Сибирский экологический журнал, 3 (2016) 390–404

УДК 574.5

DOI 10.15372/SEJ20160310

Vegetation of the *Hydrochari-Lemnetea* and *Potametea* classes in the Danube-Tisza-Danube hydrosystem (Serbia)

D. DŽIGURSKI, Lj. NIKOLIĆ, B. LJEVNAIĆ-MAŠIĆ

Faculty of Agriculture
University of Novi Sad
21000, Serbia, Novi Sad, Trg Dositeja Obradovića, 8
E-mail: brana@polj.uns.ac.rs

Статья поступила 20.10.15

Принята к печати 02.12.15

ABSTRACT

Aquatic vegetation of *Hydrochari-Lemnetea* and *Potametea* classes in the Danube-Tisza-Danube hydrosystem (Hs DTD) was studied in 2009–2012, by applying the standard Braun-Blanquet method. The canal network vegetation comprises 14 associations, with *Trapetum natantis* and *Ceratophylletum demersi* being the most widely distributed. Hs DTD is also a habitat for several important endangered species, which serve as edificators of the following phytocenoses: *Nymphaeetum albae*, *Nymphaeetum albo-luteae, Nymphoidetum peltatae, Trapetum natantis*, *Lemno-Spirodeletum*, *Salvinio-Spirodeletum polyrrhizae, Lemno-Utricularietum vulgaris, Potametum nodosi*, *Myriophyllo-Potametum* and *Najadetum marinae*. In the studied vegetation, we also found an invasive phytocenosis *Elodeetum canadensis* that did not have an expanding tendency, and *Ceratophyllo demersi-Vallisnerietum spiralis* that had this tendency, which made monitoring its stands necessary. Physico-chemical analyses of water, conducted at localities in which the studied phytocenoses thrive, revealed that the development and distribution of most phytocenoses is closely linked with specific habitat conditions. Among the studied parameters, the most significant for the phytocenoses differentiation were: pH, alkalinity, COD-MnO_4, BOD_5, NO_3^-, NO_2^-, PO_4^{3-} and the concentration of total phosphorus.

Key words: *Hydrochari-Lemnetea*, *Potametea*, properties of water, eutrophication, macrophytes.

Until the 18th century, Vojvodina was a swampy and marshy region. Being the lowest part of the Pannonian Plain, receiving the water masses formed in the Alps, Carpathians and Dinarides, it is characterized as the greatest hydro network in Europe [Milošev, 2002]. Due to the dense water flow network and unfavourable water characteristics, it was necessary to regulate the water flow regimen, which was achieved by the development of the Danube-Tisza-Danube hydrosystem (Hs DTD). However, the canal network development resulted in successive disappearance of many marshes and swamps, together with specific aquatic and semiaquatic vegetation.

According to the European Water Framework Directive (WFD) terminology, Hs DTD is an artificial water body that represents a complex system with respect to its management, and is of great strategic significance for Serbia [European Commission, 2000]. According to the WFD, artificial water bodies are required to sustain positive ecological potential (characterized by negligible changes in the values of biological parameters of the highest ecological potential) and adequate chemical status of surface water. Aquatic macrophytes are important biological elements for the ecological status assessment [WFD, European Commission, 2000]. Aquatic macrophytes are considered one of the most reliable biological parameters for eutrophication assessment, since they have an quicker response to changes in nutrient conditions than benthic invertebrates or fish, and a slower response than phytoplankton, phytobenthos and macroalgae [Laketić et al., 2013]. In addition to the findings of numerous studies confirming that macrophytes are reliable indicators of the trophic status and other hydro-chemical parameters [Papastergiadou, Babalonas, 1993; Szańkowski, Kłosowski, 1999; Janauer, Dokulil, 2006; Kłosowski, 2006; Otahelová et al., 2007; Pełechaty, 2007; Kočić et al., 2008; Grînberga, Spriòie, 2008; Schneider, 2009; Szoszkiewicz et al., 2010; Lewin, Szoszkiewicz, 2012; Hrivnák et al., 2014], it is noteworthy that plant phytocenoses, besides providing valuable information about the habitat conditions, can also reveal the reasons and patterns of the ecosystem changes. In addition to the bioindicative function, macrophyte vegetation plays a key role in maintaining the ecosystem functionality and improving the physico-chemical water parameters. It also provides the necessary amount of oxygen for other organisms, serves as food and shelter for animals, and remediates the habitat [Schneider, 2007; Lukács et al., 2014; Schneider, 2014; Nikolić et al., 2014].

The ecological balance in the Hs DTD, which is a secondary anthropogenic ecosystem, is very difficult to establish due to the dynamic changes necessary for operating the canal network. In addition to the orchestrated changes in water level, the presence of 23 dams also contributes to this challenge [Džigurski et al., 2010]. "Mechanical stress" to which hydrophytes are exposed in dynamic hydroecosystems reduces the primary production and can contribute to narrowing of the ecological amplitude [Schneider, 2007]. Moreover, rapid eutrophication, caused by the intensification of agriculture, urbanization and industrialization, is an additional factor contributing to the greater instability [Džigurski et al., 2013]. Hence, instead of successions that have existed for thousands of years and have resulted in valuable phytocenoses complexes, the anthropogenic eutrophication effects, caused by significant amounts of nutrients that are rapidly introduced into the ecosystem, can be noted after only a few decades of the canal operation [Hummel, Kiviat 2004; Balevičiene, Balevičius, 2006]. Increasing nutrient quantity favors biodiversity only to a certain extent; however, further increments, due to the disappearance of most stenovalent organisms, result in loss of biodiversity [Kremser, Schnug, 2002; Schaumburg et al., 2004; Scheffer, Van Nes, 2007; Kočić et al., 2008; Grînberga, Spriòie, 2008]. R. Hrivnák et al. [2007] noted that human influence – namely, water pollution, water regimen regulation and presence of dams – is instrumental in the changes of the macrophyte structure and distribution.

The aim of this work is to analyze the current state of the vegetation diversity in the secondary aquatic ecosystem, in the light of the changed water quality conditions of watercourses in this part of Europe that have been observed in recent decades. The paper will present: 1) floristic structure of the identified aquatic phytocenoses; 2) definition of basic physico-chemical parameters that influence vegetation development; 3) detection of threatened and endangered species that have found refuge in this fragile anthropogenic ecosystem, as well as invasive species that threaten the conservation of its biodiversity.

MATERIALS AND METHODS

Studied region. The study was conducted in the Hs DTD canal network, in Bačka (Vojvodina, Serbia). Vojvodina (44°39′15.04″ and 46°10′11.32″ north latitude, 18°°50′15.00″ and 21°33′27.82″ east longitude) is located in the southern part of the Pannonian ecoregion. Although moderate continental climate predominates in the region, the massifs of the surrounding Carpathian Mountains in the east, the

Alps in the west and Dinarides in the southwest cause the climate to take a more pronounced continental character than the general geographic location alone would entail. Moreover, owing to Mediterranean influences from the direction of the Adriatic Sea that reach the region through the Dinarides, the climate in Vojvodina can be characterized as highly heterogeneous [Lalić et al., 2011].

The Danube-Tisza-Danube hydrosystem is one of the largest hydroecosystems in Europe. In Bačka, the network comprises nine canals between Danube and Tisza, with the total length of 421 km (Fig. 1). There are 23 sluices on the main Hs DTD canal network, which were built as independent structures, or in combination with locks within a hydro-knot, which helps to regulate the canal water level. Hs DTD is important in the agricultural development of Vojvodina and the region. Its purpose is multifaceted, comprising acceptance and channeling of international waters (waters flowing from the territories of other countries); receiving and removing water from the drainage systems of agricultural lands and other types of land; providing water for irrigation systems, ponds, farms, industry and communities; receiving, implementing and diluting the wastewater coming from industrial buildings, farms and villages; providing navigation channels for vessels of 200 to 1.000 t carrying capacity; flood protection; fishing, recreation and tourism [Savić et al., 2013].

Plant communities. Phytocenological studies were conducted from 2009 to 2012, in the period of maximum vegetation growth (June to September), using the Braun-Blanquet method. Field studies were conducted from small boats or, at sites where this was not possible, from the shore using simple, yet efficacious hooks and rake-type devices, designed by J. Blaženčić and Z. Blaženčić [1991]. The surfaces from which phytocenological recordings were taken ranged from 5 to 25 m^2. In each phytocenosis (on the relevé area) water samples were taken for physico-chemical analyses. The samples were collected at the same time as the releves were performed (June – September). Each year the survey was only carried out at the peak of the growing season to ensure the comparability of the data.

Fig. 1. The Danube-Tisza-Danube hydrosystem's canal network

The syntaxonomic review of the studied vegetation was adjusted according to the R. Soó method [1973]. All videos were registered in a phytocenological synoptic table, in which level of presence (I–V), number and coverage (+, 1, 2, 3, 4, 5) were given for each species. Under the "Results" heading, the description of the identified phytocenoses was given, including synonyms, characteristic species of the association, characteristic group types, ecology, conservation status and invasion status. Characteristic groups comprise association and plant species edificators with the degree of presence IV and V, corresponding to species present in 60–80 % and 80–100 % of the images captured, respectively.

Under the "Conservation status" heading, the species that are on the Red List of Threatened Species for Europe [IUCN, 2013] and have the Least Concern (IUCN LC) status were listed, along with species that are protected in Serbia [Radulović et al., 2012], namely those given the National Conservation status – Strictly Protected (NCS-R) and National Conservation status – Protected (NCS-R). In this work, plant species invasion status was determined

T a b l e 1

Synoptic table of the plant communities of the *Hydrochari-Lemnetea* class in Hs DTD in Bačka

Phytocenoses	LS	SS	CD	HM	LU
Number of species	17	17	18	21	18
Characteristic species of the association of the alliances *Lemnion minoris, Ceratophyllion* and *Hydrocharition*					
Spirodela polyrrhiza (L.) Schleid.	$\mathbf{V^{1-4}}$	$\mathbf{IV^{\pm1}}$	$IV^{\pm1}$	$I^{\pm1}$	V^{1-5}
Lemna minor L.	$\mathbf{V^{1-4}}$	$IV^{\pm2}$	III^{+}	V^{+}	$III^{\pm1}$
Salvinia natans (L.) Allioni	$III^{\pm1}$	$\mathbf{V^{1-4}}$	II^{+}	$IV^{\pm1}$	$II^{\pm1}$
Ceratophyllum demersum L.	$IV^{\pm3}$	$IV^{\pm2}$	$\mathbf{V^{4-5}}$	V^{+-2}	$IV^{\pm2}$
Hydrocharis morsus-ranae L.	$II^{\pm1}$	$IV^{\pm1}$	$II^{\pm2}$	$\mathbf{V^{3-5}}$	$II^{\pm1}$
Utricularia vulgaris L.				I^{1}	$\mathbf{V^{3-4}}$
Characteristic species of the alliances *Lemnion minoris*, *Ceratophyllion* and *Hydrocharition,* the order *Hydrocharietalia* and the class *Hydrochari-Lemnetea*					
Lemna gibba L.	$II^{\pm2}$	I^{+}	I^{+}	I^{+}	
Lemna trisulca L.	$I^{\pm1}$	I^{+}	I^{+}	$I^{\pm1}$	
Accessory species					
Vallisneria spiralis L.	$III^{\pm1}$	$IV^{\pm1}$	$III^{\pm1}$	III^{+}	
Elodea canadensis Rich	$II^{\pm1}$	I^{+}	$I^{\pm1}$	III^{+}	
Potamogeton pectinatus L.	II^{1}	I^{+}	$II^{\pm1}$	I^{+}	
Myriophyllum spicatum L.	$II^{\pm1}$	II^{+}	$IV^{\pm1}$	$II^{\pm1}$	$IV^{\pm2}$
Trapa natans L.	II^{+}	$II^{\pm1}$	$II^{\pm1}$	$III^{\pm2}$	II^{+}
Sagittaria sagittifolia L.	I^{1}	I^{+}	I^{+}	I^{+}	
Potamogeton crispus L.	I^{+}	I^{+}	I^{+}	I^{+}	
Najas marina L.	I^{+}	$II^{\pm1}$	I^{+}	I^{+}	I^{+}
Potamogeton perfoliatus L.	I^{+}		I^{1}		
Stratiotes aloides L.	I^{1}				
Nymphaea alba L.		I^{+}	I^{+}	I^{+}	I^{1}
Myriophyllum verticillatum L.		I^{+}			$I^{\pm1}$
Nuphar lutea (L.) Sm.			$II^{\pm1}$	I^{+}	I^{1}
Potamogeton lucens L.				I^{1}	
Potamogeton fluitans Roth.				I^{+}	
Polygonum amphibium L.				I^{+}	
Phragmites communis Trin.					II^{1}
Lycopus europeus L.					$II^{\pm1}$
Typha angustifolia L.					I^{1}
Sparganium ramosum Huds.					I^{1}
Glyceria maxima (Hartm.) Holm.					I^{1}
Rumex hydrolapathum Huds.					I^{+}

N o t e. Associations: LS – *Lemno-Spirodeletum*, SS – *Salvinio-Spirodeletum polyrrhizae*, CD – *Ceratophylletum demersi*, HM – *Hydrocharidetum morsus-ranae,* LU – *Lemno-Utricularietum vulgaris.*

in accordance with the List of invasive species in AP Vojvodina [IASV, 2013].

Physico-chemical parameters. In the sections of the canal where the investigated associations were identified, water samples were collected annually 4 times per year (from 2009 to 2012) during the growing season (June, July, August and September). The water samples were taken from the surface layer (up to 0.3 m depth) in the canal sections where the existence of phytocenoses was previously ascertained. Basic physical and chemical properties

T a b l e 2

Synoptic table of the plant communities of the *Potametea* class in Hs DTD in Bačka

Phytocenoses	PN	EC	MP	NM	CV	NA	NL	NP	TN
Number of species	19	15	21	11	17	12	18	15	20
Characteristic species of the association of the alliances *Batrachion fluitantis, Potamion* and *Nymphaeion*									
Potamogeton fluitans L.	**V^{3-5}**	II^{+}	$II^{\pm 3}$						
Elodea canadensis Rich	I^{+}	**V^{4-5}**	I^{+}		I^{+}		I^{+}		I^{+}
Myriophyllum spicatum L.	$V^{\pm 2}$	III^{+}	**$V^{\pm 3}$**	II^{+}	$IV^{\pm 2}$	$IV^{\pm 2}$	$IV^{\pm 1}$	$III^{\pm 2}$	$IV^{\pm 1}$
Potamogeton lucens L.		I^{1}	**II^{4-5}**		I^{3}				
Najas marina L.	$V^{\pm 2}$	II^{+}	II^{+}	**V^{3-5}**	$I^{\pm 1}$	I^{+}	I^{+}		I^{+}
Vallisneria spiralis L.	$III^{\pm 1}$		I^{+}	I^{+}	**V^{3-5}**		$IV^{\pm 1}$	$IV^{\pm 1}$	$II^{\pm 1}$
Ceratophyllum demersum L.	$V^{\pm 1}$	$IV^{\pm 1}$	$V^{\pm 3}$	$V^{\pm 2}$	**$V^{\pm 3}$**	$IV^{\pm 3}$	$V^{\pm 3}$	V^{+-2}	$IV^{\pm 2}$
Nymphaea alba L.	$III^{\pm 1}$	I^{+}	II^{+}			**V^{3-5}**	**III^{1-3}**	II^{+}	I^{+}
Nuphar lutea (L.) Sm.			I^{+}				**V^{2-5}**	$III^{\pm 1}$	I^{+}
Nymphoides peltata Hill.				$II^{\pm 1}$		I^{1}	I^{+}	**V^{2-5}**	
Hydrocharis morsus-ranae L.	$III^{\pm 1}$	$IV^{\pm 1}$	$III^{\pm 1}$		$IV^{\pm 1}$	I^{+}	$IV^{\pm 1}$	$V^{\pm 2}$	$IV^{\pm 2}$
Trapa natans L.	II^{+}	II^{+}	III^{+}	II^{+}	$III^{\pm 1}$	I^{+}	$III^{\pm 1}$	V^{+}	**V^{3-5}**
Characteristic species of the alliances *Batrachion fluitantis, Potamion* and *Nymphaeion,* the order *Potametalia* and the class *Potametea*									
Ranunculus circinatus L.	$IV^{\pm 2}$	I^{1}	$II^{\pm 2}$						
Potamogeton perfoliatus L.	I^{+}		II^{3-4}	I^{+}	I^{+}	I^{+}	I^{+}	II^{+}	$I^{\pm 1}$
Potamogeton crispus L.	I^{+}		$III^{\pm 3}$	I^{+}	I^{+}		I^{1}		I^{+}
Myriophyllum verticillatum L.	I^{+}								
Potamogeton pectinatus L.		$II^{\pm 1}$	$II^{\pm 5}$		I^{+}			I^{+}	$II^{\pm 1}$
Polygonum amphibium L.			I^{1}			I^{+}			I^{+}
Accessory species									
Salvinia natans (L.) Allioni	II^{+}	IV^{+}	II^{+}		$III^{\pm 1}$		$IV^{\pm 2}$	$V^{\pm 1}$	$II^{\pm 1}$
Sagittaria sagittifolia L.	II^{+}				$I^{\pm 1}$		I^{1}	II^{+}	I^{+}
Lemna trisulca L.	I^{+}	$IV^{\pm 1}$	II^{+}	I^{+}	I^{+}		III^{+}	III^{+}	I^{+}
Lemna minor L.	I^{+}	IV^{+}	II^{+}	I^{+}	I^{+}	I^{+}	III^{+}	IV^{+}	III^{+}
Spirodela polyrrhiza (L). Schleid.	I^{+}	II^{+}	$III^{\pm 1}$	I^{+}	$II^{\pm 2}$	I^{+}	$II^{\pm 3}$	IV^{+}	$IV^{\pm 1}$
Sparganium ramosum Huds.	I^{+}								
Utricularia vulgaris L.			I^{+}		I^{+}	I^{1-3}	I^{+}		I^{+}
Lemna gibba L.									I^{+}

N o t e. Associations: PN – *Potametum nodosi*, EC – *Elodeetum canadensis*, MP – *Myriophyllo-Potametum*, NM – *Najadetum marinae*, CV – *Ceratophyllo demersi-Vallisnerietum spiralis*, NA – *Nymphaeeetum albae,* NL – *Nymphaeetum albo-luteae*, NP – *Nymphoidetum peltatae*, TN – *Trapetum natantis.*

of water were determined using standard methods [APHA, 1995]. The following parameters were monitored: temperature, pH value (with a pH-meter), alkalinity, chemical (COD MnO_4) and biological (BOD_5) oxygen demand, and nutrient content (NH_4^-, NO_3^-, NO_2^-, PO_4^{3-} and total phosphorus).

The data required for the chemical water analysis, pertaining to the aforementioned parameters, were processed using the STATISTICA 7.0 software. The significance of differences between the investigated phytocenoses, in relation to the water parameters analyzed, was established via ANOVA and Fisher LSD test.

RESULTS AND DISCUSSION

Syntaxonomic survey and description of aquatic plant communities

Hydrochari-Lemnetea Oberd., 1967
Hydrocharietalia Rübel, 1933
Lemnion minoris W. Koch et Tx. ex Oberd, 1957
Lemno-Spirodeletum W. Koch, 1954, Müller et Görs, 1960
Salvinio-Spirodeletum polyrrhizae Slavnić, 1956
Ceratophyllion Den Hartog et Segal, 1964
Ceratophylletum demersi (Soó 27) Hild, 1956
Hydrocharition Rübel, 1933
Hydrocharidetum morsus-ranae Van Langendonck, 1935
Lemno-Utricularietum vulgaris Soó, 1928

Potametea Tx. et Prsg., 1942
Potametalia W. Koch, 1926
Batrachion fluitantis Neuhäusl, 1959
Potametum nodosi Soy (1928) 1960, Sega, 1964
Potamion W. Koch, 1926 emend. Oberd, 1957
Elodeetum canadensis (Pign., 1953) Soó, 1964, Passarge, 1964, Westhoff, 1969
Myriophyllo-Potametum Soó, 1934
Najadetum marinae Fukarek, 1961
Ceratophyllo demersi-Vallisnerietum spiralis Lazić, 2006
Nymphaeion Oberd., 1956
Nymphaeetum albae Vollmar, 1947
Nymphaeetum albo-luteae Nowinski, 1928
Nymphoidetum peltatae (Allorge, 1922) Oberd. et Müller, 1960
Trapetum natantis Müller et Görs, 1960

***Lemnion minoris* W. Koch et Tx. ex Oberd, 1957.** This phytocenosis represents free-floating duckweed aquatic plant communities. They are capable of rapid regeneration and are present in artificial water flows (in addition to natural waters), where the influence of anthropogenic factors is intense. Sudden changes in the Hs DTD water levels induce water mass movement, which results in parts of the stands being torn off. The stands are, thus, sometimes found, in the form of fragments, on the surface of deeper canal sections, as a part of other phytocenoses.

Lemno-Spirodeletum polyrhizae (see Table 1, col. LS)

Synonyms: *Lemno-Spirodeletum polyrhizae* Koch, 1954; *Lemno-Spirodeletum* Slavnić, 1956; *Spirodeletum polyrhizae* Kehlhofer ex Tüxen et Schwabe in Tüxen, 1974; *Lemno-Spirodeletum* W. Koch, 1954.

Characteristic species of the association: *Lemna minor, Spirodela polyrrhiza*.

Characteristic group: *L. minor, S. polyrrhiza, Ceratophyllum demersum.*

Ecology: The stands are present in the form of small islands, mostly formed in shallow water in the absence of strong currents (alongside semiaquatic vegetation, in the vicinity of land reclamation facilities). Optimal conditions for the development of this phytocenosis in the Hs DTD include hypertrophic water, low alkalinity and high nitrate levels (1.03 mg/l), as well as dissolved (0.44 mg/l) and total (1.21 mg/l) phosphorus (Fig. 2).

Conservation status**:** *L. minor:* IUCN-LC.

Salvinio-Spirodeletum polyrrhizae (Table 1, col. SS)

Synonyms: *Spirodelo-Salvinietum natantis* Slavnić, 1956; *Salvinio natantis-Spirodeletum polyrhizae* Slavnić, 1956; *Lemno-Salvinietum natantis* Miyawaki et Tüxen, 1960; *Lemno minoris-Salvinietum natantis* (Slavnić, 1956) Korneck, 1959.

Characteristic species of the association: *S. polyrrhiza, Salvinia natans*.

Characteristic group: *S. polyrrhiza, S. natans, Vallisneria spiralis, L. minor, C. demersum, Hydrocharis morsus-ranae.*

Ecology: This pioneering phytocenosis favors sunlit places, protected from the wind, where the water is shallow and calm (Table 3). The stands often form long strips alongside semiaquatic vegetation. Optimum development of this phytocenosis is achieved in the second half of the summer, when the stands sometimes cover the entire canal width. The habitats in which the stands are formed are hypertrophic and warm, with a pH above 8, lower alkalinity, high nitrate, nitrite and phosphate levels (total phosphorus 1.58 mg/l) (Fig. 2).

Conservation status: *S. natans:* IUCN-LC; NCS-SP.

***Ceratophyllion* Den Hartog et Segal, 1964.** This phytocenosis includes submerged vegetation formed in the deeper parts of the watercourse. In the study area, only *C. demersi* was present.

Ceratophylletum demersi (see Table 1, col. CD)

Synonyms: *Ceratophylletum demersi* Corillion, 1957; *Ceratophylletum demersi* Eggler, 1933; *Ceratophylletum demersi* den Hartog et Segal, 1964; *Potamo-Ceratophylletum demersi* Hild & Rehnelt, 1965.

Characteristic species of the association: *C. demersum.*

Characteristic group: *C. demersum*, *Myriophyllum spicatum, S. polyrrhiza.*

Ecology: This phytocenosis is dominant in deeper canal sections, where it sometimes forms dense "underwater meadows". In the period of maximum growth, these stands make the canal impassable for boats. Less frequently, in those parts of the canal where the water flow is slightly faster and floating vegetation is poorly developed, these stands form a narrow strip alongside emerged vegetation. Optimum growth conditions are found in eutrophic water, with lower nitrite values (0.04) and the pH level of 7.86 (see Fig. 2).

***Hydrocharition* Rübel, 1933.** The phytocenoses of this alliance form large free-floating macrophytes. They are predominantly found in shallow canal sections that are in the advanced stages of terrestrialization.

Hydrocharidetum morsus-ranae (see Table 1, col. HM)

Synonyms: *Hydrocharito-Stratiotetum* Kruseman et Vlieger, 1937; *Hydrocharito morsus-ranae-Nymphoidetum peltatae* Slavnić, 1956, *Lemno-Hydrocharitetum morsus-ranae* (Oberd., 1957) Pass., 1978.

Characteristic species of the association: *H. morsus-ranae.*

Characteristic group: *H. morsus-ranae*, *L. minor, S. natans, S. polyrrhiza*, *C. demersum.*

Ecology: This two-layered phytocenosis is floristically rich (21 species). Although it belongs to floating, rootless vegetation type, in shallow water (about 0.3 m), rooting of *H. morsus-ranae* species sometimes occurs. A suitable place for its development is shallow, slow-flowing water with a muddy bottom; however, it can also be found at depths up to 1 m (see Table 3). Stands developed in the form of islands of 2–3 m diameter often create mosaics with other floating plant communities. Conditions for their optimum development are found in eutrophic waters with high BPK_5 (6.09) and ammonium ion (0.81 mg/l) values (see Fig. 2).

Lemno-Utricularietum vulgaris (see Table 1, col. LU)

Synonyms: *Utricularietum vulgaris* Passarge, 1961; *Lemno minoris-Urticularietum vulgaris* Soó (1928) ex Pass., 1964

Characteristic species of the association: *Utricularia vulgaris, Lemna minor.*

Characteristic group: *Utricularia vulgaris*, *L. minor*, *C. demersum*, *M. spicatum.*

Ecology: From the syngenetic perspective, this phytocenosis is the final member in the chain of the smallest flowering aquatic vegetation representatives. The stands were noted only at three sites, where they developed in close proximity to reed beds, interspersed among their sparse stands. Stands occur in mesotrophic, warm waters (25.6), with pH values of 8.14, and low nitrate and nitrite levels (see Fig. 2).

Conservation status: *L. minor:* IUCN-LC; *U. vulgaris:* IUCN-LC; NCS-P.

***Batrachion fluitantis* Neuhäusl, 1959.** This alliance comprises phytocenoses dominated by submerged hydrophytes, adapted to fluctuating water conditions. Roots or rhizomes of these plants are attached to the waterbed, and their trees are resilient and long.

Potametum nodosi (see Table 2, col. PN)

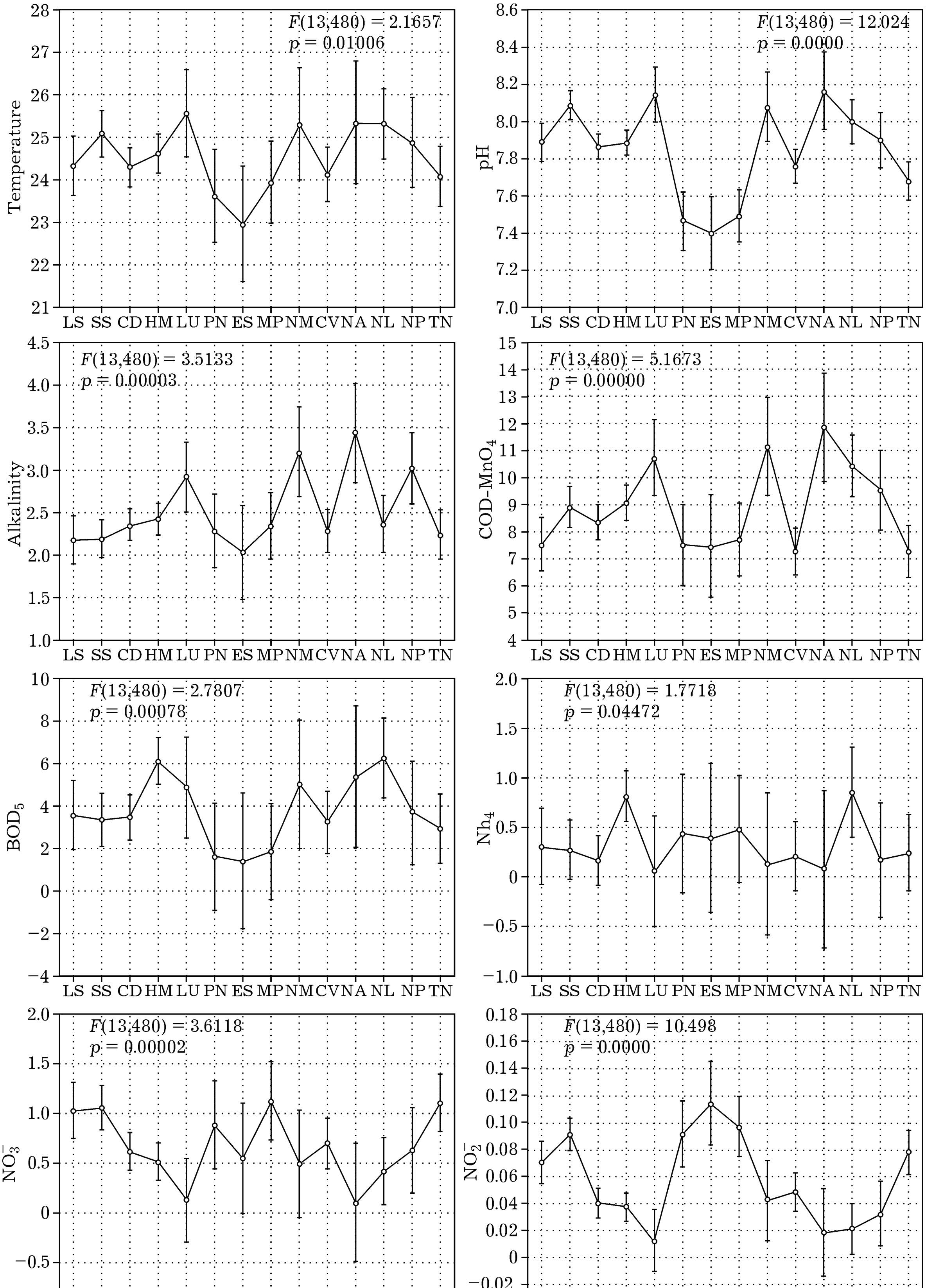
Synonyms: *Potametum denso-nodosi* de Bolós, 1957

Characteristic species of the association: *Potamogeton fluitans.*

Characteristic group: *P. fluitans*, *M. spicatum*, *Najas marina*, *C. demersum*, *Ranunculus circinatus.*

Ecology: Optimal conditions for the development of this association are central, deepest canal sections (3.0–3.5 m), where impacts of water currents are significant (see Table 3). In some locations of the studied ecosystem, the stands that were widespread at a small number of sites, covered the entire canal width. Hypertrophied water, lower temperatures and pH (7.46), and high values of dissolved phosphorus and nitrite (0.73 mg/l), are optimal for the formation of the studied stands (see Fig. 2).

Conservation status: *P. fluitans:* IUCN-LC; NCS-SP.


Temperature
F(13,480) = 2.1657
p = 0.01006
pH
F(13,480) = 12.024
p = 0.0000
Alkalinity
F(13,480) = 3.5133
p = 0.00003
COD-MnO4
F(13,480) = 5.1673
p = 0.00000
BOD5
F(13,480) = 2.7807
p = 0.00078
Nh4
F(13,480) = 1.7718
p = 0.04472
NO3−
F(13,480) = 3.6118
p = 0.00002
NO2−
F(13,480) = 10.498
p = 0.0000
LS SS CD HM LU PN ES MP NM CV NA NL NP TN

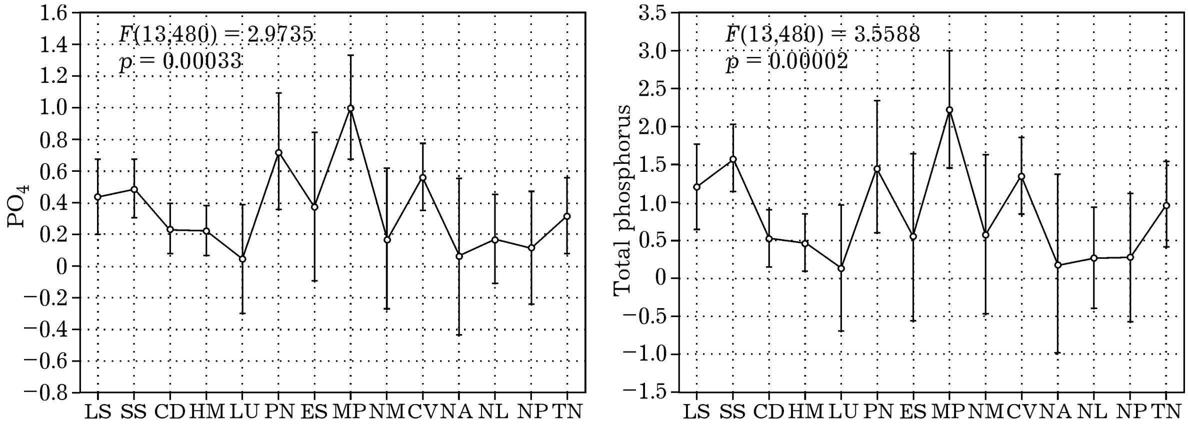


Fig. 2. Significance of differences between the studied phytocenoses compared to the analyzed water properties (ANOVA).

Associations: PN – *Potametum nodosi*; EC – *Elodeetum canadensis*; MP – *Myriophyllo-Potametum*; NM – *Najadetum marinae*; CV – *Ceratophyllo demersi-Vallisnerietum spiralis*; NA – *Nymphaeeetum albae;* NL – *Nymphaeetum albo-luteae*; NP – *Nymphoidetum peltatae*; TN – *Trapetum natantis*. Vertical bars denote 0.95 confidence intervals

***Potamion* W. Koch, 1926 emend. Oberd., 1957.** The alliance combines submerged aquatic plant communities. Submerged ecomorphs predominate, followed by species with vegetative organs that are partly submerged and partly above water surface, and species with only flowers rising above the water surface. In the studied stands, this included species of the genera *Potamogeton, Myriophyllum, Najas* and *Elodea*.

Elodeetum canadensis (see Table 2, col. EC)

Synonyms: *Elodeetum canadensis* Eggler, 1933; *Helodeetum canadensis* Eggler, 1933; *Elodeetum canadensis* Pignaatti, 1953; *Elodeetum canadensis* Soó, 1964.

Characteristic species of the association: *Elodea canćdensis*.

Characteristic group: *Elodea canćdensis, C. demersum, H. morsus-ranće, S. nćtans*, *Lemnć trisulca, L. minor*.

Ecology: This neophyte community, whose edificator is an invasive species *E. canćdensis*, is characterized by limited distribution, and develops in shallow, calm canal sections and bays, in close proximity to the emersal vegetation. During the summer season, at the time of intensive development, these stands reach water depths of 1.0–1.5 m, where they form islands several meters in diameter. These stands are found in slightly eutrophic waters, characterized by low temperature, pH (7.4), and alkalinity. However, the nitrite values (0.11 mg/l) recorded in this case are the highest compared to all other investigated plant communities (see Fig. 2).

Invasion status: *E. canćdenisis:* invasive (IASV 2013).

Myriophyllo-Potametum (see Table 2, col. MP)

Synonyms: *Potamogetonetum lucentis* Hueck, 1931; *Ceratophyllo-Potamogetonetum lucentis* Hueck (1931) ex Pass., 1964 subass. *myriophylletosum* Pass., 1994.

Table 3

Ordering plant communities following a water depth gradient

Mean depth	Vegetation unit
Up to 0.5 m	*Lemno-Utricularietum vulgaris*
	Lemno-Spirodeletum
	Salvinio-Spirodeletum polyrrhizae
Up to 1 m	*Hydrocharidetum morsus-ranae*
Up to 1.5 m	*Elodeetum canadensis*
	Ceratophyllo demersi-Vallisnerietum spiralis
Up to 2 m	*Najadetum marinae*
	Nymphaeetum albae
	Nymphaeetum albo-luteae
Up to 2.5 m	*Nymphoidetum peltatae*
	Trapetum natantis
	Myriophyllo-Potametum
About 3.5 m	*Ceratophylletum demersi*
	Potametum nodosi

Characteristic species of the association: *Potamogeton lucens*, *M. spicatum*.

Characteristic group: *P. lucens*, *M. spicatum, C. demersum.*

Ecology: This floristically rich (21 species), relatively stable submerged community, consisting mainly of rooted hydrophytes, develops on muddy waterbed, in deeper canal sections (up to 3 m). Although it favors slower water flow, it tolerates water current impacts very well. In the canal network, these stands form small islands. The water in which the stands are found is hypertrophic, characterized by lower temperature, pH (7.49) and nitrite values, and high nitrate (1.12 mg/l) and dissolved phosphorus (1.00) values (see Fig. 2).

Conservation status: *P. lucens*: IUCN-LC.

Najadetum marinae (see Table 2, col. NM)

Synonyms: *Najadetum marinae* Libbert, 1932; *Najadeto-Potametum acutifolii* Slavnić, 1956; *Potamo-Najadetum* Horvatić et Micevski in Horvatić, 1963; *Najadetum marinae* Philippi, 1969.

Characteristic species of the association: *N. marina*.

Characteristic group: *N. marina*, *C. demersum*.

Ecology: This floristically poor community (11 species) is found a few meters away from the shore, in deeper canal waters (up to 2 m). Significant proliferation of this phytocenosis along the banks of the Jegricka canal, along which the Slatinski pastures stretch, is conditioned by the adaptation of the edificator *N. marinć* to the increased salt concentration in water. Stands occur in slightly eutrophic waters, with higher temperature, pH (8.08) and alkalinity values (see Fig. 2).

Conservation status: *N. marina*: IUCN-LC.

Ceratophyllo demersi-Vallisnerietum spiralis (see Table 2, col. CV)

Characteristic species of the association: *Vallisneria spiralis, Ceratophyllum demersum.*

Characteristic group: *V. spiralis, C. demersum, M. spicatum, H. morsus-ranae*.

Ecology: This invasive association is dominant in the canal sections with steep and landscaped banks, on which emersal vegetation has not developed. The stands are found a few meters from the shore, in water depths of 0.5–1.5 m, with muddy waterbed. This association is found in hypertrophic (total phosphorus 1.35 mg/l) water with pH 7.76 (see Fig. 2).

Invasion status: *V. spiralis:* invasive (IASV 2013).

***Nymphaeion* Oberd., 1956.** Aquatic floating vegetation of this alliance includes the largest and the most attractive flowering species (*Nymphaea alba*, *Nuphar lutea, Trapa natans* and *Nymphoides peltata*).

Nymphaeetum albae (see Table 2, col. NA)

Synonyms: *Nymphaeetum albo-luteae* Nowinski, 1928 subass. *nymphaeetosum*.

Characteristic species of the association: *N. alba.*

Characteristic group: *N. alba*, *C. demersum*, *M. spicatum.*

Ecology: This two-layered, species-poor (12 species) association is developed only on the section that forms a natural depression and is used as a pond, in water depths of 0.5–2 m (see Table 3). This section is characterized by a large riverbed width and water level fluctuations of low intensity. Optimal conditions for the development of this phytocenosis are mesotrophic, hot waters, of a greater pH (8.17) and alkalinity, and low nitrite and nitrate values (0.10 mg/l) (see Fig. 2).

Conservation status: *Nymphaea alba*: IUCN-LC; NCS-SP.

Nymphaeetum albo-luteae (see Table 2, col. NL)

Synonyms: *Nymphaeo-Nupharetum luteae* Nowinski, 1928; *Myriophyllo-Nupharetum* Koch, 1926 ex Hueck, 1931; *Nupharo luteae-Nymphaeetum albae* Tomaszewicz, 1977.

Characteristic species of the association: *N. alba, N. lutea.*

Characteristic group: *N. alba*, *N. lutea, C. demersum*, *M. spicatum, V. spiralis*, *H. morsus-ranae*, *S. natans.*

Ecology: This is the most developed and stable floating rooted vegetation in the study area, where it forms a narrow border strip towards emersal vegetation, or a very wide strip that reaches the middle of the canal. For their optimum development, these characteristically two-layered stands require water depths of 1.0–2.5 m. Mesotrophic, warm water, with high ammonium ion values and low nitrite values (0.20 mg/l) are optimal for the development of these stands (see Fig. 2).

Conservation status: *N. alba*: IUCN-LC; NCS-SP; *N. lutea*: IUCN-LC; NCS-SP.

Nymphoidetum peltatae (see Table 2, col. NP)

Synonyms: *Nymphoidetum peltatae* (All., 1922) Bellot, 1951; *Trapo natantis-Nymphoidetum peltatae* Oberdorfer, 1957; *Nymphoidetum peltatae* Oberdorfer et Müller in Müller et Görs, 1960; *Polygono-Nymphoidetum* van Donselaar et al., 1961.

Characteristic species of the association: *N. peltata.*

Characteristic group: *N. peltata, T. natans, H. morsus-ranae, C. demersum, V. spiralis, L. minor, S. polyrrhiza, S. natans.*

Ecology: The stands were found only on two sites, at a significant distance from one another, in water depths of 0.5–2.5 m. Numerous characteristic group species (8 types) contribute to the heterogeneous structure of these stands. Low values of abundance and coverage of submerged plants in these stands confirm a significant impact of ass. *Nymphoidetum peltatae* on the reduced growth of submersed macrophytes [Larson, 2007]. These stands are found in mesotrophic waters with higher alkalinity values (see Fig. 2).

Conservation status: *Nymphoides peltata*: IUCN-LC.

Trapetum natantis (see Table 2, col. TN)

Synonyms: *Trapetum natantis* Kárpáti, 1963; *Ceratophyllo-Trapetum natantis* Müller et Görs (1962) ex. Pass., 1992; *Trapo natantis-Nymphoidetum peltatae* Oberdorfer, 1957.

Characteristic species of the association: *Trapa nütans.*

Characteristic group: *T. nütans, H. morsus-ranüe, S. polyrrhiza, C. demersum, M. spicatum.*

Ecology: This phytocenosis dominates in the floating vegetation of the Hs DTD canal network. For optimal development, these stands favor central, deep parts of the canal (about 3 m), where water fluctuations are frequent; nonetheless, they can also be found in calm and shallow sections (about 0.5 m). They form a nŕrrower or a wider belt and, in some places, cover the entire canal width. In deeper waters, in the absence of competition with other floating plants, these stands independently form a lush belt. At lower depths, they typically create a layer of floating vegetation with the communities *Nymphaeetum albo-luteae, Hydrocharidetum morsus-ranae, Salvinio-Spirodeletum polyrrhizae* and *Lemno-Spirodeletum* [Džigurski et al., 2013]. They favor highly eutrophic water, characterized by high nitrate levels (1.12 mg/l) (see Fig. 2).

Conservation status: *T. natans*: IUCN-LC.

The vegetation formed within the Hs DTD canal in Baka region comprises 14 associations belonging to the classes *Hydrochari-Lemnetea* and *Potametea* and alliances *Lemnion minoris, Ceratophyllion, Hydrocharition, Batrachion fluitantis, Potamion* and *Nymphaeion.* The rich macrophyte vegetation is in various stages of development, i. e., succession series. Orchestrated water regimen does not allow the habitat conditions to stabilize, and tighter cenotic relationships among hydrophytes to form; thus, in some sections of this dynamic ecosystem, pioneering phytocenoses alternate with the stabilized ones, forming vegetation mosaics. The most widespread aquatic communities of the investigated area are *Trapetum natantis* and *Ceratophylletum demersi.*

Physico-chemical water parameter analysis (see Fig. 2) revealed that the formation and distribution of phytocenoses is significantly affected by pH, alkalinity, COD, BOD_5, NO_3, NO_2, PO_4 and total phosphorus (ANOVA, $p < 0.001$), as well as temperature and NH_4 (ANOVA, $p < 0,05$).

At lower water temperatures (mean values in the range between 23 and 24 °C), the communities *Elodeetum canadensis*, *Potametum nodosi* and *Myriophyllo-Potametum* develop. Overall, phytocenoses of the *Potamion* alliance form at lower water temperatures, which is understandable considering that this vegetation favors deeper canal sections (see Table 3). In the habitat of the phytocenoses *Lemno-Utricularietum vulgaris, Nymphaeetum albae, Salvinio-Spirodeletum polyrrhizae, Najadetum marinae* and *Nymphaeetum albo-luteae*, the highest temperatures were recorded (exceeding 25 °C).

The pH values in all plant communities are within the limits (6.5–8.5) of the "good ecological status" of artificial water bodies [Sl. Glasnik RS, 2012]. Low pH (below 7.5) was recorded at the localities where the stands *Elodeetum canadensis*, *Potametum nodosi* and *Myriophyllo-Potametum* developed. Higher pH (slightly above 8) was recorded in the habitats of the associations *Nymphaeetum albae, Lemno-Utricularietum vulgaris, Salvinio-Spirodeletum polyrrhizae* and *Najadetum marinae* (see Fig. 2). In the study conducted in Romania, Gh. Coldea et al. [1997] reported pH 7–8 for the same phytocenoses. On the other hand, the values pertaining to *Nymphaeetum albae* in Poland were consistent with our results [Szańkowski, Kłosowski, 1999].

The highest mean values of total alkalinity were measured in the stands *Nymphaeetum albae*, *Nymphoidetum peltatae* and *Najadetum marinae* (above 3 mmol/l) and the lowest (below 2.2 mmol/l) in *Elodeetum canadensis, Lemno-Spirodeletum* and *Salvinio-Spirodeletum polyrrhizae* (see Fig. 2). In contrast to our findings, for the *Elodetum canadensis* phytocenosis, that developed in north-eastern Poland, S. Kłosowski [2006] reported higher values of water alkalinity.

With respect to COD-MnO_4, which is used to estimate the quantity of dissolved organic matter in water, the phytocenoses *Nymphaeetum albae* and *Najadetum marinae* were characterized by the highest values of this parameter relative to the other communities. COD-MnO_4 values in these two communities exceeded 11 mg/l, indicating their occasional exposure to water laden with organic matter. The lowest average COD-MnO_4 values were recorded in habitats of the stands *Trapetum natantis* and *Ceratophyllo demersi-Vallisnerietum spiralis*. BOD_5 results generally indicated the "good ecological status" (below 6 mg/l) for the category of artificial water bodies [Sl. Glasnik RS, 2012] at most localities in which the studied association developed. Habitats of the associations *Nymphaeetum albo-luteae* and *Hydrocharidetum morsus-ranae* were notable exceptions, whose high BOD_5 values are generally due to organic pollution caused by the discharge of untreated industrial wastewater effluents and leaching from agricultural land.

In terms of eutrophication, it is necessary to analyze the water nutrient content. In the water samples analyzed in this study, all forms of mineral nitrogen were detected, with the nitrate form being most abundant. Nitrate concentration in all stands was lower than the 3.00 mg/l limit, which defines the "good ecological status" for artificial water bodies [Sl. Glasnik RS, 2012]. The lowest nitrate content was measured in habitats of the stands *Nymphaeetum albae* and *Lemno-Utricularietum vulgaris*, and the highest in *Trapetum natantis* and *Myriophyllo-Potametum*. High nitrate levels were found at the sites favored by *Trapetum natantis* in the streams of neighboring Croatia [Kočić et al., 2008]. The analysis of water nitrite content revealed that the development of phytocenoses of the alliance *Nymphaeion* and *Hydrocharition* favored lower nitrate content. The associations *Elodeetum canadensis, Myriophyllo-Potametum, Salvinio-Spirodeletum polyrrhizae* and *Potametum nodosi* favored the water richer in these compounds compared to other stands.

Ammonia content below the 0.2 mg/l threshold was recorded at localities where the stands *Lemno-Utricularietum vulgaris, Nymphaeetum albae, Ceratophylletum demersi*, *Najadetum marinae* and *Nymphoidetum peltatae* developed (see Fig. 2). In the remaining stands studied here, the ammonium was above the threshold value of the "good ecological status", indicating impaired quality of water in which they developed. A. Kočić et al. [2008] also detected high ammonium values for Croatian water flows, especially in habitats of the *Najadetum marinae* association.

The high content of dissolved phosphorus measured in water with the stands *Myriophyllo-Potametum* (1.00 mg/l) and *Potametum nodosi* (0.73 mg/l) differed considerably with other stands, where much lower content was recorded. Total phosphorus in habitats of the stands *Lemno-Utricularietum vulgaris, Nymphaeetum albae, Nymphaeetum albo-luteae* and *Nymphoidetum peltatae* did not exceed the 0.30 mg/l limit [Sl. Glasnik RS, 2012], which defines the "good ecological status". Other plant communities developed at the sites where total phosphorus content exceeds this value, reaching 2.22 mg/l for the *Myriophyllo-Potametum* stands. According to the OECD [1982] directive, the total phosphorus value in the phytocenoses *Nymphaeetum albae*, *Nymphaeetum albo-luteae*, *Nymphoidetum peltatae* and *Lemno-Utricularietum vulgari* defines their habitat conditions as mesotrophic.

The results of other studies indicated mesotrophic conditions in the habitats of *Nymphae-*

etum albae [Papastergiadou, Babalonas, 1993; Kłosowski et al., 2011], *Nymphaeetum albo-luteae* [Balevičiene, Balevičius, 2006; Chytrý et al., 2011], *Nymphoidetum peltatae* [Papastergiadou, Babalonas, 1993; Balevičiene, Balevičius, 2006] and *Lemno-Utricularietum vulgaris* [Chytrý et al., 2011]. M. Szańkowski and S. Kłosowski [1999] highlighted that the stands of *Nymphaeetum albo-luteae* in Poland develop in a wide range of habitat conditions, and K. Szoszkiewicz et al. [2010] found that, in England, Wales and Scotland, these stands favor eutrophic conditions. Phytocenoses that formed in eutrophic waters in the study area included *Ceratophylletum demersi, Hydrocharidetum morsus-ranae, Elodeetum canadensis, Najadetum marinae* and *Trapetum natantis.*

The eutrophic status is confirmed by the literature data reported for *Hydrocharidetum morsus-ranae* [Schneider, 2009; Džigurski et al., 2013; Sýkora, 2006], *Elodeetum canadensis* [Balevičiene, Balevičius, 2006; Chytrý et al., 2011], *Najadetum marinae* [Chytrý et al., 2011] and *Trapetum natantis* [Szańkowski, Kłosowski, 1999; Schneider, 2009; Lukács et al., 2009; Chytrý et al., 2011]. For the dominant subversive phytocenosis *Ceratophylletum demersi*, in addition to several studies that confirm our findings [Dimopoulos et al., 2005; Lacoul, Freedman, 2006; Nikolić et al., 2007; Lukács et al., 2009; Chytrý et al., 2011], there is a number of works suggesting that low total phosphorous content is optimal for its development [Kočić et al., 2008]. High total phosphorous content levels in the stands *Lemno-Spirodeletum, Salvinio-Spirodeletum polyrrhizae, Potametum nodosi, Myriophyllo-Potametum* and *Ceratophyllo demersi-Vallisnerietum spiralis* characterized their habitat conditions as hypertrophic. K. V. Sýkora [2006] also noted that phytocenoses of the *Lemnion minoris* alliance develop in the waters with hypertrophic status. Similarly, L. Kufel et al. [2012] indicated that, for their optimum development, species belonging to the family *Lemnaceae* require the waters characterized by high total phosphorous content. Analysis of physico-chemical water parameters at localities where the studied phytocenoses were found, revealed that their development is usually associated with specific habitat conditions. The values of water parameters at most localities are a consequence of anthropogenic influence on the eutrophication process and the advancing succession processes, despite these aquatic ecosystems being relatively "young". Diversification of aquatic vegetation is, to some extent, affected by other habitat parameters that were not analyzed in this study, but nonetheless affect the formation of such a heterogeneous and rich vegetation both directly and indirectly (canal depth and width differences, water flow velocity, navigation intensity, orchestrated changes in water levels, presence of over 20 locks, difference in canal age, ranging from 50 to 200 years, etc.) [Džigurski et al., 2014, 2015].

Endangered and invasive plant species

In the aquatic vegetation of the Hs DTD canal network, several endangered species are present. According to the Red List of Threatened Species for Europe, the Least Concern status [IUCN 2013] was given to *Nymphaea alba*, *Nuphar lutea*, *Nymphoides peltata, Trapa natans, Lemna minor, L. gibba, L. trisulca, Najas marinaa, Polygonum amphibium, Potamogeton crispus, P. fluitans, P. lucens, P. pectinatus, P. perfoliatus, Sagittaria sagittifolia, Salvinia natans, Spirodela polyrhiza, Typha angustifolia* and *Utricularia vulgaris.* In Serbia, *N. alba*, *N. lutea*, *P. fluitans, S. natans* and *U. vulgaris* have the National Conservation status – Strictly Protected [Radulović et al,. 2012]. Some of these endangered species analyzed in this study comprise the phytocenoses *Lemno-Spirodeletum*, *Salvinio-Spirodeletum polyrrhizae, Lemno-Utricularietum vulgaris, Potametum nodosi, Myriophyllo-Potametum, Najadetum marinae, Nymphaeetum albae, Nymphaeetum albo-luteae, Nymphoidetum peltatae* and *Trapetum natantis.*

On the other hand, in terms of the degree of the threat that invasive species pose to the aquatic vegetation biodiversity, freshwater ecosystems are among the most sensitive [Thiebaut, 2007]. Large rivers, such as Danube and Tisza flowing through this region, are the main corridor for plant species invasion.

In the studied region, from the "List of invasive species at the Vojvodina territory" [IASV 2013], *Elodea canadensis* and *Vallisneria spiralis* were identified. For Hungary, as a part of Pannonian ecoregion that also comprises

Vojvodina, B. A. Lukács et al. [2014] there were also noted an invasive species *V. spiralis* and an alien plant *E. canadensis*. In Hs DTD, the aforementioned species are edificators of the phytocenoses *Elodeetum canadensis* and *Ceratophyllo demersi-Vallisnerietum spiralis*. A neophyte association *Elodeetum canadensis* was found at only two localities, and did not appear to exhibit proliferative tendencies. Thus, it does not presently pose a threat to the biodiversity of this ecosystem. A reduction in invasiveness was also noted for *Elodea canadensis* in other European habitats [Barrat-Segretain, Elger, 2004]. On the other hand, *Ceratophyllo demersi-Vallisnerietum spiralis* was noted at a significant number of localities, and has a tendency to proliferate, indicating that monitoring these stands in necessary.

CONCLUSIONS

Despite significant anthropogenic pressure due to accelerated eutrophication and orchestrated water regimen, macrophyte vegetation in this secondary ecosystem is very rich and heterogeneous. Here, vascular macrophytes, in particular, play an invaluable role in maintaining water quality and the necessary amount of oxygen, and contribute to phytofiltration and phytoremediation, acting as a protection against erosive effects. In addition, as many endangered and vulnerable species have found refuge in Hs DTD, monitoring of their distribution and ecology is necessary. R. Hrivnák et al. [2014] also indicated that artificial aquatic habitats are characterized by higher biodiversity compared to their natural counterparts; hence, they can provide appropriate environmental conditions for the survival of macrophytes. For these reasons, in order to preserve aquatic vegetation, arrest negative environmental trends in this fragile ecosystem and achieve the "good ecological status" for this canal, it is necessary to maintain adequate water flow and water quality.

REFERENCES

APHA, AWWA, WPCF, Standard methods for examination of water and wastewater. 17th ed. Washington DC: APHA, 1995.

Balevičiene J., Balevičius A. Qualitative and quantitative parameters of phytocenoses in Lithuanian lakes of different trophic state // Ekologija. 2006. Vol. 2. P. 34–43.

Barrat-Segretain M. H., Elger A. Experiments on growth interactions between two invasive macrophyte species // J. Vegetation Sci. 2004. Vol. 15. P. 109–114.

Blaženčić J., Blaženčić Ž. Makrofite Vlasinskog jezera // Glas. Prir. Muz. B. 1991. Vol. 46. P. 71–85.

Chytrý M., Čumberová K., Hájková P., Hájek M., Hroudová Z., Navrátilová J., Čtvrtlíková M., Sádlo J., Lososová Z., Hrivnák R., Rydlo J., Ot'ahel'ová H., Bauer P., Hanáková P., Ekrt L., Ekrtová E., Michalcová D., Žáková K., Danihelka J., Králová Š., Karimová K., Tichý L., Hájek O., Kočí M. Vegetace České republiky 3. Vodní a mokřadni vegetace. Praha: Academia, 2011.

Coldea Gh., Sanda V., Popescu A., Ştefan N., Les associations végótales de Roumanie. Presses Universitaires de Cluj, 1997. T. 1.

Dimopoulos P., Sýkora K., Gilissen C., Wiecherink D., Georgiadis T. Vegetation ecology of Kalodiki Fen (NW Greece) // Biologia. 2005. Vol. 60. P. 69–82.

Džigurski D., Knežević A., Stojanović S., Nikolić Lj., Ljevnaić-Mašić B. The vegetation of canal Novi Sad-Savino Selo // Thaiszia, Journ. Botany. Košice, 2010, Vol. 20. P. 137–145.

Džigurski D., Ljevnaić-Mašić B., Milić D., Aćanski J. Impact of Climate Changes on Aquatic Vegetation of Hydromeliorative Facilities // Contemp. Probl. Ecol. 2015. Vol. 8, N 3. P. 295–308.

Džigurski D., Ljevnaić-Mašić B., Nikolić Lj. The effects of physical-chemical water parameters on the Nymphaeion alliance development in northwestern Serbia // Acta Soc. Bot. Pol. 2014. Vol. 83. P. 103–111.

Džigurski D., Ljevnaić-Mašić B., Nikolić Lj. *Trapetum natantis* Müller et Görs, 1960 in hydromeliorative facilities in Serbia // Acta Soc. Bot. Pol. 2013. Vol. 82, N 2. P. 125–133.

European Commission. Directive 2000/60/EC of the European Parliament and of the Council of 23rd October 2000: establishing a framework for Community action in the field of water policy // Official Journ. of the European Communities. 2000. Vol. 327. P. 1–72.

Grīnberga L., Spriņģe G. Potential impact of climate change on aquatic vegetation of river Salaca, Latvia // Proc. of The Latvian Acad. Sci. 2008. Vol. 62. P. 34–39.

Hrivnák R., Kochjarová J., Ot'ahel'ova H., Palove-Balang P., Slezák M., Slezák P. Environmental drivers of macrophyte species richness in artificial and natural aquatic water bodies – comparative approach from two central European regions // Ann. Limnol. Int. Journ. Lim. 2014. Vol. 50. P. 269–278.

Hrivnák R., Ot'ahel'ová H., Valachovič M. The relationship between macrophyte vegetation and habitat factors along a middle-size European river // Pol. Journ. Ecol. 2007. Vol. 55. P. 717–729.

Hummel M., Kiviat E. Review of World Literature on Water Chestnut with Implications for Management in North America // J. Aquat. Plant Manage. 2004. Vol. 42. P. 17–28.

IASV, 2013. List of invasive species in AP Vojvodina [Internet]. Version 0.2beta / eds. G. Anačkov, O. Bjelić-

Čabrilo, I. Karaman, M. Karaman, S. Radenković, S. Radulović, D. Vukov, P. Boža. Novi Sad (Serbia): Department of Biology and Ecology [cited 2013 February 12]. Available from: http://iasv.dbe.pmf.uns.ac.rs/ Serbian, English.

IUCN. Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 29 November 2013.

Janauer G., Dokulil M. Macrophytes and algae in running waters // Water quality measurements / ed. G. Ziglio, M. Siligardi, G. Flaim. Chichester: John Wiley & Sons, 2006. P. 89–109.

Kłosowski S., Jabłocska E., Szańkowski M. Aquatic vegetation as an indicator of littoral habitats and various stages of lake aging in north-eastern Poland // Ann. Limnol. Int. Journ. Lim. 2011. Vol. 47. P. 281–295.

Kłosowski S. The relationships between environmental factors and the submerged Potametea associations in lakes of north-eastern Poland // Hydrobiol. 2006. Vol. 560. P. 15–29.

Kočić A., Hengl T., Horvatić J. Water nutrient concentrations in channels in relation to occurrence of aquatic plants: a case study in eastern Croatia // Ibid. 2008. Vol. 603. P. 253–266.

Kremser U., Schnug E. Impact of fertilizers on aquatic ecosystems and protection of water bodies from mineral nutrients // Landbauforschung Volkenrode. 2002. Vol. 52. P. 81–90.

Kufel L., Strzałek M., Wysokińska U., Biardzka E., Oknińska S., Ryś, K. Growth rate of Duckweeds (Lemnaceae) in relation to the internal and ambient nutrient concentrations – testing the droop and monod models // Pol. Journ. Ecol. 2012. Vol. 60. P. 241–249.

Lacoul P., Freedman B. Environmental influences on aquatic plants in freshwater ecosystems // Environ. Rev. 2006. Vol. 14. P. 89–136.

Laketić D., Radulović S., Živković M., Jurca T., Alford M. Lake Macrophyte Nutrient Index of standing waters in Serbia (LIMNIS) // Ecological Indicators, 2013. Vol. 25. P. 200–204.

Lalić B., Mihailović D., Podražčanin Z., Buduće stanje klime u Vojvodini i oиekivani uticaji na ratarsku proizvodnju // Field Vegetable Crop Research. 2011. Vol. 48. P. 403–418.

Larson S. Growth of three submerged plants below different densities of *Nymphoides peltata* (S. G. Gmel.) Kuntze. // Aquatic Botany. 2007. Vol. 86. P. 280–284.

Lewin I., Szoszkiewicz K. Drivers of macrophyte development in rivers in an agricultural area: indicative species reactions // Cent. Eur. Journ. Biol. 2012. Vol. 7. P. 731–740.

Lukács B., Dévai G., Tóthmérész B. Aquatic macrophytes as bioindicators of water chemistry in nutrient rich backwaters along the Upper-Tisza river (in Hungary) // Phytocoenologia. 2009. Vol. 39. P. 287–293.

Lukács B. A., Mesterházy A., Vidéki R., Király G. Alien aquatic vascular plants in Hungary (Pannonian ecoregion): Historical aspects, data set and trends // Plant Biosystems. 2014. P. 1–8.

Milošev Ž. Hidrotehnički radovi u Banatu i Bačkoj pre izgradnje hidrosistema Dunav – Tisa – Dunav (In: Hidrosistem Dunav – Tisa – Dunav, 25 godina kasnije). JVP Srbijavode, Novi Sad, 2002. P. 1–21.

Nikolić Lj., Čobanović K., Lazić D. *Nymphoides peltata* (Gmel.) Kunt., *Myriophyllum spicatum* L. and *Ceratophyllum demersum* L. biomass dynamics in the Lake Provala (the Vojvodina Province, Serbia) // Cent. Eur. Journ. Biol. 2007. Vol. 2. P. 156–168.

Nikolić Lj., Džigurski D., Ljevnaić-Mašić B. Nutrient removal by *Phragmites australis* (Cav.) Trin. Ex Steud. in the constructed wetland system // Contemp. Probl. Ecol. 2014. Vol. 7, N 4. P. 448–453.

OECD. Eutrophication of Waters: Monitoring, Assessments and Control. Organisation for Economic Cooperation & Development. Paris, 1982.

Otahelová H., Hrivnák R., Valachovic M., Janauer G. Temporal changes of aquatic macrophyres vegetation in a lowland groundwater feed eutrophic course (Klátovske Rameno, Slovakai) // Acta Soc. Bot. Pol. 2007. Vol. 76. P. 141–150.

Papastergiadou E., Babalonas D. The relationships between hydrochemical environmental factors and the aquatic macrophytic vegetation in stagnant and slow flowing waters // Arch. Hydrobiol. Suppl. 1993. Vol. 90. P. 475–491.

Pełechaty M. Does Nymphaeid distribution reflect the spatial heterogeneity of abiotic conditions in a shallow lake? // Belg. Journ. Bot. 2007. Vol. 140. P. 73–82.

Radulović S., Boon P., Laketić D., Simonović P., Puzović S., Živković M., Jurca T., Ovuka M., Malaguti S., Teodorović I. Preliminary checklists for applying Sercon (system for evaluating rivers for conservation) to rivers in Serbia // Arch. Biol. Sci. 2012. Vol. 64. P. 1037–1056.

Savić R., Pejić B., Ondrašek G., Vranešević M., Bezdan A. Iskorišćenost prirodnih resursa Vojvodine za navodnjavanje // Agroznanje. 2013. Vol. 14. P. 133–142.

Schaumburg J., Schranz C., Foerster J., Gutowski A., Hofmann G., Meilinger P., Schneider S., Schmedtje U. Ecological classification of macrophytes and phytobenthos for rivers in Germany according to the Water Framework Directive // Limnologica. 2004. Vol. 34. P. 283–301.

Scheffer M., Van Nes E. Shallow lakes theory revisited: various alternative regimes driven by climate, nutrients, depth and lake size // Hydrobiol. 2007. Vol. 584. P. 455–466.

Schneider E. Aquatic macrophytes in the Danube Delta – indicators for water quality and habitat parameters-Studia Universitatis Babes – Bolyai, Biologia, LIV, 2009. N 1. P. 21–31.

Schneider E. Aspects of Wetland Habitat Restoration and Monitoring in the Danube Delta: Water Macrophytes as Quality Indicators in Evaluation Processes // Acta zool. bulg. 2014. Vol. 7. P. 97–102.

Schneider S. Macrophyte trophic indicator values from a European perspective // Limnologica. 2007. Vol. 37. P. 281–289.

Sl. Glasnik RS. N 50/2012. Uredba o granicnim vrednostima zagadujucih materija u povrsinskim i podzemnim vodama i sedimentu i rokovima za njihovo dostizanje. (Official Gazette of RS, N 50/2012. Regulation on the pollutant limits in surface and ground waters and sediment, and the deadlines for attaining these goals), 2012.

Soó R. A Magyar Flóra és Vegetáció Rendszertani-növényföldrajzi Kézikönyve V. Akadémiai kiadó. Budapest, 1973.