation **2.1 Cover/composition % (expressed from 0 to 1)**	
Trees %	
Shrubs%	
Reeds%	
Grasses%	
Bare soil%	
2.2 Hygrophilous and non-hygrophilous vegetation (expressed from 0 to 1)	
Hygrophilous	

Non-hygrophilous	
2.3 Presence of exotic species	
Exotics	
2.4 Heterogeneousness of arboreal-shrub vegetation	
Diversified	1
Intermediate (from 0.9 to 0.7)	
Monospecific	0.6
Autochthonous hygrophilous arboreal-shrub species >2/3	
Diversified	0.5
Intermediate (from 0.4 to 0.3)	
Monospecific	0.2
Autochthonous hygrophilous arboreal-shrub species <2/3 and autochthonous arboreal-shrub <2/3	
Autochthonous prevalence	0.1
Exotic prevalence	0
Arboreal-shrub vegetation absent	0
3. Continuity of the lake shorezone vegetation	
Arboreal and shrub zone	
Absent	0
Discontinuous	0.5
Continuous	1
Wet reed zone	
Absent	0
Discontinuous	0.5
Continuous	1
Dry reed area	
Absent	0

Discontinuous	0.5
Continuous	1
4. Presence of interruption in the lake shorezone	
Absent	0
Intermediate (from 0.1 to 0.9)	
Present along the whole stretch	1
5. Typology of anthropogenic uses within the lake shorezone	
Uncultivated meadows or unpaved streets, etc.	0
Sparse urbanisation, cultivated meadows, etc.	0.5
Urbanised area	1
SHORE AND SURROUNDING TERRITORY	
6. Main use of nearby territory	
Woods and forest	0
Meadows, forests, arable land, uncultivated farmland	1
Seasonal and/or permanent cultures, and sparse urbanisation	2
Urbanised area	3
7. Infrastructure	
Provincial/state roads	
Absent	0
Intermediate (from 0.1 to 0.9)	
Present along the whole stretch	1
Railroads	
Absent	0
Intermediate (from 0.1 to 0.9)	
Present along the whole stretch	1
Parking	
Absent	0

Intermediate (from 0.1 to 0.9)	
Present along the whole stretch	1
Tourism-related infrastructure	
Absent	0
Intermediate (from 0.1 to 0.9)	
Present along the whole stretch	1
8. Emerged portion of the lakeshore zone **8.1 Average slope**	
Flat	0
Slightly noticeable slope	1
Obvious but can be overcome without problem	2
Significant but can be overcome with trails or ramps	3
Strong slope, roads or trails with bends	4
Extreme, vehicles cannot negotiate it	5
8.2 Comparison between the slopes of the emerged and submerged areas	
Not consistent	0
Consistent	1
9. Shore profile **9.1 Concavity and convexity**	
Concavity	
Absent	0
Intermediate (from 0.1 to 0.9)	
Present along the whole stretch	1
Convexity	
Absent	0

Intermediate (from 0.1 to 0.9)	
Present along the whole stretch	1
9.2 Complexity	
Absent	0
Intermediate (from 0.1 to 0.9)	
Present along the whole stretch	1
10. Shoreline artificiality	
Absent	0
Intermediate (from 0.1 to 0.9)	
Present along the whole stretch	1
11. Apparent channelling of runoff	
No prevalent direction for the flow	0
Intermediate (from 0.1 to 0.9)	
All the runoff converges on a single point	1
12. Personal evaluation	
High	1
Good	2
Moderate	3
Poor	4
Bad	5