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# TOWARDS CANDIDATURE OF THE CRNO JEZERO (BLACK LAKE) (DURMITOR, MONTENEGRO) AS A HIGH ECOLOGICAL STATUS (HES) SITE OF THE DINARIC WESTERN BALKAN ECOREGION

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*Abstract* - The aim of this study was to assess whether the Crno jezero (Black Lake) could be designated as a site possessing specific reference conditions of a glacial lake in the Dinaric Western Balkan ecoregion. The results of a Lake Habitat Survey (LHS), analysis of macrophytes and a basic water quality assessment indicate that the lake is in a near pristine state, particularly with regard to its hydromorphological status, and that it fulfills the requirements of High Ecological Status (HES), as set by the Water Framework Directive. However, to confirm these preliminary findings, an integrated assessment of the ecological and chemical status, using other biological quality elements and a full set of physico-chemical parameters, is necessary.

*Key words*: Lake, macrophytes, water quality, HES, LHS

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## INTRODUCTION

A wide range of national and international legislations provides a powerful impetus for undertaking freshwater assessment. The European Directive 2000/60/EC establishes a framework in the field of water policy, commonly known as the Water Framework Directive (WFD), placing emphasis on the biological, as well as chemical and hydromorphological elements in the ecological classification of surface waters.

For a lake to be considered of High Ecological Status (HES, or 'reference condition'), the various quality elements that define hydromorphology must be in a pristine, or near pristine condition. Below HES the hydromorphological conditions are not defined but must support the needs of the biota (Rowan 2004).

Outside Europe, New Zealand has a rich tradition in lake monitoring and an ecosystem approach is advocated for assessing development proposals that may affect morphology by altering water level regimes (Riis and Hawes, 2002). In the USA, the most significant standard tool for physical lake monitoring is the US Environmental Protection Agency's Environmental Monitoring Assessment Program (EMAP) Field Operations Manual for Lakes (FOML, Kaufmann and Whittier, 1997). A similar strategic river habitat monitoring protocol has been developed by the Environment Agency of England and Wales (Raven et al. 1997, 1998). The development of RHS has been given further impetus owing to the regulatory requirements of the WFD, and it has become a central element in the CEN guidance standard for assessing the hydromorphological features of rivers. The LHS methodology draws extensively on both the FOML and RHS approaches (Rowan, 2004).

A Lake Habitat Survey (LHS) was thus developed to capture primary field data, generate metric parameters relevant to the WFD and feed into decision-support tools e.g. to determine whether a lake has hydromorphological conditions consistent with HES, or to establish if it has been 'substantially changed in character' and so qualifies as a candidate for the class of Heavily Modified

Water Body (HMWB, Rowan, 2004). The underlying principle of the system is that it performs a pressure-based assessment of impacts on biologically and ecologically relevant features and processes, thereby promoting the protection of morphological and ecological status. Many European countries, including Serbia, have focused recently on testing the Lake Habitat Survey (LHS) method, originally developed in the UK in 2004. Those countries working with LHS have all contributed to the EU standard for assessing lake hydromorphology, under the auspices of the CEN (European Committee for Standardization/Comité Europeén de Normalisation).

The initial development of LHS was carried out by the University of Dundee (Rowan, 2005). LHS has been tested in the UK, Ireland, France, Spain, Portugal, the Netherlands, Finland, Poland, Serbia and now Montenegro, with recent trials in the Ukraine, Russia and Hungary. With the draft version of a CEN standard completed in May 2009 (CEN 2009), refining and implementing this method depends crucially on its testing and researchers exchanging experience through workshops, seminars and training events, and by setting up a central LHS database for EU countries.

Aquatic macrophytes have also been used relatively widely to determine the ecological status and water quality or habitat characteristics. These are mostly established on the basis of the occurrence of species growing in oligo-, meso- or eutrophic waters, as well as on their proportions within the assemblages of whole species (Toivonen and Lappalainen, 1980, Palmer, 1992, Toivonen and Huttunen, 1995). The first record of the aquatic macroflora of Montenegrin lakes dates from Cvijic, (Cvijić, 1899). Since then, there have been many records that primarily describe Lake Skadar (Janković and Blaženčić, 1973; Janković, 1983; Blaženčić and Blaženčić, 1983, 1983a; Ristić and Vizi, 1981; Lakušić and Pavlović, 1981). These are followed by more recent research undertaken from 1972 on other lakes in the Prokletije Range and on Mts. Bjelasica, Sinjajevina, Durmitor, and Volujak (Briks and Walters 1972, Blaženčić and Blaženčić, 1986, 1989, 1991, 1993, 1994, 1994a, 1994b, 1996, 1997; Blaženčić et al. 1994, 1995, 1997, 2002, 2003, 2004).

All EU member States and accession countries (those in the process of joining the EU) are charged with the duty to develop monitoring and classification tools for biological, physico-chemical and hydromorphological attributes, as well as environmental standards, and to ensure that the environmental objectives of the WFD are met. As a signatory party of the Convention on Cooperation for the Protection and Sustainable Use of the Danube River (Danube River Protection Convention) and Framework Agreement on the Sava River Basin (FASRB), and as a full member of the International Commission for the Protection of the River Danube (ICPDR) and International Sava River Basin Commission (ISRBC), Montenegro is committed to apply the principles of integrated water management (including water monitoring and assessment) as stipulated by the WFD.

The basic act in Montenegro within the sector of water protection is the Water Law (Službeni List RCG, 16/95). Article 28, the Ordinance on water classification and water body categorization (Službeni List RCG 15/96 and amendments 19/96 and 15/97) specifies the outline for surface, groundwater and coastal water quality classes and water body categories in the Republic of Montenegro. The general classification is done exclusively according to the intended use of the water as follows: water intended for drinking, water intended for fish and shellfish aquaculture and water intended for bathing.

Waters intended for drinking are further divided into 3 subclasses depending on the complexity of the pre-treatment needed (similar to the Council Directive 98/83/EC). The numerical environmental standards for 42 water quality parameters are given for each of the classes mentioned. The environmental standards (EQS) are basically in accordance with the Council Directive 98/83/EC. Waters intended for fish and shellfish aquaculture are also further divided into 3 subclasses: S – water for *Salmonid* aquaculture, Š – water intended for shellfish aquaculture and C – water for *Cyprinid* aquaculture, similar the manner stipulated by Directive 2006/44/EC. The water classes S and Š correspond to class A1, while water class C fits into the demands of class A2. In the end, water intended for bathing and recreation is divided into 2 subclasses, mainly according to microbiological parameters, however, they differ substantially from Directive 2006/7/EC. According to the required or desired water quality, all surface waters are divided into 2 categories: A1 S I and A2 C II.

For the purposes of protection and water quality monitoring, Article 30 of the Water Law introduces systematic water quality and quantity surveillance. The Ministry for Water Management, in consultation with the Ministry for Environmental Protection, should produce an annual monitoring program (e.g. Službeni List RCG 25/09), which would be implemented by the Hydrometeorological institute of Montenegro.

*Background of the study site*

Mountainous areas are now recognized as important regions of biodiversity and endemism. Moreover, mountain regions are a principal source of fresh water, giving rise to many of the world's major rivers, and are therefore fundamental to the providing of this resource to downstream ecosystems, agriculture and human populations (Rose et al. 2007). The lakes of these regions often possess fragile ecosystems, owing to a number of factors, including thin soils and often harsh meteorological conditions. Despite their isolation from direct contamination and human pressure, the stress of atmospheric pollutant deposition on remote lakes in upland areas often results in detectable chemical and/or biological changes (Lotter et al. 2005). Hence, remote mountain lakes can act as 'early warning' indicators for less sensitive sites, and the wider environment, and they have become a useful tool in monitoring the impacts of atmospherically deposited pollutants. Recent studies in Europe have shown that these pollutants have been impacting remote lakes for hundreds of years (Bindler et al. 2001, Yang et al. 2002).

In spite of the magnitude of the freshwater resource in the highlands of Montenegro, to set them in an international and local context, relatively little information linking biology, hydrology and chemistry is available. It has been estimated that there are 17 lakes (including ephemeric) within the Durmitor Mountain National Park. These range in size from ponds and lakes (Zeleni Vir, Barno jezero, Suva Lokva, Modro jezero, less than 5 m deep) to the expanse of the Crno Jezero lake (45 m depth, Radulović 1971). Crno jezero is the largest and deepest lake in the Durmitor National Park. Apart from it being located within an area that is protected by the national legislation of the Republic of Montenegro, Crno jezero was designated as a World Heritage Site by UNESCO in 1980.

The spectacular Durmitor massif, 'wild and majestic', like in Byron's poems (Lord Georg Gordon Byron, 1788 – 1824, died in Greece during fight against the Ottoman Empire), creates the 'mad, bad and dangerous to know' skyline and ambiance of the area. Apparently, every attempt to describe the harsh beauty of this amazing mountain, either in scientific papers or touristic flyers, seems to bring out both the poet and the warrior. Nevertheless, the specific drama of the Durmitor scenery stems from the unique layout of the slopes of the massif with cliffs that define the margins of the cirque and glacial valleys which are typical of landscapes of selective glacial erosion (Sugden 1968, Rose et al. 2007). Crno jezero's surface lies at the concave amphitheatre corrie valley, a tarn, formed at the head of a valley created by glacier-erosion (the foot of Međed peak, an area of 0.515 km2).

The Crno jezero tarn consists of two lakes: Veliko jezero (a comparatively bigger lake with an area of 0.338 $km^2$, maximum depth of 24.5 m, maximum length of 855 m and maximum width of 615 m), and Malo jezero (a small lake with an area of 0.177 $km^2$, maximum depth of 49.1 m, maximum length of 605 m and maximum width of around 400 m).

The lakes are connected by a narrow strait, which sometimes dries up during the summer, thus creating two separate bodies of water. The maximum length of the entire Crno jezero is 1.155 m. The small lake actually has the greater volume, being deeper (up to 50 m). The upland nature of the National Park with the Durmitor Mountain results in heavy rainfall, often in excess of 1 270 mm per year (Radulović, 1971).

The lake is fed with water by three small streams flowing into the north and east shores of the lake that serve as a relatively small catchment which is only approximately 10 times the lake area. These inflow streams are generally rather small, and originate from the steeper parts of the catchment. Although a few flow all year round, many of the streams are ephemeral. The main drainage is into the Piva river at the north-west of the lake. There is a lack of information on the drainage of the surrounding area, particularly in relation to land drainage corresponding to changes in land use. Thus, no quantitative estimations or predictions of groundwater trends and surface-water flows in the catchment can be made.

Due to the range of climatic zones present within mountain regions, the sensitivity to change is high, with the potential for loss of alpine species and considerable impact on hydrology across broad areas (Rose and Battarbee, 2007). To conserve and protect the overall ecological integrity of this unique lake, a series of measures, including continuous integrated environmental monitoring, is essential. As a first step towards the ecological status evaluation this study aimed at assessing the water quality, the hydromorphological and the biological status of the lake with the further goal of examining the possibility of designating Crno jezero as a site or type possessing specific reference conditions for qualifying as a glacial lake of the Dinaric Western Balkan Ecoregion.

## MATERIAL AND METHODS

Field work was carried out during the summer months of 2005 and 2006, using the LHS protocol as a base. The protocol involves a complete circumnavigation of the lake at wader depth in order to record the shoreline and shallow water aquatic plant species.

### *Summary of the LHS protocol*

Fundamental background information is collated prior to arrival at the lake, including physical data such as depth, surface area, altitude and catchment area, along with information on any conservation designations. The position of the first plot is randomly located to remove bias. Hab-Plots were 15 m wide and extend 15 m into the riparian zone from the bank edge, and 10 m into the littoral zone from the waterline.

Observations for the entire plot are made from an ‘offshore station’, either from a boat or while standing in the water (not exceeding the maximum wading depth of 0.75 m), to ensure consistency between boat- and foot-based versions. The dimensions of the riparian and littoral zones were selected to capture the composition and diversity of features to be assessed, and corresponds to the field of view of the surveyor from the offshore station. The shore zone (especially beach width) is of variable dimension depending on the water level at the time when the survey is carried out (Rowan, 2005).

### *Field survey*

In accordance with the LHS protocol, each Hab-Plot was divided into three zones (riparian, shore and littoral), and detailed information was collected in each e.g., land cover and riparian vegetation structure, shore zone geomorphology and macrophyte abundance. All modifications and human pressures were also recorded. Through the perimeter survey, information was collected on a whole-lake scale on the distribution of natural habitats, as well as shore zone pressures (e.g. tourism). Data on water level fluctuations were sought; hence at the deepest point of the lake an ‘Index Site’ was established, where a temperature and dissolved oxygen profile was collected, along with water transparency (Secchi Disk depth) readings. The following metrics were generated: (i):the Lake Habitat Modification Score (LHMS) which can be used to classify the degree of alteration, and (ii) the Lake Habitat Quality Assessment (LHQA) score, which provides a measure of diversity and naturalness of the site.

Water samples for chemical analysis were collected in August 2006 at the Index site position of the lake. The dissolved oxygen and temperature profile were measured at the following depths: 0.5, 1, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, 35 and 40 m.

Water quality along the vertical profile at the Index site was evaluated using the following basic water quality parameters: temperature (T), dissolved oxygen content (DO) and oxygen saturation, electrical conductivity (EC) and pH (measured electrochemically with WTW Inco Lab 4), while biological and chemical oxygen demand (BOD & COD), total organic carbon (TOC), total suspended solids (TSS), nitrates ($NO_3$), and surfactants (SUR) were analyzed using Sekomam Pastel UV. Besides these results, water quality was assessed using the official data (HMZCG 2006-2009), presented in Table 3.

Other observations were made on the substrate, water color and clarity, adjacent land use, wetland edges, artificial features, use of or damage to the site, inflows and outflows and obvious fauna.

All geospatial data were derived using Trimble Nomad GPS, integrated into a Microsoft Access LHS database which has been developed to allow for the storage and analysis of LHS survey data. This accommodates data from repeated surveys of sites and generates automated results for the two LHS metrics: Lake Habitat Modification Score (LHMS) and Lake Habitat Quality Assessment (LHQA). In Appendix 1 the summary of attributes measured in LHS is given (Rowan, 2006).

## RESULTS AND DISCUSSION

### *Hydromorphology*

In spite of its high altitude and general physical characteristics, the area studied possesses a range of aquatic habitats composed either of boulders and cobbles or of small gravel beach areas

Entries into the LHS field form were done using numerical estimations (width of beach to nearest meter), dichotomous (present/absent), categorical (represented by a two-letter code corresponding to the feature of interest, e.g. type of bank reinforcement), or classed into percentage bands for areal coverage of a feature: 0 (0%), 0 (>0–1%), 1 (>1–10%), 2 (>10–40%), 3 (>40–75%), 4 (>75%). While sacrificing resolution, the use of classes rather than absolute percentages is time-efficient and increases inter-surveyor reproducibility (Fox et al., 1998).

Both the LHQA and LHMS were generated using boat and foot, and the full boat-based version (the report is given in Tables 1 and 2). Scores ranged from zero for many attributes, such as shore zone modification; shore zone intensive use; hydrology; sediment regime and introduced species, to 18 for littoral score modification. A high degree of consistency was evident in the LHMS for all attributes except in-lake pressures. Most natural lakes scored below 10, with a substantial number scoring zero indicating no significant pressures (Rowan et al., 2006). Gaining an LHMS of zero, combined with the high LHQA (65) give a solid base for the candidature of the Crno Jezero Lake for High Ecological Status in the region.

### *Macrophytes*

The presence of only four vascular aquatic species was recorded, these are: *Potamogeton natans* L., *Potamogeton crispus* L., *Potamogeton pusillus* L. *and Myriophyllum spicatum* L. Despite the general floristic impoverishment with tracheophytes in the studied area, the charophytes (stonewort) are relatively diverse, even though, in accordance with the LHS protocol, they are given in a lower taxonomic resolution. On that premise, the presence of the cryptogamic flora was recorded as *Chara* ssp. This relative diversity may be related to the ability of these organisms to utilize an array of niches in a nutrient-poor environment where competition by major plant groups is low. On the other hand, the

**Table 1**. LHS database generated report and derived LHMS and LHQA Score of the Crno Jezero Big Lake.

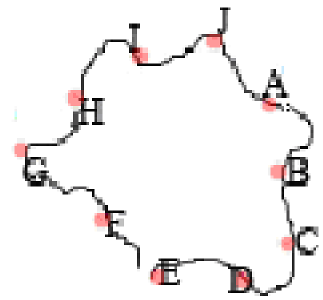
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LAKE INFORMATION | | | | | | | |
| LHS ID | **Big Basin** | | |  | | | |
| Name of lake: | **Crno jezero** | | | | | | |
| Country: | **Montenegro** | | | | | | |
| Date last surveyed: | **02.8.2006** | | | | | | |
| Hab-Plots: | **10** | | | | | | |
| Principle use: | **Natural** | | | | | | |
| Hydrological Regime Class: | **Natural** | | | | | | |
| Lake surface area(km2) | **0.338** | | | | | | |
| Catchment area(km2) | **30** | | | | | | |
| Lake attitude(m) | **1418.5** | | | | | | |
| Total surface area of reservoirs in upstream catchment (%) | | Lake perimeter (m) | **4395** | | | | |
| Summary estimate of overall intensity of pressures: | **<5 %** | Maximum depth(m):7 50 | **25** | | | | |
| Lake Perimeter Bank Construction Pressures and Land Uses % (whole numbers) | | | | | | | |
| Impoundments: | **0** | Moorings(high density) | **0** | Residential | **0** | Tiled lend: | **0** |
| Hard Engineering: | | Outfalls and intakes: | **0** | Roads or railways: | ✓ | Imp grass land: | **0** |
| Hard open: | **0** | Land Claim: | **0** | Parks and gardens | **0** | Soil poaching: | **0** |
| Hard closed: | **0** | Dumping: | **0** | Camping and caravans: | **0** | Orchard: | **0** |
| Soft Engineering: | **0** | Sediment Extraction: | **0** | Educational recreation: | **0** | Cause ways: | **0** |
| Flow and sediment control | **0** | Recreational beaches: | ✓ | Quarrying or mining: | **0** | Macrophyte manipulation: | **0** |
| Piled Structures: | **0** | Erosion: | **0** | Coniferous plantations: | **0** | Recreational Pressures: | ✓ |
| Floating and tethered structures | **0** | Commercial activities: | ✓ | Coniferous logging: | **0** | Riparian Vegetation Loss: | **0** |
| Lake Site Activities/Pressures(presence) | | | | | | | |
| Bridges | **0** | Angling | **0** | Litter | **0** | Introduced species | 0 |
| Causeways | **0** | Angling from boat: | **0** | Wildfowling | **0** | Macrophyte control: | **0** |
| Fish cages | **0** | Angling from shore | **0** | Surface films | **0** | Power lines | **0** |
| Commercial Fishing | **0** | Non-motor boat activities | ✓ | Liming | 0 | Non-boat recreation/swimming | **0** |
| Navigation | **0** | Motor boat activities | **0** | Dumping | **0** | Military activities | **0** |
| Sediment Extraction | **0** | Other pressures | | | | | |
| Fish stocking | **0** | | | | | | |

**Table 1**. (Continued).

| Wetland and Other Habitats%(whole numbers) | | | | Geomorphology | |
|---|---|---|---|---|---|
| Emergent reed-bed | **5** | Rough grassland: | **0** | Vegetated islands (non-deltaic) | **0** |
| Wet Woodland: | **10** | Other: | **0** | Unvegetated islands (non-deltaic) | **0** |
| Bog: | **5** | Broadleaf/mixed woodland: | **0** | Aggrading vegetated deltaic deposit: | **1** |
| Fen or marsh: | **5** | Coniferous woodland: | **95** | Stable vegetated islands(deltaic) | **0** |
| Floating veg mats: | **0** | Moorland/heath: | **0** | Deltaic unvegetated gravel bars: | **0** |
| Open water: | **0** | Rock, scree or dunes: | **65** | Deltaic unvegetated fines bars: | **0** |

| LHMS Score | 2 | LHQA Score | 65 |
|---|---|---|---|
| Shore zone modification | 0 | Riparian score | 14 |
| Shore zone intensive use | 0 | Shore score | 16 |
| In-lake pressures | 2 | Littoral score | 18 |
| Hydrology | 0 | Whole lake score | 17 |
| Sediment regime | 0 | | |
| Introduced species | 0 | | |

vascular species *Potamogeton pusillus* L., *Myriophyllum spicatum* L., *Ranunculus trichophyllus* Chaix, recorded by Blaženčić (1991) cannot be considered as indicative of high mountain conditions *per se* as they occur in many lakes at a variety of altitudes (Flower et al. 2007, Radulovic, 2005). Consequently, the alpine nature of the Crno jezero is perhaps best exemplified by the presence of *Nitella* ssp (Blaženčić, 1991) and the absence of some aquatic macrophytes characteristic for meso-oligotrophic lakes within the Durmitor area, such as *Nuphar lutea* (L.) Sm (recorded at the Zmijsko and Riblje jezero lakes), and mesotrohic *Phragmites australis* (Cav.) Trin. ex Steud (Vrazje and Riblje jezero lakes). As these plants occur frequently elsewhere, they are excluded from the study area by ecophysiological limitations (Radulović, 2005).

According to Blaženčić and Blaženčić (2005), by far the most common species of Dinaric lakes are *Alisma plantago-aquatica* L., *Myriophyllum spicatum* L., *Carex rostrata* Stokes, *Eleocharis palustris* (L.) Roemer & Schultes subsp. *palustris, Potamogeton natans* L., *Potamogeton lucens* L., *Ranunculus trichophyllus* Chaix subsp. *trichophyllus*, *Chara contraria,* and *Chara aspera* Deth. ex Willd that have a broad amplitude of vertical distribution, from 1.0 up to 1780 m above sea level. As for the Crno jezero, the majority of the species, *Deschampsia cespitosa* (L.) Beauv. subsp. *cespitosa, Eleocharis palustris* (L.) Roemer & Schultes subsp. *palustris, Mentha longifolia* (L.) Hudson, *Potamogeton crispus* L., *Potamogeton pusillus* L., *Myriophyllum spicatum* L., *Ranunculus trichophyllus* Chaix subsp. *trichophyllus, Chara contraria* A. Br. ex Kutzing, *Chara aspera* Deth. ex Willd., *Chara globularis* Thuill, *Chara rudia* (A. Braun) Leonh, *Chara delicatula* Agardh, *Nitella flexilis* (L.) C. Agardh, *Nitella opaca* Agardh (Blaženčić, 1991) can be found and identified with certainty, thus providing a degree of confidence in the majority of the data.

Despite uninformed opinions about mountain lakes being of little botanical interest, the physiological adaptations of plants growing in these waters are notable (Rörslett and Brettum, 1989; Farmer 1990), as is the botanical diversity, albeit low (Duigan, 2005). The oligotrophic nature of high altitude lakes is natural and reflects location and elevation; located at an altitude of almost 1500 m, with

**Table 2**. LHS database generated report and derived LHMS and LHQA Score of the Crno Jezero Small Lake.

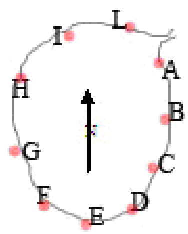
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LAKE INFORMATION | | | | | | | |
| LHS ID | Small Basin | |  | | | | |
| Name of lake: | Crno jezero | | | | | | |
| Country: | Montenegro | | | | | | |
| Date last surveyed: | 02.8.2006 | | | | | | |
| Hab-Plots: | 10 | | | | | | |
| Principle use: | Natural | | | | | | |
| Hydrological Regime Class: | Natural | | | | | | |
| Lake surface area(km2) | 0.177 | | | | | | |
| Catchment area(km2) | 30 | | | | | | |
| Lake attitude(m) | 1418.5 | | | | | | |
| Total surface area of reservoirs in upstream catchment (%) | | Lake perimeter( m) | 4395 | | | | |
| Summary estimate of overall intensity of pressures: | <5% | Maximum depth (m) | 49.5 | | | | |
| Lake Perimeter Bank Construction Pressures and Land Uses % (whole numbers) | | | | | | | |
| Impoundments: | 0 | Moorings(high density) | 0 | Residential | 0 | Tiled lend: | 0 |
| Hard Engineering: | | Outfalls and intakes: | 0 | Roads or railways: | 0 | Imp grass land: | 0 |
| Hard open: | 0 | Land Claim: | 0 | Parks and gardens | 0 | Soil poaching: | 0 |
| Hard closed: | 0 | Dumping: | 0 | Camping and caravans: | 0 | Orchard: | 0 |
| Soft Engineering: | 0 | Sediment Extraction: | 0 | Educational recreation: | 0 | Cause ways: | 0 |
| Flow and sediment control | 0 | Recreational be aches: | 0 | Quarrying or mining: | 0 | Macrophyte manipulation: | 0 |
| Piled Structures: | 0 | Erosion: | 0 | Coniferous plantations: | 0 | Recreational Pressures: | ✓ |
| Floating and tethered structures | 0 | Commercial activities: | 0 | Coniferous logging: | 0 | Riparian Vegetation Loss: | 0 |
| Lake Site Activities/Pressures(presence) | | | | | | | |
| Bridges | 0 | Angling | 0 | Litter | 0 | Introduced species | 0 |
| Causeways | 0 | Angling from boat: | 0 | Wildfowling | 0 | Macrophyte control: | 0 |
| Fish cages | 0 | Angling from shore | 0 | Surface films | 0 | Power lines | 0 |
| Commercial Fishing | 0 | Non-motor boat activities | ✓ | Liming | 0 | Non-boat recreation/swimming | 0 |
| Navigation | 0 | Motor boat activities | 0 | Dumping | 0 | Military activities | 0 |
| Sediment Extraction | 0 | Other pressures | | | | | |
| Fish stocking | 0 | | | | | | |

**Table 2**. (Continued).

| Wetland and Other Habitats%(whole numbers) | | | | Geomorphology | |
|---|---|---|---|---|---|
| Emergent reed-bed | 0 | Rough grassland: | 0 | Vegetated islands (non-deltaic) | 0 |
| Wet Woodland: | 0 | Other: | 0 | Unvegetated islands (non-deltaic) | 0 |
| Bog: | 0 | Broadleaf/mixed woodland: | 0 | Aggrading vegetated deltaic deposit: | 1 |
| Fen or marsh: | 0 | Coniferous woodland: | 100 | Stable vegetated islands(deltaic) | 0 |
| Floating veg mats: | 0 | Moorland/heath: | 0 | Deltaic unvegetated gravel bars: | 0 |
| Open water: | 0 | Rock, scree or dunes: | 50 | Deltaic unvegetated fines bars: | 0 |
| LHMS Score | 2 | LHQA Score | 48 | | |
| Shore zone modification | 0 | Riparian score | 17 | | |
| Shore zone intensive use | 0 | Shore score | 15 | | |
| In-lake pressures | 2 | Littoral score | 14 | | |
| Hydrology | 0 | Whole lake score | 2 | | |
| Sediment regime | 0 | | | | |
| Introduced species | 0 | | | | |

high precipitation, high winds, relatively low temperature and a severe microclimate. These conditions conspire to produce lakes with very low nutrient and mineral contents, supporting rather specialized species and aquatic plant communities of low species diversity. It is true that the aquatic plant communities are species poor (compared with richer lowland sites). However, monitoring the species which do persist in these extreme habitats can yield valuable ecological information about the current biological status and about the nature, rate and influences of processes of environmental changes.

One of the main problems for performing a Europe-wide assessment of macrophyte responses to pressures is the lack of a Europe-wide homogenous monitoring methodology (Penning et al., 2008), although attempts are being made to harmonize the methodology using a common CEN standard or lake habitat survey (CEN 2006).

Many previous reports on the use of macrophytes as indicators of eutrophication in lakes are confined to single countries (e.g. Palmer et al., 1992), or to relatively small geographical regionswithin Europe (e.g. Rørslett 1991). Other approaches focus only on selected groups of macrophytes, such as isoetids (Murphy et al., 1990). The REBECCA (the 6th Framework Program) lists include all the large isoetids, and some *Chara* spp., among the sensitive species, while most other macrophytes are included among the tolerant species. The remaining species are partly indifferent to eutrophication pressure, but also include species missing or rare in some regions or countries. However, only three *Chara* species are included among the sensitive species. This may be because of the heterogeneous character of high alkalinity lakes and/or the fact that many lake surveys in the REBECCA database included several merged *Chara* spp. species, making the discussion about the classification of the *Chara* species difficult (Penning et al., 2008).

Many factors influence plant occurrences and abundances in natural aquatic systems. Nevertheless, in any attempt to evaluate the aquatic flora of a particular lake or loch, water quality is of primary consideration as an intrinsic factor. Low nutrient status surely can favor certain plant species, but productivity is limited and the aquatic system is referred to as oligotrophic (Rose et al., 2007). Irrespective of the nutrient status of an aquatic system, underwater light availability has a primary influence on aquatic plant growth; very high light intensity can suppress photosynthesis. Temperature diminishes with altitude and in harsh mountain

**Table 3**. Water quality of Crno jezero (2006-2009) according to the official data (HMZCG 2007-2010).

| | | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| pH | Range | 6.8-8.5 | 7-9 | 6.8-8.5 (8.3)* | |
| | Quality class | A1 | A2I | A1 | |
| TSS | mg/l | | <10 | | <20 |
| | Quality class | | A1S | | A2 |
| EC | µS/cm | <400 (213) * | | | |
| | Quality class | A1 | | | |
| DO | mg/l | >7 (9.4) * | | | |
| | Quality class | S | | | |
| SAT $O_2$ % | Range | 80 - 120 (98-109) | | | |
| | Quality class | A1SI | | | |
| COD | mg$O_2$/l | <8 (1.8) * | | | |
| | Quality class | A1 | | | |
| $BOD_5$ | mg$O_2$/l | <3 | | | |
| | Quality class | A1 | | | |
| SUR | mg/l LAS | <0.1 | | <0.2 | <0.1 |
| | Quality class | A1 II | | A2 | A1II |
| $NO_3^-$ | mg/l | <20 (0.48) * | | | |
| | Quality class | A1 | | | |
| $NO_2^-$ | mg/l | <0.03 (0) * | | | |
| | Quality class | A1S | | | |
| $NH_4^+$ | mg/l | >1 | 0.5-1 | 0.05-1 (0.07) * | 0.04-0.5 |
| | Quality class | A3C/VK | A2 C /VK | A2C | A1S |
| $PO_4^-$ | mg/l | <0.08 | | 0.28 | <0.5 |
| | Quality class | A1 | | VK | VK |
| $SO_4^-$ | mg/l | <50 (6.6) * | | | |
| | Quality class | A1 | | | |
| Phenols | mg/l | <0.005 | | <0.01 (0.001) | |
| | Quality class | A1SI | | A1S | |
| Fe | mg/l | <0.1 | | | |
| | Quality class | A1 | | | |
| $Cl^-$ | mg/l | <20(8.4) * | | | |
| | Quality class | A1 | | | |
| Total coli | No/100 ml | 500 - 5000 | | 500 – 10000 (1068) * | |
| | Quality class | A2SI | | A2SII | |
| Phoecal coli | No/100 ml | <20 | | | |
| | Quality class | A1I | | | |

* Indicative values for each water quality parameters, as set in 2008, are given in brackets.
A – natural waters which can be used as drinking water: A1 – after having been only disinfected; A2 – after having been treated with commonly applied water treatment process which includes pre-chlorination, followed by coagulation, flocculation, filtration, active carbon treatment and final disinfection (ozonisation or chlorination); A3 – only after having been treated with complex water treatment process, including prolonged disinfection. S: waters suitable for salmonid species and shellfish; C: waters suitable for cyprinids. I and II: bathing water classes. VK: beyond any class

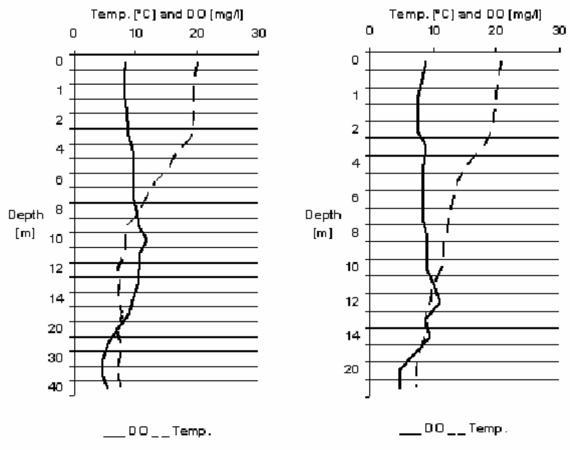



**Fig. 1**. Temperature and dissolved oxygen content along the vertical gradient in a) Big basin and b) Small basin in summer 2006.

climates light is often reduced by frequent low clouds over the higher ground. Consequently, aquatic plant communities in upland water bodies are exposed to a variety of natural climate stressors that can either select or deselect particular species. However, it is the impact of human activities that, indirectly or directly, has promoted the most rapid environmental changes in the uplands (Darling and Boyd 1964, Flemming et al. 1997, Battarbee et al. 2005). Direct impacts can include the introduction of unwanted species or promotion of local landscape changes, usually by enhancing soil erosion or by causing hydrological disturbances. Probably the most pervasive form of human disturbance, however, results from the deposition of chemical pollutants from the atmosphere (Flower et al. 2007). Hence, the composition of the aquatic flora in many upland waters today is the result of a multiplicity of impacting factors that have acted over a range of time-scales.

*Water quality*

The data on basic water quality parameters (dissolved oxygen – DO in the first place) along the whole vertical profile at the Index site present an integral part for the LHS. Since the official monitoring program is restricted to only 3 samples along the vertical profile, the measurements had to be done during the study, as there is no sufficient official information to fulfill the requirements of the applied method (LHS). The results presented in Fig. 1 and Table 3 correspond very well with the official data (Table 4). The high content of DO as well as low BOD and COD values along the profiles in both basins should be particularly underlined.

In the case of Crno jezero, the monitoring program specifies that the sample for water quality analysis should be taken from one sampling site only - the middle of the lake, as 3 sub-samples along the vertical profile, 4 times per year, but strictly during the period June – October. The required water quality of Crno jezero is set to be A1SI. The available official data on the water quality of Crno jezero during the period of the study (2006 – 2009) are summarized in Table 3. Generally, the water quality complies with the requested national A1SI class, with only a few exceptions. The concentrations of suspended solids (TSS), phosphates ($PO_4^-$) and ammonium ion ($NH_4^+$), as well as the number of total coliform bacteria exceeded national environmental quality standards.

According to our results as well as the official data, Crno jezero, if evaluated against the national water quality standards and criteria, could be classified, in general, as required A1 S I water. The occasional elevated concentrations of TSS and $NH_4^+$ (exceeding the EQS) should rather be seen as natural characteristics which failed to be respected in national regulations. In the case of $NH_4^+$,the national EQS are set too stringently (0.05 and 0.5 mg/l for A1 and A2 waters respectively and even 0.04 mg/l for S waters), ignoring the fact that geographical or climatic conditions, particularly low water temperature, lead to reduced nitrification which results in a slightly higher content of $NH_4^+$. Respecting those facts, Directive 2006/44/EC allows member states to fix $NH_4^+$even above 1 mg/l, providing that there are no harmful consequences for the balanced development of the fish population. The slightly higher TSS values come as a direct consequence of the nature of alimentary waters. The high

**Table 4**. Range and average values of the water quality parameters measured in two basins of the Crno jezero along the vertical profile in summer 2006.

| | Veliko jezero (Big basin) | | | Malo jezero (Small basin) | | |
|---|---|---|---|---|---|---|
| | Epilimnion | Metalimnion | Hypolimnion | Epilimnion | Metalimnion | Hypolimnion |
| Depth [m] | Surface – 2 | 2 – 5 | 5 – 23.5 | Surface – 3 | 3 – 9 | 9 – 49.1 |
| Temp. [°C] | 19.8 – 21 | 13.8 – 19.6 | 7.2 – 13.2 | 19.1 – 20.2 | 8.4 – 20.2 | 6.8 – 8.2 |
| pH | | | | | | |
| Range | 7.81 - 8.05 | 8.12 - 8.18 | 7.24 - 8.20 | 8.06 - 8.14 | 8.15 - 8.29 | 7.38 – 8.29 |
| Average | 7.98 | 8.16 | 7.89 | 8.11 | 8.20 | 7.91 |
| Quality Class* | A1 | A1 | A1 | A1 | A1 | A1 |
| EC [μs/cm] | | | | | | |
| Range | 164 - 173 | 157 - 164 | 160 - 226 | 160 - 163 | 147 - 160 | 146 - 207 |
| Average | 168 | 161 | 187 | 161 | 254 | 176 |
| Quality Class | A1 | A1 | A1 | A1 | A1 | A1 |
| DO [mg/l] | | | | | | |
| Range | 7.4-9.1 | 8.5 – 8.9 | 4.6 – 11.1 | 8 - 9 | 9.5 – 10.5 | 4.4 – 11.7 |
| Average | 8.02 | 8.58 | 8.26 | 8.48 | 9.78 | 8.08 |
| Quality Class | S | S | S | S | S | S |
| Sat $O_2$ [%] | | | | | | |
| Range | 81 - 102 | 81 - 94 | 38 - 97 | 87 - 96 | 88 - 98 | 36 - 99 |
| Average | 90 | 85 | 74 | 92 | 93 | 67 |
| Quality Class | A1 | A1 | A2 | A1 | A1 | A2 |
| BOD [mg $O_2$/l] | | | | | | |
| Range | 0.80 - 1.30 | 0.80 - 1.20 | 0.80 - 3.10 | 0.9 - 1.8 | 1.00 -2.80 | 1.3 - 3.1 |
| Average | 1.00 | 0.93 | 1.71 | 1.34 | 1.46 | 1.92 |
| Quality Class | A1 | A1 | A1 | A1 | A1 | A1 |
| COD [mg $O_2$/l] | | | | | | |
| Range | 2.00 - 2.90 | 2.00 - 2.80 | 2.10 - 8.40 | 2.20 - 4.70 | 2.60 - 7.40 | 3.10 - 6.90 |
| Average | 2.43 | 2.30 | 4.19 | 3.40 | 3.59 | 4.43 |
| Quality Class | A1 | A1 | A1 | A1 | A1 | A1 |
| TOC [mg/l] | | | | | | |
| Range | 0.60 - 0.90 | 0.50 - 0.80 | 0.60 - 2.30 | 0.60 - 1.50 | 0.70 -2.10 | 0.90 - 2.10 |
| Average | 0.75 | 0.63 | 1.21 | 1.00 | 1.01 | 1.31 |
| Quality Class | n.a. | n.a | n.a | n.a | n.a | n.a |
| TSS [mg/l] | | | | | | |
| Range | 7 - 12 | 10 - 13 | 10 - 68 | 10 - 39 | 10 - 61 | 11 - 14 |
| Average | 10 | 11 | 21 | 22 | 19 | 13 |
| Quality Class | A2S | A2S | A2S | A2S | A2S | A2S |
| $NO_3$ [mg/l] | | | | | | |
| Range | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 |
| Average | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 |
| Quality Class | A1 | A1 | A1 | A1 | A1 | A1 |
| SUR [mg/l] | | | | | | |
| Range | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 |
| Average | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 |
| Quality Class | A1 | A1 | A1 | A1 | A1 | A1 |

n.a. *not applicable*
* according to Službeni List RCG 14/97, 19/96 and 15/97 (1996/7)

concentrations of phosphates ($PO_4^-$) were recorded in 2008 and 2009; however, the data are not sufficient to evaluate the nutrient status of the lake. The official monitoring programs still rely on individual P and N compounds (phosphates, nitrates, nitrites), and do not include total P and total N, which present not only more reliable parameters, but are already requested under various EU regulations. Also, the official annual reports lack information on the acidification status of the lake – another crucial parameter, which, according to WFD, is listed among the mandatory chemical and physico-chemical elements supporting the biological elements.

Although the official monitoring program includes some specific synthetic and non-synthetic pollutants, and even several priority pollutants (listed in Decision No 2455/2001/EC), the data are not available, as either the parameters are not regularly measured or the results are not being reported. Therefore, the shortcomings of the official monitoring programs, as a consequence of the lack of harmonization of the national regulations with the EU in the water sector in general, prevent the accurate integral assessment of chemical status of the lake, as requested by WFD.

According to the results of this study as well as available data on basic water quality, it could only be conservatively concluded that the water quality of Crno jezero is good and that the lake fulfils the requirements of a good ecological status and unchanged hydromorphological conditions. However, further studies are needed to answer yet another open question – whether the overall ecological quality, evaluated using other biological quality elements and the full set of parameters needed for an accurate assessment of the chemical status, complies with the narrative criteria set down by the WFD for water bodies of excellent ecological and good chemical status, and consequently, whether Crno jezero can be designated as having the type specific reference conditions for this type of lake.

Since the Republic of Montenegro has not submitted any official report or even raw data on the water typology, ecological status and major pressures which should have already been included into the recently published Danube River Basin District Management Plan (ICPDR, 2009), the data reported in this paper indeed timely and could present a valuable contribution to the competent authorities of Montenegro in their attempts to catch up with the rest of the countries of the Danube River Basin in the near future.

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**Appendix I** - Summary of attributes measured in LHS

| Hab-Plots (10) | Perimeter | Whole lake |
|---|---|---|
| Riparian zone | Bank construction | In-lake pressures |
| Dominant land-cover type | Impoundments | Bridges; Causeways; Fish |
| Vegetation structure | Hard engineering | cages; Navigation; Dredging; |
| Presence of nuisance species | Closed and open types of | Dumping; Macrophyte |
| Bank-top features | engineering* | control; Motorboat sporting; |
| Streams/flushes | Soft engineering | activities; Non-motor-boat |
| | Docks, marinas, jetties and | activities; Angling from boat; |
| Bankface | moorings | Angling from shore; |
| Height and slope | | Recreation/swimming; Litter; |
| Material | Pressures and land uses | Nuisance species; Fish |
| Modifications | (within 15m and 50 m*) | stocking; Wildfowoling; |
| Vegetation cover/structure | Commercial activities; | Military activities; |
| Erosion | Residential areas; | Powerlines; Liming; |
| | Roads, railways, paths; | Surface films;Odour |
| Beach | Parks and gardens; | |
| Width and slope | Camping and caravans*; | Landform features |
| Material | Recreational beaches; | Vegetated islands |
| Modifications | Educational recreation; | Non-vegetated islands |
| Vegetation cover/structure | Litter, dump, landfill; | Vegetated deltaic deposits |
| Erosion or sedimentation | Quarrying mining; | Non-vegetated deltaic deposits |
| | Coniferous plantation; | Dimensions of outflow* |
| Littoral zone | Evidence of recent | |
| Slope and depth | logging; Pasture; | Hydrology |
| Substrate | Observed grazing; Tilled | Principal use of water body |
| Habitat features | land; Orchard; Erosion | Details of water level |
| Gravel to mud boundary* | | alterations |
| Macrophyte extent/structure | Natural habitats* | Number of influent streams |
| Percent volume inhabited by | (within 15 m and 50 m*) | Upstream impoundments |
| aquatic macrophytes* | Emergent reed-bed | Flow diversion |
| Nuisance macrophytes | Wet woodland (carr) | Tidal influence |
| Surface films/phytobenthos | Bog | Daily water level fluctuation |
| | Fen or marsh | Annual water level |
| Human pressures | Floating vegetation mats | fluctuation |
| (entier plot and within 50 m) | Broadleaf/mixed | Hidrological structures |
| Commercial activities; | plantation | |
| Residential developments; | Coniferous woodland | Index Site (deepest location) |
| Roads or railways; Unsealed | Scrub and shrubs | Maximum water depth |
| tracks and footpaths; Parks | Moorland/heath | Secchi dept |
| and gardens; Camping and | Open water | Temperature profile |
| caravans; Docks, marinas, | Rough grassland | Dissolved oxygen profile |
| boats; Walls, dykes or | Tall herb/rank vegetation | Surface conditions |
| revetments; Recreational | Rock, scree or dunes | Surface films |
| beaches; Educational | | Odor |
| recreation; Litter, dump, | | Grab sample from lake bed* |
| landfill; Quarrying or mining; | | |
| Pasture; Other grazed land; | | |
| Coniferous plantation; Tilled | | |
| land; Orchard; Pipes, outfalls; | | |
| Dredging; Riparian vegetation | | |
| control; Aquatic macrophyte cutting | | |