

**MORPHOLOGICAL AND ECOLOGICAL CHARACTERISTICS  
OF RARE AND ENDANGERED SPECIES  
*LEMANEA FLUVIATILIS* (LINNÉ) C. AG. (LEMANEACEAE,  
RHODOPHYTA) ON NEW LOCALITIES IN SERBIA**

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**ABSTRACT.** In this study, morphological and ecological characteristics of *Lemanea fluviatilis* (Linné) C. Ag. that was found on localities in Resava River (East Serbia), Božička River and Vlasina River (South Serbia) are presented. All mentioned localities are new finds of *L. fluviatilis*. It was noticed certain variability in appearance and structure of algae on different localities and confirmed stenovalence of this alga in relation to ecological factors, such as: substrate, speed of water, aeration, temperature, pH, electro conductivity and water quality. Thali of species *L. fluviatilis* were found on 450-1100m a.s.l., in running waters (around 1m/s), on boulders and rocks (in fish pond Lisine, on concrete), in cold (10-13.8<sup>0</sup>C) and well aerated water (concentration of oxygen from 8.59 to 8.71mg/L), with high saturation (from 90.6 to 98.7%), pH values from 7.1 to 7.8 and electro conductivity from 70 to 160µS /cm.

At the one side, certain stenovalence of the *L. fluviatilis* in relation to the mentioned ecological factors, and greater endangerment of its habitats by different antropogenic influences on another side, speaks about its vulnerability and endangerment, and need for protection of its habitats.

**Key words:** *Lemanea fluviatilis* (Linné) C. Ag., morphology, ecology, new localities, Serbia.

## INTRODUCTION

Freshwater red algae (Rhodophyta) appear to be endangered algal group in many countries. These algae can characterize their environments in many ways and are connected to their different preferences for physical, chemical and biological variables (ELORANTA & KWANDRANS 2004).

Data about distribution of *L. fluviatilis* indicate that this species was found on relatively small number of localities in Europe: (PEVALEK, 1916; VOUK 1953; PETROVSKA, 1966; MATONIČKIN & PAVLETIĆ, 1960; WHITHON, 1975; STARMACH, 1977; KAWECKA, 1980; SABATER *et al.*, 1989; ELORANTA & KWANDRANS, 1995; ROTT *et al.*, 1999, KUČERA & MARVAN, 2004) of the North America (VIS & SHEATH, 1992), South America (Brazil) (NECCHI *et al.* 1999) and Australia (ENTVISLE, 1989).

In Serbia, genus *Lemanea* (species *Lemanea fluviatilis*) was recorded at the first time in Crnovrška River (Stara planina) (SIMIĆ, 1995), and after that on some other localities in rivers of East (Golema River, Svrliški Timok River and Mlava River) and West Serbia (Studnica) (SIMIĆ, 2002).

Knowledge about small-number localities of species *L. fluviatilis* with specific ecological conditions contributed to including of this algae in Red list of algae, in some countries, where this species is defined as a vulnerable (V) (SIEMINSKA, 1992) or as (endangered) EN (HINDAK, 2001).

The aim of this study is to present new data about morphological and ecological characteristics of *L. fluviatilis* populations that were found on new finds in rivers of Serbia.

## MATERIAL AND METHODS

Algological material, in which species *L. fluviatilis* was recorded, was collected in Resava River (South Serbia), on two localities, as well as, per one locality on Božička River and Vlasina River (South Serbia).

Physical and chemical characteristics on investigated localities were measured by field laboratory HANA INSTRUMENTS (APHA 1985). These measurements included: velocity, temperature of water, pH, electro conductivity of water, BOD, saturation with and concentration of oxygen and concentration of biogenic salts (phosphates and nitrates) (Table 1).

All samples were collected from running water with turbulent flow (weirs and riffles). The algological material was fixed in 4% formaldehyde and is stored in the Algological collection of the Institute of Biology and Ecology, Faculty of Science, University of Kragujevac. For taxa identification the material was magnified 640 times and analyzed with a C. Zeiss-Amplival microscope. Measurements were performed with ocular micrometer whereby the material was magnified 160-640 times.

In the laboratory we recorded the following morphological characters (Table 2): presence and incidence of branched plants, presence of a stalk, plant length, nodal diameter (ND), internodal diameter (ID), presence of axial cortical filaments, arrangement of spermatangial sori, length and diameter of carospores (VIS & SHEATH, 1992; KUMANO, 2003; KUČERA & MARVAN, 2004)

## RESULTS AND DISCUSION

### Description of the sampling localities

The **Resava River** is 70 km long right tributary of the River Velika Morava. Its flow covers an average area of about 450km<sup>2</sup>. It is one of the largest rivers of the East Serbia. The Resava River, with its tributaries represents river basin in the Lisine ravine, where the biggest spring, called the Great spring occurs. The Resava River sources from Kučajske Mountains, and in upper part of its course is virgin wood and Vitanovac reservation. On protected area of around 38 h, huge beech trees grow. Canyon part of Resava River is 25 km long, and after that it is calm river running alongside Manasija Monastery, Despotovac town and Svilajnac town, and after 65km flows into West Morava. Water of this river is exceptionally clear, so it together with ravine of Suvaja River represents strict nature reservation of I category and it is under protection of our state.

In May 1st 2003, thali of the species *L. fluviatilis* were found in trout fish pond "Lisine" (locality RR1), on concrete substrate, in zone of surf, on depth from 10 to 15cm. Fish pond is located on 450m a.s.l. Water depth of fish pond was from 1.5 to 2m (Table 1).

In 12 April 2004, thali of the species *L. fluviatilis* were found in the river, on 700 a.s.l., (locality RR2) on locality with wide from 2 to 6 m, depth from 0.3 to 1m (thali were always found on rocks, which were flooded by water, on depth of a few centimeters), in water of 10<sup>0</sup>C temperature, pH 7.8, concentration of dissolved oxygen 8,59mg/l, saturation 90,6% and electro conductivity 160μS/cm (Table 1).

**Božička River (BR)** sources on south-east slope of Vlasina plateau, after that fuses with Ljubatska River in Dragovištica River, which after some kilometers leaves territory of Serbia and passes into Bulgaria.

In 11 July 2003 and 15 August 2004, thali of the species *L. fluviatilis* were found on over 1100m a.s.l., on part of river where width is from 3-5m, depth from 0.1 do 0.7m, speed 1.1m. pH values measured in 11 July 2003 was 7.3, and 7.1 in 15 August 2004, concentration of oxygen 10.87mg/l, versus 8.71mg/l, saturation 99.2 and 98.4%, respectively, with small concentration of nutrients (nitrates 4.4 and 4.6mg/l, and fosfates 0.400 and 0.443mg/l. Electro conductivity was 90μS/cm and 70μS/cm, respectively (Table 1).

**Vlasina River (VR)** is situated in the mountain region of the south-east part of Serbia. Its source is below the dam on the Vlasinsko Jezero reservoir, at 1210m a.s.l. and the month is near town Leskovac in the Južna Morava River. Primarily, Vlasina River was a natural arm of a Vlasina pest-bog. After the construction of the dam on the Vlasina River in 1949, 2km downstream from the place where it flowed out from the peat-bog the course of the river was out from the newly created reservoir. Geological substratum of the river bottom is mainly composed of crystalline shists. The main components of these rocs are sercite, chlorite, quartz and albite. Due to geological substratum, the hole area is permeate with a dense network of periodical and permanent streams.

In 15.08.2004, the thali were found on locality below fish pond, at temperature 12<sup>0</sup>C and pH 7.2, on 1150m a.s.l (Table 1).

**Table 1. Physical and chemical parameters of streams from which *Lemanea fluviatilis* plants were collected**

Rivers/ Lokality	Resava River		Božička River		Vlasina River
	RR1	RR2	BR		VR
Date/ Years	1. 05 2003.	12. 04. 2004.	11. 07. 2003.	15.08. 2004.	15. 08. 2004.
Altitude (m)	450	800	1100	1100	1000
Max. bed width (m)		6.0	5	3.5	
Max depth (m)		1.0	0.70	0.70	
Velocity (m/s)	1.5	1.1	1.1	1.1	
Temperat. of waters (°C)		10	10.2	13.8	
Disolved oxygen (mg/l)		8.59	10.87	8.51	
O <sub>2</sub> (%)		90.6	99.2	98.4	
BOD <sub>5</sub> (mg/l)			0.5	0.4	
pH		7.8	7.3	7.1	
Phosphate (P) (mg/l)		0.058	0.400	0.443	
Nitrate ( N) (mg/l)		4.7	4.4	4.6	
Conductivity (µS/cm)		160	90	70	

### Description of the alga

The recent taxonomic concept of the family Lemnaceae is based on both morphological and ultrastructural characters (VIS & SHEATH, 1992, SHEATH *et al.*, 1996, ELORANTA & KWANDRANS, 2002; KUMANO, 2003). However, identification of the species is difficult (VIS & SHEATH, 1992). The morphological variability and its subjective evaluation does not allow a clear delimitation of the species. Thus, for delimiting species of Lemnaceae both the morphology of vegetative and reproductive features and ultrastructural and molecular information is required (CARMONA & NECCHI, 2002).

On the occasion of review of algological material and comparison of morphological and anatomical features, some variability in relation to appearance of algae on different localities, as well as in different periods of the year was recorded (Table 2).

Adult plants are in clods, in form of needle, to 12 cm height (on locality Vlasina maximum was 4.5cm), unbranched or branched (on locality Resava and secondarily). The thali get narrower to apex in thin thread, and in base in thin, cylindrical stem. They do not have cortex around central axis cell. Their color is from olive green to violet green. Width of nodus is from 400 to 900µm, and of internodus is from 210 to 770µm (ratio nodus:internodus is from 1.16 to 1.33). Knotty swellings are moderately visible, less in spring than in summer months. Length of carpospore is from 16 to 54µm, and width from 9.9 to 39.0µm.

Primary stadium (*Chantransia* stadium) was found on stand, on localities Resava in April and Božička River in July. It is 1-2 mm long, clod-like, branched, without hairs on the top. Mature individuals grow from lower cells of primary stadium. Cells are 16.5 to 24µm long, 9.9 to 16 µm width (ratio length:width is 1.7 to 3.3). Monosporangia unknown.

### **Distribution and ecology of species *L. fluviatilis***

On the base of relatively small number of data from contemporary literature, as well as new data presented in this study, it can be noticed that the *L. fluviatilis* is stenovalent when are in questions ecological factors, such as: type of water ecosystem, type of substrate, depth where thali develop, speed of water, aeration, temperature, pH and electro conductivity of water.

Populations of species *L. fluviatilis* were found in hill-mountain rivers and streams of Europe, North and South America, on altitudes from 305 to 888m (SABATER *et al.*, 1989; VIS & SHEATH, 1992; NECCHI *et al.*, 1999; KUČERA & MARVAN, 2004). In Serbia, the thali of species *L. fluviatilis* were found on latitudes from 500 to 1100 m. Rivers in which this alga was found are mainly to 10m width, depth to 1m, open or partially shaded (SABATER *et al.*, 1989; VIS & SHEATH 1992; NECCHI *et al.*, 1999; SIMIĆ, 2002; KUČERA & MARVAN 2004). ELORANTA & KVADRANS (2004) reported data that this species was found in larger, open river.

This algae always has been found on stable and hard substrates (stones, large rocks, and also concrete blocks or walls). The species was observed in Czech Republic on stony substrates (boulders and cobbles) in riffles or weirs on depth from 2 to 15cm (KUČERA & MARVA 2004).

It is known that red algae, and particularly algae of Lemnaceae family generally were found in running, turbulent waters. It was shown that in the rivers of Serbia, this species was found on localities where measured speed of water was from 0.4 (in Mlava River, at locality M1) to 1.40m/s (in Crnovrška River, at locality CR11) (SIMIĆ, 2002). Also, in the rivers of Finland, it was found at different speeds of water (min. 0.20 - max. 1.90m/s) (ELORANTA & KWADRANS, 1996). American authors (VIS & SHEATH, 1992) cited similar data for this species. However, it was noticed that thali of this algae were always found in those parts of river's course where water speed was greater than average measured speed for that locality (around 1m/s), as well as, on places which were exposed to strong blow of water, or at least to pounding, that is places with high aeration. The thali were always found on small depth from 2 to 15cm, and sometimes in direct contact with air.

Need of red algae for high concentration of oxygen confirms data that show frequency and coverness of this algae are much greater in water with high concentration of oxygen (SHEATH, 1984; SABATER *et al.*, 1989; NECCHI *et al.*, 1999). In rivers of Brasil, 80% of recorded species were found in waters where saturation of oxygen was from 60 to 100% (NECCHI *et al.*, 1999). At localities in Resava River and Božička River, the thali of *L. fluviatilis* have developed well in good aerated water (concentration of oxygen from 8.59 to 8.71mg/l, high saturation from 90, 6 do 98.7%).

Also, many investigations confirmed stenovalence of this species in relation to temperature. This species prefers cold water (mainly under 15°C). There are interesting data of Vis i Sheath (1992), who found this algae on habitats where measured temperature of water was above 15°C (max. 24°C), in rivers of Ontario State (North America).

**Table 2. Characteristics of populations of *Lemanea fluviatilis***

Locality	Stalced od plants	Branched plants	Plant length (cm)				Axial cortical filaments	Spermatangial sori arrangement	Nodial Diameter ( $\mu\text{m}$ )				Internodal Diameter ( $\mu\text{m}$ )				
			Range		mean $\pm$ SD				Range		mean $\pm$ SD		Range		mean $\pm$ SD	Ratio ND:ID	
Resava River (RR1)	yes	yes	5,0	12	8,0	3,0	no	patches	500	900	603,6	112,6	340	620	451,8	80,6	1,33
Resava River (RR2)	yes	yes	1,5	10	4,8	2,5	no	patches	620	880	700,0	87,0	540	770	605,6	72,3	1,16
Božička River 17.07 2003.	yes	no/ yes	1,2	5	2,9	1,0	no	patches	400	700	545,8	81,2	210	600	423,6	114	1,29
Božička River 15.08 2004.	yes	no/ yes	1.5	4.5	3.4	1.0	no	patches	500	700	598	71,2	430	600	506	70,2	1.18
Vlasina River	yes	no/ yes	1,5	10	4,8	2,3	no	patches	500	700	566,3	61,9	380	530	451,9	54,9	1,25

Some stenovalence can be observed in relation to electro conductivity. There are records of this algae in habitats with water electro conductivity to 300 $\mu$ S/cm (VIS & SHEATH, 1992), and also, to 400 $\mu$ S/cm (SIMIĆ, 2002), as well as here presented results (from 70 to 160 $\mu$ S/cm). Exceptions are data of ELORANTA and KWANDRANS (1996), and according them the *L. fluviatilis* is very tolerant in relation to electro conductivity (from 150 to 3 056 $\mu$ S/cm).

ROTT and colleagues (1999) characterized the species *L. fluviatilis*, in relation to phosphorus, as indicator of oligo-mesotrophic water (indicator height G-1). In relation to nitrogen, they gave data that the this species is good indicator of oligotrophic waters (G-4).

The thali of this alga were found in community with *Chamaesiphon polonicus*, *Homeoethrix janthina*, *Hydrurus foetidus* (Crnovrška River), than together with thali of species of genus *Paralemanea* (Golema River, Studenica), *Vaucheria* and *Cladophora glomerata* (Svrlijski Timok River), as well as in rich community of silicate algae (SIMIĆ, 2002).

On the thali of *L. fluviatilis* (on localities Vlasina River and Božička River), macroscopically visible colonies of epifitic algae in form of oliva green warts with diameter from 2 to 5 mm, were observed. By microscopical review, in common hard mucus, silicate algae of genera *Navicula*, *Cymbella* and *Ceratoneis* were found. In material collected on locality Vlasina, gelatinous oliva green colonies *Nostoc sp.* with diameter to 1cm were recorded. By review of algological material from fish pond "Lisine", threads of *Ulothrix zonata* (Chlorophyta) and *Vaucheria sp.*, as well as, algae of genera *Diatoma* and *Gomphonema* were observed in base of the thalus *L. fluviatilis*.

At the one side, known stenovalence of this alga in relation to mentioned ecological factors, and at the other side, more and more increased endangerment of habitats where this alga lives by different antropogenic influences are the basic reasons why this alga is on some existing Red list of algae defined as vulnerable (V) (SIEMINSKA 1992) or as EN (endangered) (HINDAK, 2001).

New habitats of this species, which were mentioned in this study, as well as, habitats where it was formerly recorded in Serbia (SIMIĆ, 2002) are located mainly on areas of protected nature (Resava River – landscape of extraordinarily characteristics), so completely expectation exists that these habitats will stay unendangered by further respect of measures for protection and decrease of antropogenic influences.

However, in practice, without respect to some level of protection, some activities occure in protected areas, which can lead do endangerment of this species, but also of greater number of other important species that charaterized that protected natural property. Habitats of this species on Crnovrška River and Golema River on territory Stara planina (which is declared as Natural park in 1997), where at the first time genus *Lemanea* was recorded at territory of Serbia and Montenegro, are directly and indirectly endangered, because in immediate vicinity there are activities in formation sports-recreative center, which can lead to significant negative antropogenic influences.

## CONCLUSION

New data about morphology, ecology and biogeography of the *L. fluviatilis* presented in this study, together with already existing data show that this species, which is relatively very rare in the world, as well as in Serbia, stenivalent in relation to greater number of ecological factors (altitude, substrate, speed of water, aeration, temperature, pH, electro conductivity and water quality). It speaks about its vulnerability, need for knowing of its ecology and distribution, as well as necessity for protection of its habitats.

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