Studenchishte Marsh as an Integral Part of Ancient Lake Ohrid: Current Status and Need for Protection

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INTRODUCTION

This article describes the past and current state of Studenchishte Marsh, the last remaining 50-ha wetland bordering Lake Ohrid, Macedonia, in the context of plans for developing tourism infrastructure along the lake's shores. These plans have raised concerns among regional stakeholders and organizations promoting wetland protection. Lake Ohrid is one of the largest and deepest, and certainly the oldest lake in Europe (Wagner et al. 2014). It has a large number of endemic species (Albrecht and Wilke 2008) and is still predominantly pristine (Veljanoska-Sarafiloska et al. 2011). Studenchishte Marsh purifies inflowing surface and ground water to Lake Ohrid and provides habitat for important biodiversity elements in the area. Agricultural activities already influence the wetland, but the current plans for urban development would result in greater deterioration because they include complete drainage of the area. Our goal is to describe this unique wetland by giving information on the past and current state of the ecosystem and to make a plea for its conservation and protection. Before focusing attention on the Studenchishte Marsh, the article begins with a general review of the services wetlands provide, wetland degradation and impacts, and an overview of the Lake Ohrid ecosystem.

WETLANDS AND ECOSYSTEM SERVICES

As defined by RAMSAR, wetlands are coastal or inland surfaces inundated or saturated with fresh water or salt water (www.ramsar.org). They include many types of natural wet habitats and human-made wetlands (e.g., rice paddies and impoundments). Marshes are one type that is frequently or continually inundated, having mostly mineral soil and characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions. Marshes can be categorized as non-tidal and tidal, with the former being widely distributed in Europe where they are associated with streams, lakes, ponds and rivers. In contrast to marshes, fens have organic soils (peat at least 40 cm thick), receiving water from both surface and groundwater sources that greatly influences their soil-water chemistry.

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Wetlands represent some of the world's richest and most productive ecosystems. They are particularly important for carbon sequestration. While covering less than 10% of Earth's surface, they contain about 35% of global terrestrial carbon (Ramsar Convention Secretariat 2013). Wetlands facilitate the horizontal and vertical transport of carbon and nutrients between ecosystems, especially through their hydrologic connections to streams and overland flow; these connections are essential for the functioning and integrity of complex floodplain-river-lake systems. Wetlands provide numerous other services such as provisioning and purification of water and floodwater detention. Their services are also important for socioeconomic reasons, offering fishery and forestry resources as well as recreational and tourism opportunities. Located between the upland and large coastal areas, wetlands are a key landscape component. Wetland loss and degradation undermine the services and benefits that they provide, negatively impacting human welfare and contributing to species extinction.

The majority of biogeochemical reactions in wetlands occur in the underlying, highly organic and mineral-rich (sand, silt and clay) soil (Mitsch and Gosselink 2015). Links between substrate characteristics and ecological functioning are receiving increased attention because the associated processes are important providers of goods and services that benefit human health and well-being. Due to high nutrient levels, freshwater marshes are among the most productive ecosystems on Earth, frequently sustaining a diversity of life disproportionate to size. Beyond their considerable habitat value, non-tidal marshes: 1) mitigate flood damage by storing water after heavy rain or snowmelt; 2) alleviate drought as they recharge groundwater supplies and moderate streamflow; and 3) filter excess nutrients from surface runoff which is fundamental to the maintenance of the water quality in the watershed. Consequently, wetland degradation often detrimentally affects nearby surface water bodies in terms of hydrology, climate and ecology (Mitsch and Gosselink 2015; Verhoeven 2014).

WETLAND DEGRADATION AND ITS WIDER CONSEQUENCES

Over 60% of European wetlands were lost before the 1990s. Although drainage of wetlands has been common for centuries, its extent spiked in the past century leading to a substantial decline in number, size and quality of wetland habitats across the European landscape. According to a recent European Environment Agency (EEA) report, 73% of assessments for European Union (EU) wetlands demonstrate unfavorable conditions (European Environment Agency 2012). Over the past century, Europe´s landscapes have undergone substantial changes: "Core natural" landscape patterns have transitioned to mosaics of "mixed" (semi-natural) and/or "some natural" patches. Recently, this trend has increased in the Republic of Macedonia (hereafter Macedonia) (European Environment Agency 2015), which has undergone increased industrialization, infrastructure development and urbanization. Such modifications have largely compromised the distribution and quality of wetlands.

LAKE OHRID – A NATURAL SANCTUARY

The Ohrid-Prespa region in the southwest of the Balkan Peninsula is one of the world's most ancient inland watershed systems, formed during the late Miocene (Albrecht and Wilke 2008). Lake Ohrid (Table 1) is recognized as Europe´s oldest inland water, with age estimates ranging from 2 to 5 million years (Albrecht and Wilke 2008), while Lake Macro Prespa (or simply Prespa) may be just as old (Wagner and Wilke 2011). Lakes Ohrid and Prespa are only 10 km apart, separated by the 2,255 m high Galichica Mountain, whose karstic subterranean channels connect the two (Vogel et al. 2010). According to the World Wildlife Fund Conservation Science Program's Freshwater Ecoregions of the World, the Ohrid-Prespa area belongs to the Ecoregion "Southeast Adriatic Drainages" (Hales 2015) which is characterized by very high endemism. For freshwater fishes, it is one of the world's richest areas with more than 8 species per 10^4 km^2 (Abel et al. 2008) and a rate of endemism greater than 50%. Lake Ohrid, a United Nations World Heritage Site since 1980, is a "museum of living fossils", providing sanctuary for Tertiary Period creatures that died out elsewhere during the ice ages (Stankovic 1960). It contains at least 200 endemic species that have evolved in isolation over millions of years, including at least 7 of its 17 native fish species, such as "belvica" (*Salmo ohridanus*), Ohrid roach (*Rutilus ohridanus*), summer trout (*Salmo aphelios*), Pestani or Ohrid trout (*S. letnica*), Struga trout (*S. balcanicus*), and lumi trout (*S. lumi*) (Kottelat and Freyhof 2007). Lake Ohrid is also noted for its exceptional inverte-

TABLE 1. Main geographic and hydrologic characteristics of Lake Ohrid.

Location	41º05´ N; 20º45´ E	Shore line	87.53km (56.02 belong to Macedonia)
Type	Tectonic	Surface area	358.18km^2 (2/3 belong to Macedonia)
Elevation	693.17m above sea level	Dimensions	Maximal width: 14.8km Maximal length: 30.37km
Age	3-5 million years (recognized as ancient lake)	Littoral zone width	1-2km in the southern and northern part and much more narrow on the western and eastern shore (less than 10m at some points)
Depth	Max: 288.7m Average: 163.7m	Volume	58.64 km^3
Trophic state	Oligotrophic	Average phosphorus concentration	4.5 µg/L
Climate	Average air temperature registered in the period 1951-2009: 11.3ºC. Insolation: Total number of daylight hours: 4,399 h/year, (2,257 h/year with sunshine - 56% of the maximal daylight duration). Cloud cover per annum: 4.9 tenths of the sky-dome Average air humidity: 70% Average wind speed per annum: B=1.8m/sec; Average wind frequency per annum expressed by promille is 297‰, and blows in a northerly direction with an average calmness C=138%0.		
Catchment area	1,487 km^2 after it was artificially enlarged in 1962 by 460 km^2 when the River Sateska, previously a tributary of River Crni Drim, was diverted into the lake near the town of Struga. The effective size is substantially larger because several springs along the shores are supplied from Lake Prespa providing approximately 46% of the inflow of water to Lake Ohrid.		
Water level	Regulated since 1963 (intergovernmental agreement between the Republic of Albania and the former Yugoslavia). Acceptable oscillations: minimal and maximal elevation of 693.10m and 693.75m asl respectively (water layer difference of 65cm).		

brate endemism (89% of gastropod species, two-thirds of crustaceans and 71% of flat worms are endemic) (Albrecht and Wilke 2008) and is internationally recognized as an Important Bird and Biodiversity Area for its ornithological significance (over 40,000 water-bird individuals during winter; Birdlife International 2016).

Lake Ohrid is oligotrophic according to Carlson´s Trophic State Index (Carlson 1977) for lakes which is based on Secchi Disc transparency, chlorophyll and total phosphorus (Veljanoska-Sarafiloska et al. 2011). Nevertheless, parts of the littoral zone are under substantial anthropogenic pressure: areas where the rivers Sateska, Koselska, Velogoska and Cherava discharge into the lake display water pollution and changes in trophic status (Kostoski et al. 2010). Disturbed trophic conditions are evidenced by an absence of charophytes, low biomass or absence of other aquatic plant species in tributary inflows, and by changes in the density and composition of benthic fauna, with an altered ratio between cosmopolitan and endemic species (Trajanovski et al. 2015). Concerns exist that Lake Ohrid could become eutrophic, leading to summer stagnation and dangerously low oxygen levels. The main source of pollution is untreated sewage produced by the resident lakeside population which is now estimated at about 200,000 people (Avramoski et al. 2006). Its growth has been accompanied by the massive development of tourism infrastructure. The population around the lake multiplies several-fold during summer, far beyond the capacity of regional infrastructure, drinking water supplies, and waste disposal (Kostoski et al. 2010). Several projects once inspired hopes for the protection of Lake Ohrid water quality such as the primary collector and wastewater treatment plant on the Macedonian side of the lake (1988) and the bilateral Lake Ohrid Conservation Project with Albania (1998). Unfortunately, neither has proved a satisfactory solution and a great volume of untreated water from the catchment reaches the lake (Kostoski et al. 2010). Water pollution is probably the main threat to the lake's ecological stability given the lake's long water-retention time (60 years). The second major source of eutrophication is inflow of nutrients from erosion and agricultural run-off including fertilizers and herbicides. About 150 tons of dissolved phosphorus are estimated to enter the lake each year, and, with this, the total phosphorus load may be 3 to 5 times greater than it should be to keep the lake in an oligotrophic state (Avramoski et al. 2006).

FIGURE 1.

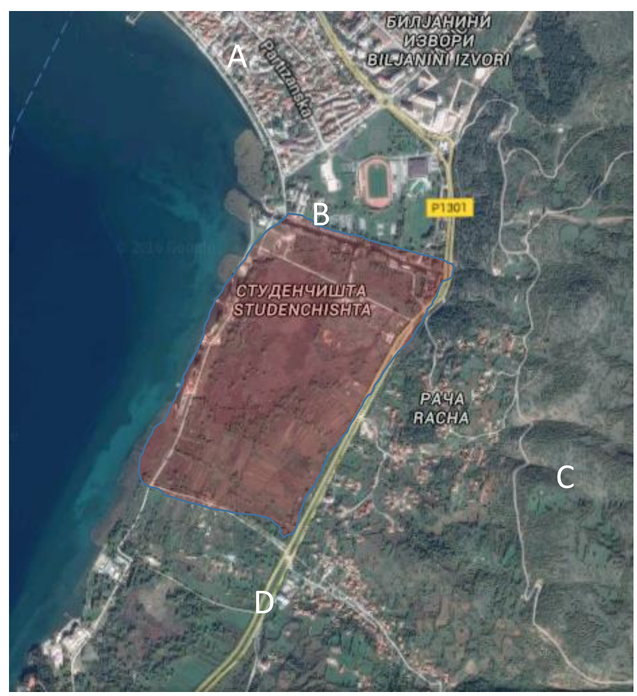

Fig. 1. Geographic aspects of Studenchishte Wetland. Left: Location of region in Europe (arrow); location of Wetland bordering Lake Ohrid (red rectangle). Right: Aerial photo of Studenchishte and surroundings. A: City of Ohrid; B: Studenchishte Canal; C: Galichica Mountain; D: Road to St. Naum Monastery

STUDENCHISHTE MARSH LOCATION

In the past, there were several wetlands around Lake Ohrid, most of which have been drained and converted to agricultural and urban land. Presently, only one wetland remains: Studenchishte Marsh (hereafter Studenchishte) (Figure 1). It is located 694-696 m above sea level to the lake's northeast (41º06'08''north and 20º48'49'' east), on lowland, narrow terrain bordered on the north by Studenchishka River (now Studenchishte Canal), on the south by the Racha River, on the west by the shore of Lake Ohrid, and on the east by a regional road. This road represents a geomorphological boundary, with the terrain rising steeply at the foothills of Galichica Mountain. A survey using Google Earth in 2010 revealed that wetlands in this area occupied 50 ha with marshy and peaty habitats extending over 25 ha (Spirovska et al. 2012). The total inundated area fluctuates depending on precipitation patterns and on lake levels. The altitudinal gradient feeding the wetland with water spans 965 m, between Gjafa Mountain, and where Biljanini Springs flow into the lake (Figure 1). This gradient extends over a 4.6 km distance and has a 21% slope. However, during heavy rainfall only mild landslides occur in small rivulets and watercourses (Spirovska et al. 2012).

GEOPHYSICAL AND HYDROLOGICAL CHARACTERISTICS

Geological Composition. The Ohrid-Prespa region belongs to the West-Macedonian zone and is part of the Dinaric system characterized by Paleozoic, Triassic, Cretaceous, Neogene and Quaternary geological formations (Hoffmann et al. 2010). The Paleozoic rocks are the oldest and form the base, whereas the largest portion is made of Triassic rocks with substantial facial diversity. Studenchishte contains materials belonging to the Neogene basin, mainly divided into three sediment series (basal, productive and upper layer) as well as Quaternary sediment formations. Alluvial sediments are the most common (Spirovska et al. 2012). The sediments consist of sands and marly-clay materials, which lay unevenly and are often unconsolidated. Quaternary lake–marshy sediments are represented by mud and very fine materials. Geological formations of the Quaternary-Diluvial are terraced lake and river sediments, moraine materials, fluvial-glacial materials and karst detritus. The alluvial sediments along the lake which are part of the loose Quaternary sediments display high water porosity. Here, 30 m-deep wells provide medium and high water potential. Under this layer, loosely-tied rock masses of capillary porosity have been found (clay, marly-clay and marl), which constitute hydro-geologic insulators (Spirovska et al. 2012).

Hydrology. The subterranean aquifer at Studenchishte is dense with a level of free groundwater running northeast to southwest (Spirovska et al. 2012). The terrain abounds with water: the hydraulic head of the groundwater is high (above 10 m) and discharge is constant. The amount of discharging water depends on the grain sizes of the Quaternary sediments and the resultant porosity as well as on the amount of precipitation. Unconsolidated sediments make the terrain at Studenchishte highly porous; hence, the filtration index is quite high. The upper 20 m of sediments are loose materials, enabling rapid water infiltration. The semi-bound rocky masses below can act as hydro-geological conductors. The surrounding terrain contains Triassic limestone with a low filtration index yet this occurs only at depths greater than 30 m at Studenchishte (Spirovska et al. 2012).

The hydrographic network of the catchment that discharges into Studenchishte consists of a single surface stream called Dlabok Dol (Spirovska et al., 2012). However, the wetland borders Biljanini Springs, an important source of water that discharges into Lake Ohrid and Studenchishte. Groundwater discharging into Studenchishte mainly originates from atmospheric precipitation filtered through the highly porous, karstic Galichica massif. Water levels of Lake Ohrid also influence hydrologic conditions in the wetland. During high-water extremes such as in 1963 and 2010, the wetland fully merges with the lake. Importantly, the contact between the groundwater inputs to Studenchishte, its influence

TABLE 2. Plant associations present in Studenchishte Marsh.

Marsh	Class PHRAGMITETEA Tx. et Preis. 1942 Order Phragmitetalia eurosibirica W. Koch 1926 Union Phragmition 1. Association Scirpeto-Phragmitetum W. Koch 1926 2. Association Oenantheto-Roripetum Lohm. 1950 Union Sparganio-Glycerion Br.-Bl. et Siss. 1942 3. Association *Sparganio-Glycerietum fluitantis* Br.-Bl. 1925 Union *Magnocaricion* W. Koch 1926 4. Association *Caricetum elatae* W. Koch 1926 Sub-association lysimachietosum Mic. 1959 5. Association *Cyperetum longi* Mic. 1957
Wet meadow	Class MOLINIO-ARRHENATHERETEA Br.-Bl. et Tx. 1943 Order *Trifolio-Hordeetalia* H-ić 1963 Union *Trifolion resupinati* Mic. 1957 1. Association *Trifolietum nigrescentis-subterranei* Mic. 1957

on the lake and the movement of groundwater between the lake and the wetland have not been adequately studied (Spirovska et al. 2012).

Soils. Studenchishte soils are mainly organic (histosols) and, less extensively, swampy-gley soils (Filipovski 1999). In Macedonia, histosols are not common, covering just 700 ha or 0.03% of the entire territory. This figure includes the former Struga Marsh (500 ha) adjacent to Lake Ohrid, which was drained for agriculture in the 1940s. Currently, the total area of histosols around Lake Ohrid is 90 ha, mainly in the proximity of the city of Ohrid (Filipovski 1999). Studenchiste's histosols are of the lowland type, which is formed near lakes, in depressions or in groundwater discharge areas. Lowland peats in Macedonia usually belong to the category of lowland peat soils, i.e., histosols whose organic-horizon is relatively thin. With a maximum peat depth of 300 cm and averaging 220 cm, Studenchishte's histosols are an exception (Filipovski 1999). This wetland is regarded as having the largest and most representative remnant of the lowland peat histosol type in Macedonia, worthy of protection in its own right. The major part of Studenchishte can therefore be classified as fen wetland, which is exceptionally rare in the region.

Climate. The climate in the Ohrid region including Studenchishte, is moderate–continental (Table 1), modified by air currents from the Adriatic Sea via the river Crni Drim, which, combined with the lake influence, induces a specific thermal and pluvio-metric regime that is characterized by small air-temperature changes throughout the year and autumn/winter concentrations of heavier rain.

BIODIVERSITY

In this section, some major components of the biodiversity of Studenchishte are described with an emphasis on flora and fauna groups for which there is available information (Figure 2). The major plant associations in the wetland are discussed and information on the diatom flora is also provided. A number of invertebrate fauna groups are briefly discussed, such as *Odonata* (dragonflies), *Lepidoptera* (butterflies) and *Coleoptera* (beetles), along with vertebrate groups including fishes, amphibians and other animals characteristic for the wetland.

FIGURE 2. Characteristic flora and fauna of Studenchishte Marsh. (A) Caricetum elatae, (B) Utricularia sp., (C) Plegadis falcinellus, and (D) Rorippa amphibia

Plantlife. *Vascular plants*. Although relatively small in size, Studenchishte contains 6 plant associations (Table 2). Several habitat types are present including natural alkaline marshes and fens, one semi-natural wet meadow, and several anthropogenic habitats: orchards, fields, gardens, houses and infrastructure facilities. Alkaline marshes and fens are humid habitats that receive water and nutrients from sources other than precipitation. For Studenchishte, these sources are the springs at the foothill of Galichica and groundwater movement. Alkaline fens differ from bogs in that they have less acidic conditions and higher nutrient levels, and can therefore support far greater plant and animal diversity. Studenchishte has 4 plant associations that develop in alkaline conditions. Marsh habitats are characterized by mineral-rich substrates and a constantly submerged portion that does not accumulate organic matter. This habitat in Studenchishte is represented by the association *Sparganio-Glycerietum fluitantis* that develops in the canals and is linked to the reed association (*Scirpeto-Phragmitetum*) in the lake's littoral zone. The alkaline fen habitats are characterized by the association *Caricetum elatae*, although only a small area of this community remains. In the part of the lake adjacent to the wetland - Mazija and Ajvan Beach, 11 vascular hydrophytes and 6 fringe associations can be found (Talevska 2005). Wet meadows are the only type of semi-natural habitat in Studenchishte. Macedonian wet meadows are not registered as priority habitats in Annex I of the European Union (EU) Directive 92/43/EEC. However, similar habitats phytocoenologically belonging to the alliances *Molinion W. Koch* and *Molinio-Holoschoenion Br.-Bl.* (semi-natural wet meadows with high herbaceous plants—code 6410 and 6420 of Annex I of the EU Directive 92/43/EEC—and the alliance *Arrhenatherion Koch*—circum-Mediterranean mesophilic meadows, code 6510) are considered endangered in Europe (http://ec.europa.eu). Farmlands, mainly used for corn cultivation, are the anthropogenic habitats that occupy the largest proportion of the land in Studenchishte. Unlike farmlands, the orchards (apple, pear, plum and walnut) do possess certain significance in terms of biological diversity as several bird species use them for nesting (*Lanius minor*, *Pica pica*, and *Corvux cornix*).

Diatoms. Eighty-nine species of *Diatomeae* are reported for the wetland, of which

TABLE 3. Plant species in Studenchishte Marsh (SM), most of which are common in European wetlands but are considered rare for the Republic of Macedonia.

Carex elata All.	Disappeared from SM
Ceratophyllum submersum L.	In danger of extinction from SM
Nymphaea alba L.	Probably disappeared from SM
Nuphar lutea L. (Sm.)	Reintroduced and revitalized in Mazija by the Macedonian Limnological Society
Myosurus minimus L.	Disappeared from SM
Polygonum amphibium L.	In danger of extinction from SM
Leucojum aestivum L.	Probably disappeared from SM
Senecio paludosus L.	Disappeared from SM
Ranunculus lingua L.	Disappeared from SM
Cyperus longus L.	In danger of extinction from SM

TABLE 4. List of Odonata species in Studenchishte that are on the International Union for Conservation of Nature's Global Red List. LC (least concern), NT (near threatened).

Species	IUCN Global Red List	EU Habitats Directive
Aeshna isoceles (Müller)	LC	
Calopteryx splendens (Harris)	LC	
Coenagrion mercuriale (Charpentier)	NT	Annex II
Coenagrion puella L.	LC	
Cordulegaster bidentata (Selys)	NT	
Cordulia aenea L.	LC	
Enallagma cyathigerum (Charpentier)	LC	
Erythromma lindenii (Selys)	LC	
Lestes barbarus (Fabricius)	LC	
Orthetrum albistylum (Selys)	LC	
Orthetrum brunneum (Fonscolombe)	LC	
Orthetrum coerulescens (Fabricius)	LC	
Platycnemis pennipes (Pallas)	LC	
Sympecma fusca (Vander Linden)	LC	
Sympetrum sanguineum (Müller)	LC	

TABLE 5. Species of beetles (Coleoptera, Carabidae) found in Studenchishte considered rare for the Republic of Macedonia.

Coleoptera (beetles) species
Agonum lugens and *A. piceum* *Amara convexiuscula* *Stenolophus skrimshiranus* and *S. proximus* *Brachinus elegans* *Pterostichus elongates* *Oodes helopioides and O. gracilis*

4 are rare (present in 2-5 localities in Macedonia) and 11 endemic to Lake Ohrid as described in the assessment of the condition of the wetland elaborated in 2012 by a Macedonian interdisciplinary team of experts (Spirovska et al. 2012). Interestingly, Studenchishte's *Diatomeae* include both those characteristic for oligotrophic conditions (springs) such as *Amphora,* and others found typically in wetlands - *Gomphonema*, *Stauroneis*, *Navicula*, and *Nitzschia*.

Fauna. *Invertebrates.* Studenchishte has a specific invertebrate fauna, differing fundamentally from that of Lake Ohrid. Hence, despite its comparatively limited area, the wetland needs to be regarded as a vital contributor to the biodiversity of the Lake Ohrid region. The wetland and other coastal waters contain 16% of the Gastropoda, 20% of the Tricladida (Smiljkov and Shapkarev 1998), 35% of the Oligochaeta (Shapkarev 1966) and 22.5% of the Chironomidae (Smiljkov and Shapkarev 1998) that are found in Lake Ohrid. Dragonflies and damselflies (*Odonata*) display both widespread European species (81%) and Southern European species (19%) (Zawal et al. 2010) and the latest report specifies 34 species in Studenchishte (Table 4). Recently, 39 species of beetles (*Coleoptera)* have been recorded in Studenchishte, some of which are rare for Macedonia and found only in this location (Spirovska et al. 2012; Table 5). Studies on daylight butterflies (*Lepidoptera*) include 138 species for the Ohrid region (Scheider and Jakšić 1989), but there are no data specific to the Studenchishte Marsh. In the Biljanini Springs region of the wetland, 5 chironomids (*Diptera, Chironomidae*) have been identified: *Ablabesmya monilis, Thienemannimya lentiginosa, Potthastia gaedi, Eukifferiella quadridentata,* and *Cricotopus inaequalis* (Smiljkov and Shapkarev 1998) as well as 9 species of planarians (*Plathelminthes, Turbellaria, Tricladida*), most of which are endemic to the springs in the coastal area of Lake Ohrid or to the lake itself (Kenk 1978; Krstanovski 1994). Lastly, Ikonomov provides data on 10 species of mayflies (*Baëtidae, Ephemeroptera): Baëtis pumilus, B. rhodani, B. carpatica, B. vernus, B. tenax, B. bioculatus, B. tricolor, Cloëon dipterum, C. praetextum,* and *Procloëon bifidum (*described as *P. lychnidense*), as well as *Heptagenia macedonica* (*Ecdyonidae*) (Ikonomov 1962; Ikomonov 1963).

Vertebrates. Due to proximity and direct connection to the lake, the aquatic vertebrate fauna of the wetland has historically been considered to be part of the lake. Therefore, little data relates specifically to Studenchishte. Owing to its low water level, presently, the wetland does not contain dense fish populations. However, 17 fish species can be found in Studenchishte Canal (14 native and 3 alien) (Spirovska et al. 2012). In the past, before most of the marsh and fen were drained, Lake Ohrid and Studenchishte were directly connected and many lake species would enter Studenchishka River and its spring branches (Stankovic

TABLE 6. Categorization of the current threats to the existence of Studenchishte Marsh.

A	**Poor level of protection, without clear regulatory support. Lack of system for sustainable management.**
B	**Drainage of the marsh and conversion of parts to cultivated land and urban areas.** This includes the construction of road infrastructure.
C	**Non-functional communication between the marsh and Lake Ohrid.** Prior to the marsh´s significant size reduction, a large number of Lake Ohrid's fish species spawned in the marsh. The construction of the road along the coastline (landfilling and paving) severed the direct communication between the marsh and Ohrid Lake.
D	**Dumping of waste.** Over the past 20 years, huge amounts of construction waste have been dumped in the marsh, covering nearly 6 ha of wet meadows and other marsh habitat, at the expense of the relict association *Caricetum elate*.
E	**Inappropriate maintenance of the grass areas in wet meadows** Mechanized methods for maintaining the grass areas represent a possible threat.
F	**Utilization of the beaches.** In the past 15 years, beaches have been "urbanized"; the reed areas have been decreasing and the willow belt near the coast has been completely destroyed.
G	**Pollution**. Wash off and degradation of dumped solid waste from various origins (generally mixed waste and inert construction waste) and the utilization of chemical pesticides and mineral fertilizers for agricultural activities that are conducted in the marsh and its surroundings have polluted the marsh. The plant nursery, which is operational in the area of the marsh, is a serious and significant threat due to the high use of fertilizers and other pesticides.

1960). A large number of Ohrid's fish fauna used to spawn in the wetland, primarily in the group *Cyprinidae* (*Cyprinus carpio*, *Scardinius erythrophthalmus*, *Phoxinus phoxinus, Pachychilon pictum*, *Rutilus ohridanus*, and *Alburnus alburnus arborella)*. Today, fish spawning no longer occurs and instead, permanent populations of Eurasian minnow (*Phoxinus phoxinus L.)* and stone loach (*Nemachilus barbatulus sturanyi St*.) are present in the Studenchishka Canal.

At least 9 amphibian species have sustainable populations in the wetland, all of which are classified as strictly protected or protected fauna species (according to Annexes II and III of the Bern Convention (BC; https://www.cbd.int/). The most important ones at the European level are the Macedonian crested newt (*Triturus macedonicus*) and the yellow-bellied toad (*Bombina variegata*). Regarding reptiles, at least 4 snake species have been found in Studenchishte: *Emys orbiculari, Elaphe quatuorlineata, Natrix natrix,* and *Natrix tessellata* (Spirovska et al. 2012), which are also listed in Annexes II and III of the BC.

Studenchishte was previously considered one of the primary nesting sites for waterbirds along Lake Ohrid's shores, but its significance has decreased. Presently only a few species rear young: some warblers (*Acrocephalidae*), waterfowl (*Anatidae*), and the little bittern (*Ixobrychus minutus*). It remains, however, one of Macedonia's few nesting locations for the mute swan (*Cygnus olor*). Around 50 other bird species, including 15 rated as 'rare or endangered' in Annex I of the Birds Directive (http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm), can be found migrating and foraging in Studenchishte (herons, ibises, godwits, harriers and ducks). The little bittern is the only Annex I species observed nesting (Spirovska et al. 2012).

Mammal reliance on Studenchishte cannot be assessed due to insufficient study. Particularly striking is the lack of data on bat fauna, one of the more important and endangered groups. Species present include otter (*Lutra lutra)*, fox (*Vulpes vulpes*), European polecat (*Mustela putorius*), white-breasted marten (*Martes foina*), and several rodent species (Spirovska et al. 2012).

STUDENCHISHTE - PAST AND PRESENT

Connected by multiple channels, Studenchishte was once an integral part of Lake Ohrid (Cvijic 1911). At that time, it occurred within a much larger wetland that has now been lost, and was considered a biodiversity hotspot and regarded as vital for the maintenance of the water level of the lake. Over the past 30 years, however, the wetland has become the last remaining part of the buffer zone between the lake and upland areas. This remnant wetland continues to be subject to direct and indirect intervention that have resulted in extensive ecological degradation. Today only remnants of the original channels and various springs remain to provide hydrologic inputs to the wetland. Large portions of the wetland have been drained and converted to farmland (fields, meadows and orchards) or impervious surfaces (buildings, a helipad, and local roads). Meanwhile, the coastal area adjacent to the city of Ohrid has undergone massive construction in line with the rapid development of tourism facilities. Along the border between the wetland and the lake, recreation facilities, beach platforms, bars, and even car parks have been built.

Over the past decades, there have been several attempts to provide specific legislation for the protection of Studenchishte. The 1979 Basic Urban Plan for the city of Ohrid granted the wetland protected status as a special-purpose area. Studenchishte was part of the city territory covered by the Master Urban Plan of 1987, and various categories of protection were proposed. The 2006 General Urban Plan (GUP) suggested categorization for the wetland as a landscape with outstanding natural features and established it as a protected area (51.55 ha) to be used for basic education and specific kinds of recreation. Since 2004, the Spatial Plan for Macedonia has proposed the category of Special Nature Reserve, yet the protection level in accordance with Macedonia's Law on Nature Protection has not been defined. Moreover, recent plans for "protection" within the GUP (2002-2012) and the modification of the GUP for 2014-2024 are so contradictory that they allow part of the coastal strip along Studenchishte Canal and its estuary to be converted to a water sports centre with accompanying facilities (hotels, shops, and restaurants) and the rest of the nearby coast used as an urban beach. The latest GUP also includes measures to improve the supply of drinking water which would inevitably affect the integrity and viability of the wetland. Overall, although a series of documents are aimed at protection for Studenchishte, subsequent plans and actions are contradictory, and it is clear that the wetland has not been, and will not be, protected adequately. The long-term lack of proper care (Table 6) endangers the wetland ecosystem, compromising some of the most important values of Lake Ohrid (Spirovska et al., 2012) such as elevated rates of biodiversity in niche habitats, the maintenance of specific lacustrine conditions to which unique species have evolved, and the harbouring of relict and locally endemic species.

Several construction activities have been particularly detrimental: 1) a plant nursery "Rasadnik" (in the ´90s) destroyed large portions of the relict association *Caricetum elatae*—the only site for this community in Macedonia, 2) the sports center "Biljanini Springs" (inaugurated in 1998) caused the disappearance of a large share of *Senecio paludosus* and *Ranunculus lingua*, and 3) construction of army and police facilities eliminated the rare plant *Myosurus minimus.* Anthropogenic pressure has likely led to the disappearance or danger of extinction of floating plants such as white water lily (*Nymphaea alba*), yellow pond lily (*Nuphar lutea*), and longroot smartweed (*Polygonum amphibium*), as well as the area's white willow, the reed-belt, and the association of *Cyperetum longi* (Spirovska et al. 2012).

TABLE 7. Intrinsic ecological and economic significance of Studenchishte Marsh.

Features of Ecological and Conservation Importance	
1. Geological significance	The histosols of Studenchishte Marsh are the deepest and most representative of lowland histosols in the Republic of Macedonia, amounting to 3 m depth.
2. Ecosystem services	(1) Storage of carbon in its 5,000-year peatlands, (2) water quality improvement, and (3) habitat provision. Historically, services also included habitats for spawning of major fish species.
3. Habitats	The area has 3 characteristic wetland habitats: alkaline marshes, alkaline swamps, and wet meadows.
4. Plant associations and plant associations with limited dissemination	5 marsh plant associations. This is a real treasure because Studenchishte Marsh includes 50% of the total diversity of marsh associations recorded in the Republic of Macedonia. In the Republic, the plant association *Cariteum elatae* is found only in Studenchishte and thus its protection is of particular importance. It could serve as a source for *Carex elata* individuals to repopulate other nearby sites, e.g., Struga Marsh.
5. Biodiversity - General	The marsh ecosystem is a habitat for rare and endemic species. 34 spp. of *Odonata* (some are extremely rare), 39 spp. of beetles, 23 spp. of water insects, and 9 spp. of amphibians (all included in the Bern Convention).
- Rare plant and animal species	5 rare plant spp. (*Carex elata, Ceratophyllum submerse, Nymphaea alba, Nuphar lutea* and *Myosurus minimus)*. Only 1 species —the yellow lotus—has been reintroduced near the marsh. 9 spp. of beetles in Macedonia are known to exist only in Studenchishte, and this site is also home to several hygrophilic species.
- Endemic species	11 diatom species are endemic or rare in the Republic of Macedonia. The highest rate of endemism is found among planarians (most of the 9 known species are endemic for the springs by the lake).
- Endangered species	The Odonata of the marsh contain several rare species. 15 spp. of *Odonata* are included on the Global Red List of the IUCN (13 of which are least concerned and 2 near threatened). 1 species (*Coenagrion mercurial*) is listed in Annex II in the European Union Habitats Directive; it is also listed in the Bern Convention.
- Species and habitats with a conservational significance for the European Union	6 spp. of amphibians, 3 spp. of reptiles, 15 spp. of birds, 1 sp. of *Odonata* and 1 sp. of butterfly have this significance. Regarding habitats, the most important are those with the plant associations *Caricetum elatae* and *Cyperetum longi* (*Magnocaricion*) that are included in the Habitats Directive.
- Refugium	Relict presence identifies Studenchishte Marsh as a safe haven where species have been able to cling to existence through the environmental flux that erased their existence in other parts of their one-time range. This is no doubt correlated with the local climate, which moderates extremes of both hot and cold. A protected Studenchishte Marsh would continue to fulfil this role. This is particularly important in the Balkans where certain species exhibit high genetic diversity, both a driving factor for evolution and a reducer in terms of extinction exposure.
Features of social/economic importance	
1. Uniqueness	The marsh ecosystem is strongly interconnected with the lake ecosystem. Studenchishte is the only remnant of the once extensive wetlands along the coastline of the lake. Despite its area being reduced, it still features various natural phenomena and ecological processes.
2. Research	It represents a unique ecosystem that needs to be preserved for future generations. It is a valuable site for scientific research of natural conditions and processes. Investigations are needed into the taxonomy and habitat preferences of animal groups not previously studied in this region.
3. Tourism and recreation	The proximity of the city of Ohrid, its connection to the sports-recreation centre, "Biljanini Springs," and the lakeshore provide ideal conditions for the marsh to be used for educational purposes and for selective tourism - hiking, birdwatching, landscape photography, relaxation and "educational tourism."
4. Landscape	The harmonious landscape makes this site naturally beautiful; it constitutes an important landmark that bestows Ohrid Lake with particular beauty and authenticity.

STUDENCHISHTE – WIDER IMPORTANCE AND RECOMMENDATIONS

Studenchishte Marsh matters from two perspectives: its own significance and its role in the resilience of the wider ecosystem of Lake Ohrid. These call for immediate and appropriate conservation and protection.

The significance of the wetland itself resides in its hydrological and geomorphological characteristics, soil composition, and the abundance and diversity of plants and animals (Table 7). Moreover, the wetland cleans raw sewage and other pollution flowing from the Ohrid region into the lake and functions as a carbon storage system. Since the entire of Studenchishte was recognized as contributing to the outstanding natural qualities that saw the Ohrid region enshrined on the World Heritage List in 1980, the wetland further requires protection in accordance with the Convention on the Protection of the World Cultural and Natural Heritage of UNESCO - the most important international convention relevant to spatial planning in the Ohrid region.

Studenchishte should also be considered in the context of ancient Lake Ohrid. Of the 117,000,000 lakes on Earth (Verpoorter et al. 2014), only a few have been concretely identified as ancient, of which Lake Ohrid is one (Albrecht et al. 2006). These inland waters have been in extended isolation, leading to unique evolutionary and speciation pathways. Indeed, Lake Ohrid may present an almost globally unique opportunity for interdisciplinary research due to its long existence, freshwater biodiversity, accessibility, and well-defined physicogeographical boundaries (Albrect et al. 2006; Lorenschat and Schwalb 2014; Hauffe et al. 2011). By buffering against pollution and contributing to the maintenance of the specific water composition that enables Lake Ohrid's ecosystem to thrive, Studenchishte is providing a service of great value to humankind.

Another consideration is that Studenchiste is the last remaining site of a once large wetland complex along the borders of Lake Ohrid. Although its functioning is known in general terms, many of the detailed interactions remain largely unexplored, among them, the surface water and groundwater flows, soil biogeochemical functioning, and their significance for the biota in the wetland as well as Lake Ohrid as a whole. Future developments should lead to plans to restore the vast wetland areas around the lake to better protect its immensely important biodiversity and ecological integrity. It is of the utmost importance to have a functioning wetland system in place to serve as a blueprint for the systems to be restored.

CONCLUSIONS

Freshwater ecosystems occupy only 0.8% of Earth's surface, but harbor nearly 6% of all known species (Dudgeon et al. 2006). Currently, freshwater habitats are among the world's most endangered and their future is not promising. In the past, wetlands such as marshes were regarded not only useless wastelands but also as serious hazards to human health due to mosquito breeding. Nowadays, a paradigm shift is overdue: wetlands must be reevaluated as ecological assets with benefits ranging from water-quality improvement and flood attenuation to aesthetics and recreational opportunities. In the past, these values alone have not been sufficient to protect them. Concerted efforts are urgently needed by local and state decision-makers to develop effective policies that protect biodiversity and work for agricultural producers, consumers, tourists and outdoor enthusiasts. Studenchishte Marsh is the only surviving wetland on Lake Ohrid's shore. Despite its recognized importance, authorities in Macedonia have so far avoided implementation of measures for its proper protection. As Studenchishte gradually disappears, policy initiatives aimed at protection are now more urgently needed than ever before. Proper protection of Studenchishte would require a moratorium on all lakeshore construction, and the establishment of an independent expert consultation unit, preferably of international composition, whose role is to review and assess regional development proposals including commercial and tourism infrastructures as has been proposed by two international researchers in an article for the Macedonian magazine "Fokus" (Albrecht and Wilke 2015). The overall objective should be strong and permanent regional and international cooperation, efficient and responsible management of Studenchiste Marsh, as well as a solid legal basis for the protection of its many values. ■

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