CONTRIBUTION TO BRYOPHYTE FLORA OF CROATIA: NEW FINDING OF RARE AQUATIC MOSS FISSIDENS FONTANUS (BACH. PYL.) STEUD. IN LAKE VISOVAC (KRKA NATIONAL PARK)

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The rare bryophyte species Fissidens fontanus was found within the course of a comprehensive field study of the aquatic flora and vegetation of Lake Visovac (Krka National Park). This is the second record of this species in Croatia after the recent discovery in the Trepča River. The species grows among rich macrophyte vegetation, forming small patches up to 2.5 m in depth. Due to its rarity and plausible threats, we assessed F. fontanus as critically endangered in Croatia.

Key words: rare moss, critically endangered species, Southeastern Europe

INTRODUCTION

Although Croatia is bryologically one of the most explored countries of the former Yugoslavia and Southeastern Europe (Sabovljević et al., 2011), the data are to a large extent spatially and temporally biased (Alegro & Šegota, 2019). Starting in the first decades of the 19th century, the research was at its peak of intensity at the turn of the 19th and the 20th century, to be intensified again in the 1950s and 1960s, followed by the almost complete lack of any bryological work until 2009 (Alegro et al., 2012). Thenceforward, during the last decade, 58 new taxa were discovered as new for Croatia, mainly owing to cooperation between the Hungarian Natural History Museum and the University of Zagreb, (Blockeel et al., 2009, Ellis et al., 2012a, 2012b, 2014, 2015, 2016, 2017, 2018; Papp & Sabovljević, 2009; Köckinger et al., 2012; Papp et al., 2013a, 2013b, 2013c; Alegro et al., 2014, 2015, 2018a, 2018b, 2019; Sabovljević et al., 2018).

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In addition, a publically available database with geocoded spatio-temporal data has been established in order to summarise all historical literature and herbarium data (Alegro & Šegota, 2019). However, despite considerable progress in knowledge of the diversity and distribution of Croatian bryophytes in the last decade, a great shortage of data is still evident.

The main objective of this paper is to provide further additions to the inventory of bryophytes in Croatia by presenting the new locality of *Fissidens fontanus* (Bach. Pyl.) Steud., which is extremely rare in Southeastern Europe.

**MATERIAL AND METHODS**

In summer 2018, during five field surveys, the line transect sampling method was applied for vegetation mapping of Lake Visovac. In total 21 transects were made from a boat, perpendicularly to the shore. The sampling was performed down to the depth at which aquatic vegetation ceases to appear (at a maximum depth of 17 m). Extendable rakes were used for sampling the vegetation in shallow water, while a sampling rake (two metal leaf rakes bolted back-to-back, handles removed and replaced with a rope), and a sampling grab were used to collect vegetation from deeper parts of the lakes (Stelzer & Schneuder 2001, CENT/TC 230, 2007). Simultaneously, the lake depth was measured using another rope and the coordinates were recorded using Garmin e-trex GPS device. Bryophyte taxa were sampled and stored within the plastic containers, not preserved, but identified in fresh condition using Smith (2004) and Frey et al. (2006). Nomenclature follows Ros et al. (2013), applied in Alegro & Šegota (2019). Afterwards, the bryophytes were dried and placed within the paper envelopes and stored at the ZA collection (Thiers, 2019) where they were digitized within the Flora Croatica Database (Alegro & Šegota, 2019) with all metadata publically available via the virtual herbarium (Rešetnik & Šegota, 2019).

**Study area**

Lake Visovac is situated in Mediterranean Croatia, in Central Dalmatia, within the Krka National Park (Fig. 1). This natural lake is a result of tufa-formed barriers - Roški slap (upstream) and Skradinski buk (downstream) and represents the largest extension of the Krka River (Mihaljević et al., 2001; Špoljar et al., 2005). It encompasses an area of 7.9 km² with a maximal depth of 55 m, however in the narrower sense the lake encompasses only the water body around the islet of Visovac. The lake is a monomictic system characterised by a relatively high input of fresh water from the Krka River, and to a lesser extent of the tributary Čikola River and torrent waters from surrounding landscape (Ciglenečki-Jušić et al., 2015).
RESULTS AND DISCUSSION

The dominant aquatic vegetation of Lake Visovac is composed of vascular flora in the shallow zone (down to 6 m depth) and charophytes in the deeper zone (from 6 to maximum 17.5 m depth) (Fig. 2).

Fig. 1. Geographical position (left) and shape of Lake Visovac (Google Earth) (right).

Fig. 2. Typical vegetation profile of Lake Visovac.
Bryophytes are rarely represented in lake vegetation, not forming any particular vegetation belt. Only two bryophyte species were found, occasionally intermixed with other vegetation. *Fontinalis antipyretica* Hedw., a common aquatic moss of the streams and stagnant water in Croatia (Alegro & Šegota, 2019), was found within nine transects, mostly in shallow water (less than two meters deep), generally in small patches. Three larger stands were recorded in northern, northwestern and southwestern parts of the lake, not forming a clear vegetation belt.

An even more interesting finding was the discovery of *Fissidens fontanus*, recorded only at two sites, near the western shore of the lake (Fig. 3). At the first site (43,859472°N, 15,969000°E), the species was found at depth of less than one meter, intermixed with *Fontinalis antipyretica*, *Myriophyllum spicatum* L., *Myriophyllum verticillatum* L. and a submerged form of *Scripus lacustris* L. At the second site (43,857861°N, 15,971556°E), it was found at a depth of 2.5 m, in the midst of *Potamogeton perfoliatus* L., *Myriophyllum verticillatum* L., *Nuphar lutea* Sibth. et Sm., *Najas marina* L., *Chara* spp. and a submerged form of *Scripus lacustris* L. In both localities the species was found in very small populations containing only a few plant shoots. The specimens from the second locality are deposited in the ZA collection under inventory number ZA53232.

*F. fontanus* is flaccid, with much-branched shoots up to 3 cm long. The shoots appear flattened, with long, narrow leaves in 2 rows on the stem. Each leaf is up to 5 mm long and about 10 times as long as wide, with unbordered margins. It is easily distinguishable from other congeneric species: it lacks a central strand in the stem (thus sometimes included in the separated genus *Octodiceras*), the sheathing lamina reaches less than 1/3 of total leaf length, and it has immersed an capsule without stomata (Fig 4.) (Privitera & Puglisi, 1994; Smith, 2004; Erzberger, 2016).
Fissidens fontanus is a European Temperate species (Hill & Preston, 1998) occurring from the Mediterranean to Northern Europe (Smith, 2004; Frey et al., 2006). It was recorded in Great Britain, Ireland, Denmark, Finland, Sweden, Estonia and Latvia in the North, in Belgium, Luxemburg, Netherlands, Switzerland, Austria, Germany, Czech Republic and Poland in Central Europe, while in the Mediterranean it is known from Portugal, Spain, France, Italy and the larger islands, Sardinia, Sicily and Madeira (Hodgetts, 2015). Boros (1968) described F. fontanus...
as a species to be expected in Hungary, however, it was hitherto searched for with no result (Erzberger, 2016). The species is extremely rare or, more likely, under recorded in Southeastern Europe (Šabovljević et al., 2008), until recently known only from Bulgaria and Romania (Natcheva et al., 2006, Stefănuţ & Goia, 2012). More recently, it has been recorded on Lesbos Island in Greece (Blockeel & Nieuwkoop, 2016) and in Montenegro (Andić et al., 2018). Interestingly, Düll et al. (1999) provide a record from Slovenia, however this was somehow overlooked in the Slovenian checklist (Martinčič, 2003) and all following European checklists (e.g. Ros et al., 2013, Hodgetts, 2015). Regarding Croatia, the species was very recently found in the Trepča River (Banovina Region, central Croatia), representing the first Croatian record of this moss (Alegro et al., 2019).

In Lake Visovac *F. fontanus* formed very small patches, each containing only a few plant shoots. Similarly, the only two known populations in Montenegro, recently discovered in theSitnica and Cijevna rivers, covered only a few square centimetres each (Andić et al., 2018). One population of *F. fontanus* in Lake Visovac was growing intermixed with *Fontinalis antipyretica*, also observed in the Cijevna River (Montenegro), where those two species grow together on lime-containing conglomerate rocks (Andić et al., 2018). However, in the Trepča River (Croatia), *F. fontanus* grows in a rather rich aquatic moss community, associated not only with *Fontinalis antipyretica* but also with several other aquatic moss species such as *Cinclidotus riparius* (Host ex Brid.) Arn., *Leptodictyum riparium* (Hedw.) Warnst. and *Rhynchostegium riparioides* (Hedw.) Cardot (Alegro et al., 2019). This bryophyte community (*Octodiceratetum juliani* (W. Koch 1936) Krusenstjema 1945 from alliance *Fontinalion antipyreticae* W. Koch 1936 and class *Fontinaletea antipyreticae* Hübschmann 1957) was recorded previously in other countries as well (Hübschmann, 1986; Nebel & Philippi, 2000).

The species usually grows in clean to moderately polluted rivers and can tolerate a certain amount of pollution (Neumayr, 1971; Smith, 2004; Erzberger, 2016). This was observed previously in the Trepča River, where a significant amount of cyanobacteria from the Oscillatoriales group was found, suggesting moderately polluted conditions (Alegro et al., 2019). Two main threats were detected in Lake Visovac: the increased inflow of nutrient rich water from the city of Knin and a significant impact of boat anchoring on the vegetation cover of the lake.

Conducting a multiannual project of surveillance of water bodies throughout the whole Croatia, comprising several hundreds of rivers, streams, channels, lakes and reservoirs, we are able to conclude that *F. fontanus* is an extremely rare species in Croatia. According to the available data and following the latest criteria (IUCN, 2017), Criterion D (a very small or restricted population with fewer than 50 mature individuals) could be applied for the evaluation of *F. fontanus*; thus we propose that it should be classified as critically endangered t the national level. The same category is assigned to the species in Bulgaria (Natcheva et al., 2006) and Romania (Stefănuţ & Goia, 2012), whereas it is considered endangered in Latvia, vulnerable in Estonia, Ireland, Luxemburg, Poland and Switzerland and near threatened in the Czech Republic and Finland (Hodgetts, 2015).
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