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BIODIVERSITY OVERVIEW OF SODA PANS IN THE VOJVODINA REGION (SERBIA)

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Abstract: Due to their specific physical and chemical properties of water and soil soda pans of the Vojvodina region represent a unique type of habitats. Salinity is a major structuring factor which strongly affects species richness. Many halotolerant, alkalotolerant and halophilic organisms, together with numerous eurytopic elements inhabit these kinds of ecosystems. In this review we tried to compile the biodiversity information from various literature sources and give the best representation of what can be expected to be found in these shallow, temporary and intermittent aquatic environments. Only a few groups of organisms are fairly well studied, while many others are insufficiently investigated or the knowledge of them is lacking altogether. Best investigated are certain groups of algae and birds. Bacterial communities, as well as many invertebrate groups, are poorly studied or not investigated at all. Characteristic elements of flora and fauna, together with growing anthropogenic pressures make soda pans prime targets for protection.

Keywords: soda pans, Vojvodina region, biodiversity, literature review

Introduction

Soda pans represent a unique type of habitat, exclusively restricted to the Central Europe (Boros, Ecsedi, & Oláh, 2013; Hammer, 1986). Soda pans differ from other similar saline waters mainly due to the dominant presence of Na^+, HCO_3^- and CO_3^{2-} ions (Boros, Horváth, Wolfram, & Vörös, 2014). Astatic soda pans of the Vojvodina region constitute the southernmost domain of these saline systems distributed throughout the Carpathian Basin. These shallow, temporary and intermittent aquatic environments are inhabited by a number of species that can

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thrive in extreme environments or tolerate “boundary” life conditions in them (Boros, Balogh, Vörös, & Horváth, 2017; Nicolet, 2004; Williams, 2006). Numerous rare species and unique communities, as well as a great biogeographical importance of these habitats, make them a prime target for conservation and restoration (Boros et al., 2013; Collinson et al., 1995; Schwartz & Jenkins, 2000).

Soda pans are found on solonetz and solonchak soils in depressions within a matrix of salt steppes and as subhalophytic meadows (Schaminée et al., 2016). European soda pans were formed on various geological substrates by specific climatic, geologic and hydrologic conditions in the groundwater discharge areas of the Carpathian Basin at the end of the Pleistocene and the beginning of the Holocene. Shallow geological factors define sodification, especially in the case of sodic waters with higher salt content. It is also believed that deep upflow systems, in which the abyssal and shallower subsurface water flows are mixed, also have a role in the formation of soda. Sodification processes are further promoted by changeable continental climatic conditions, and the alternation of wet and dry seasons (Boros et al., 2013).

Biological diversity of soda pans is limited due to a natural stress gradient. Physical and chemical stress factors include: variation in salinity, high pH values, great seasonal and daily water temperature fluctuation and periodic drying out (Boros et al., 2013; Boros et al., 2017). Salinity is a major structuring factor which strongly affects species richness. It affects aquatic organisms directly, but it also shapes biotic interactions (food chains) and structuring components, such as macrophytes (Horváth et al., 2014). For example, fish as a vital component of aquatic habitats, are almost always lacking from soda pans. Plant and animal communities are typically composed of halotolerant, alkalotolerant and halophilic organisms, although numerous eurytopic elements are also present.

In the last 50 years the ecological status of numerous soda pans in the Vojvodina region was negatively affected by anthropogenic disturbance. Certain soda pans perished irreversibly, while a great many of them deteriorated to such an extent that they lost their natural characteristics. Biotic elements are the main shaping components of an ecosystem, while a biodiversity is a good measurement of its health (Rapport, Costanza, & McMichael, 1998). In general, little is known about the diversity of organisms associated with soda pans in Vojvodina. The existing information is scarce and incomplete and more detailed future studies are required. Similar habitats in the rest of the Carpathian Basin (Hungary and Austria) have been investigated for decades and most were put under protection.

Only three soda pans have a legal protection in Serbia (http://www.zzps.rs). In this review, we have summarized the available information on the biodiversity of soda pans, ranging from bacteria to various animal groups. Vascular plants are not presented here as they will be a part of some other review.

Material and methods

Based on their appearance, the majority of sodic waters in the Vojvodina region are classified as pools or small shallow lakes (Boros et al., 2013). According to Boros et al. (2013) these include small or medium sized shallow still waters that periodically dry out. This review focuses on the diversity of organisms living in or near these kinds of waters we collectively call soda pans.

After completing an extensive search of literature and going through the numerous published studies referring to saline habitats in Vojvodina, we realized that a very small number of papers and books actually dealt with what we term as soda pans. Only several larger soda pans (e.g. Slano Kopovo, Rusanda, Pečena Slatina, Okanj bara) were studied in some detail, while a large number of smaller ones were not investigated. Certain groups of organisms were never studied in soda pans in Serbia, hence we sometimes give results of what was found in similar habitats in other countries (Hungary, Austria), indicating that same or similar taxa can be expected to be found in our soda pans.

In this paper we wanted to give a reader an overall picture of what organisms can be expected to be found in Vojvodina's soda pans. Without compiling long lists (that would probably take up to a hundred or more pages) of taxa historically registered on selected soda pans, instead we presented only some of the more common species.

Results and Discussion

Prokaryotes

Soda pans represent an ideal environment for alkali-halophilic bacteria. Both photosynthetic and chemosynthetic bacteria can be found in the water and sediment of soda pans. Communities are mainly composed of Gram-positive taxa with aerobe metabolism (Boros et al., 2013).

No precise data exist on the prokaryotic taxa living in soda pans of the Vojvodina region. However, based on the results of microbiological studies of soda pans elsewhere in the Carpathian basin (Hungary), we could expect a major proportion of isolates to be classified as *Bacillus* (Firmicutes), *Halomonas* and

Pseudomonas (Proteobacteria). Very common alkaliphilic species of the genus *Bacillus* are: *Bacillus horikoshii*, *B. pseudofirmus*, *B. akibai*, *B. agaradhaerens* and *B. alkalinitrilicus*. Common alkali–tolerant species are: *B. pumilus, B. cereus* and *B. niacini*. Other close relative genera include *Marinibacillus* and *Halobacillus* (Boros et al., 2013). Species of the genus *Halomonas* have been very frequently isolated worldwide in various soda and natron lakes (Duckworth, Grant, Jones, & van Steenbergen, 1996). *Pseudomonas* species that are typically found in fresh and seawater and soils (Palleroni, 2008) are also commonly found in soda pans.

Cyanobacteria are very frequent dwellers of alkaline salt pans. Trichal forms are probably most interesting since they form algal mat and biofilms like *Nodularia crassa* (Woronichin) J.Komárek, M.Hübel, H.Hübel and J.Smarda recorded in Rusanda (Boros et al., 2014). Moreover, cyanobacteria sometimes form surface scum in soda pans and there was a nice example of *Gloeotrichia natans* f. *bucharica* Kissel observed in Velika Slatina (Subakov–Simić, Karadžić, & Krizmanić, 2007). Another interesting cyanobacteria *Arthrospira fusiformis* (Voronikhin) Komárek and J.W.G.Lund, a species recently known from tropical Africa and Asia, was recorded in Europe for the first time in phytoplankton of two soda pans in Vojvodina (Fužinato, Fodora, & Subakov–Simić, 2010). However, *Oscillatoria* Vaucher ex Gomont and *Phormidium* Kützing ex Gomont species are more likely to be found in these salt habitats (Guelmino, 1973). *Oscillatoria willei* N.L.Gardner was among dominant species in Slatina and Pečena Slatina, together with aforementioned *A. fusiformis* which was at first identified as *Spirulina fusiformis* Voronikhin (Subakov–Simić, Karadžić, V., Fužinato, Fodora, & Cvijan, 2006). Other typical inhabitants of salt habitats are *Gloeocapsa minuta* (Kützing) Hollerbach, *Oscillatoria chlorina* Kützing ex Gomont and *Phormidium fragile* Gomont (Subakov–Simić, Plemić, Karadžić, Cvijan, & Krizmanić, 2004).

Algae

In soda pans different taxonomic and ecological groups of algae can be found. They vary from picoplanktic to macroscopic dimensions, and can build planktic, benthic, epiphytic as well as neuston assemblages. In these extreme habitats mostly alkaliphilous (mainly occurring at pH > 7) and salt tolerant (fresh brackish and brakish fresh) species are common. In soda pans of the Carpathian Basin some new species of algae were described and some tropical, subtropical and species from temperate climate spread their distribution using the specific nature of alkaline salt environment (Cvijan & Krizmanić, 2009; Fužinato,

Fodora, & Subakov–Simić, 2010; Cvijan & Fužinato, 2011; Vörös & Boros, 2010).

There is no typical algal community inhabiting soda pans neither in plankton nor littoral zone (benthos). However, in salt ponds and lakes which are not quite turbid, phytoplanktic assemblage is comprised of cyanobacteria, euglenoid and green algae. Taxa from the order Desmidiales and diatoms are mostly found in periphyton. In addition to these algae, in alkaline salt habitats it is not unusual to find a few species which belong to Dinophyta and Xanthophyceae. Since turbidity represents competitive advantage for small sized cells in turbid soda pans, picoplankton with coccoid cyanobacteria and some green algae less than 2 μm are dominant (Boros et al., 2014). In addition to free floating forms in soda pans, some species can develop algal mat, known as "meteor paper", covering the bottom near the shoreline, after pans dry out.

Diatom community can be very diverse in soda pans (Lengyel et al, 2016). Around 43 genera were recorded in investigated salt ponds and marshes in Vojvodina (Krizmanić, Subakov–Simić, Cvijan, & Karadžić, 2008). The highest species diversity was observed in genera *Nitzschia* Hassall, *Gomphonema* Ehrenberg and *Navicula* Bory. Some of those taxa are eurivalent, but it would not be wrong to say that more than a half of observed diatoms in soda pans in Vojvodina can be classified as alkaliphilous and fresh brackish taxa using ecological indicator values given by Van Dam, Mertens and Sinkeldam (1994). For example, *Navicula slesvicensis* Grunow, *Nitzschia frustulum* (Kützing) Grunow, *Surirella angusta* Kützing and *S. brebissonii* Krammer and Lange–Bertalot are frequently observed in soda pans with pH > 7 (Krizmanić, Subakov–Simić, Cvijan, & Karadžić, 2008; Krizmanić, 2009). Very common fresh brackish algae with frustules in Vojvodina are *Nitzschia palea* (Kützing) W.Smith, *Gomphonema parvulum* (Kützing) Kützing, *Hantzschia amphioxys* (Ehrenberg) Grunow and *Navicula cryptocephala* Kützing (Krizmanić, 2009). Nevertheless, salt ponds and marshes enable some alkalibiontic (exclusively occurring at pH > 7) and brackish species to survive and successfully reproduce. In the first group, species *Anomoeoneis sphaerophora* Pfitzer and *Bacillaria paxillifer* (O. F. Müller) T.Marsson are frequently present in several studied soda pans. Among brackish diatoms known from salt habitats in the Serbian part of Carpathian Basin the most common are *Fragilaria fasciculata* (C. Agardh) Lange-Bertalot, *Navicula salinarum* Grunow, *Nitzschia clausii* Hantzsch and *N. commutata* Grunow (Krizmanić, 2009).

It is known that euglenoids prefer water bodies with higher trophic status and since soda pans are often eutrophic Euglenophyta can have high species richness

and abundance in these aquatic habitats. They are mostly observed in plankton, but can also be found in benthos and neuston. The highest number of euglenoid species recorded in alkaline salt habitats belongs to genera *Euglena* Ehrenberg and *Phacus* Dujardin. For instance, *E. vermicularis* Proskina-Lavrenko is typically associated with higher salinity in Serbian soda pans, and is followed by another salt preferring species *Lepocinlis salina* F.E.Fritsch (Subakov–Simić et al., 2006). On the contrary, some euglenoids of cosmopolitan distribution like *Trachelomonas volvocina* (Ehrenberg) Ehrenberg can be dominant in soda pans (Subakov–Simić, Karadžić, & Krizmanić, 2007).

In the last century phycologists discovered *Chloroparva pannonica* Somogyi, Felfoldi & Voros, a new species of green alga found in picoplankton of some soda pans in Hungary, which was at the same time a new genus for science (Somogyi et al., 2011). Apart from their presence in picoplankton, Chlorophyta are frequently observed in microplankton (20–200 μm) of alkaline salt habitats (Fužinato et al., 2008). The majority of identified green algae from the soda pans in Vojvodina were freshwater species such as *Pediastrum boryanum* (Turpin) Meneghini and *Scenedesmus communis* E. Hegewald (Subakov–Simić et al., 2006). According to the Boros et al. (2014) algae of the order Desmidiales are able to form a dense mat (biofilm, or "meteor paper" when dry). Except for a few, for most planktic desmids, such as *Cosmarium laeve* Rabenhorst (Subakov–Simić et al., 2006; Fužinato, 2012), this phenomenon was not noticed in Serbian soda pans.

Finally, it is worth to mention several species that belong to other not so diverse algal groups in salt habitats like *Peridinium cinctum* (O. F. Müller) Ehrenberg, *P. umbonatum* Stein and *Ceratium hirundinella* (O.F.Müller) Dujardin (Dinophyceae) and *Tribonema ambiguum* Skuja, *T. regulare* Pascher and *T. vulgare* Pascher (Xanthophyceae) (Subakov–Simić et al., 2006; Pokrajinski zavod za zaštitu prirode, 2011).

Charophytes

Unlike other algal groups that can be found in soda pans, charophyte algae (Charales, stoneworts, charophytes) are macroscopic and ecologically more similar to higher plants. However, their ecology is very specific and, in these kind of habitats, that very often dry out, charophytes have an advantage over vascular plants thanks to their ability to withstand periods of drought. Many species are able to develop early in the spring and quickly finish their life cycle before the drought. What they leave behind are their resistant oospores able to stay viable for a long period of time and germinate when favorable conditions

are met. (Bonis & Grillas, 2002; Casanova & Brock, 1990, 1999; Mouronval, Baoudouin, Borel, Soulié–Märche, & Grillas, 2015).

Unfortunately, there were no systematic studies of charophytes in soda pans of Vojvodina, to confirm expected presence, but there are some data we can draw conclusions from. Historical literature data testify about some finding of these algae in saline aquatic habitats, although, they are not defined as soda pans considering this term is relatively new (Boros et al. 2013). However, findings of charophytes in Vojvodina's salty shallow, very often ephemeral, aquatic waterbodies, are known. Guelmino (1973) reported finding of *Tolypella prolifera* (Ziz ex A. Braun) Leonhardi 1863 and *Chara vulgaris* L. 1753 (sub *Chara foetida* A. Br.) in the oxbow of the Tisa river "Mrtva Tisa", near Senta. Charophytes were confirmed for this locality almost four decades later, in 2008 and 2012 (personal comment Perić, R.) but were not determined on the species level. Slavnić (1956) reports finding of *Chara* sp. in Slana bara near Novi Sad. Blaženčić (2014) reported finding of *Chara globularis* Thuill. 1799 and *Chara hispida* (L.) Hartm. 1820 in 2011 in the sandpit "Selevenj" near Subotica.

Recent charophyte survey in Vojvodina conducted in summer 2012 and 2013 (Vesić, 2016; Vesić, Blaženčić, & Šinžar-Sekulić, 2016) gave only a few findings of charophytes in soda pans. Soda pans were not the focus of the study, but several were investigated. There are different definitions of soda pans and for this purpose, only those with salinity values above or very close to 1000 mg/l were selected, which is in accordance with Boros et al. (2013). Taking this criterion into account, charophytes were found in four sites, among which three can be considered soda pans, while one is a river. Two sites are located near Subotica. One of them is previously mentioned sandpit "Selevenj", where *C. globularis* and *C. hispida* were confirmed and one additional species, *Chara intermedia* A. Braun in A. Braun, Rabenh. & Stizenb. 1859, was found. This was the first finding of this species for the territory of Serbia. The other site is the sandpit "At Lofej's" where species *Chara tenuispina* A.Braun 1835 and *Chara hispida* were found. The third site is a puddle in the marsh Monoštorski Rit (SNE "Gornje Podunavlje") where even five species of charophytes were found together: *Tolypella prolifera*, *Nitella syncarpa* (Truill.) Chevall. 1827, *Chara vulgaris*, *Chara contraria* A.Braun ex Kütz. 1845 s.str. and *Chara globularis*.

Species of the genus *Chara – C. vulgaris, C. globularis, C. contraria*, *C. hisida* and *C. intermedia*, are freshwater species according to literature, but have a certain tolerance to higher salt content (Gollerbah & Krasavina, 1983; Schubert & Blindow 2004; Mournval, Baoudouin, Borel, Soulié–Märche, & Grillas,

2015). *Chara tenuispina* is mostly known from freshwater habitats, but some authors do report these species for salty waters as well (Corrilion, 1957; Krause, 1997). It is interesting to mention it is one of the most rare and most threatened charophyte species in Europe (Auderset–Joye & Schwarzer, 2012; Korsch, Doege, Raabe, & van der Weyer, 2013; Urbaniak & Gabka, 2014). There are no data for species *Nitella syncarpa* and *Tolypella prolifera* findings in saline–influenced waters. Considering the only new findings are from an ephemeral pool having current salinity of about 960 mg/l, and knowing that lower limit for soda pans is 1000 mg/l given as average annual value (Boros et al., 2013), we can assume that this site is generally less salty than measured at the moment of investigation. Regarding "Mrtva Tisa" oxbow, the salinity values measured in summer 2013 were relatively high (1358 mg/l) but it is hard to assume what was the value in 1973 as well as to revise Guelmino's Tollypela finding since it is only literature data. No charophytes were found at this site in 2013 (Vesić, 2016).

Chara canescens Desv. & Loisel. in Loisel. 1810 is a typical brackish water species (Schubert & Blindow, 2004; Boros et al., 2013; Mouronval et al., 2015) not yet found in Vojvodina soda pans. However, there are findings of this species in Serbia, in a salt marsh near Prokuplje (Blaženčić, 2014) and we expect this species to be found in the future in soda pans of Vojvodina too.

Invertebrates

Crustaceans and rotifers are the dominant faunal elements of soda pans water. Currently, 28 species of crustaceans from 17 genera (12 Diplostraca – Cladocera, 11 Copepoda – Calanoida and 5 Sarsostraca – Anostraca) are known from soda pans in the Vojvodina region. Rotifers are represented with 19 species from 15 genera (Monogononta and Bdelloidea) (Lukić et al., 2012; Tóth et al., 2014). Rotifera, Cladocera and Copepoda are the major components of zooplankton community. Anostraca is a nektonic group characteristic for ephemeral waters.

Crustacean taxa frequently found in the Vojvodina's soda pans are: *Arctodiaptomus spinosus* (Daday, 1890), *A. bacillifer* (Koelbel, 1885), *Diacyclops bisetosus* (Rehberg, 1880), *Megacyclops viridis* (Jurine, 1820), *Daphnia atkinsoni* Baird, 1859, *D. magna* Straus, 1820 *Macrothrix hirsuticornis* Norman and Brady, 1867, and *Moina brachiata* (Jurine, 1820) (Boros et al., 2013; Tóth et al., 2014). *A. spinosus* is considered a true indicator species of sodic waters (Megyeri, 1971). It feeds on phyto– and bacterioplankton. The species is very tolerant in regard to turbidity, carbonate and bicarbonate ions of

water and can become the dominant species in soda pans during summer when salinity increases (Löffler, 1959). Among the Anostraca, halophilic *Branchinecta orientalis* G. O. Sars, 1901 is the most common species (Horváth, Vad, Vörös, & Boros, 2013).

Some examples of the commonly found rotifer taxa are *Brachionus asplanchnoidis* Charin, 1947 and *Hexarthra fennica* (Levander, 1892), and species of the genera *Keratella*, *Lepadella* and *Testudinella* (Megyeri, 1970; Boros et al., 2013; Tóth et al., 2014). Certain species prefer open water, while others can be found in the littoral zone, and near vegetation.

Planktic and nectic communities are represented by eurytopic and "specialist" species characteristic of salt waters. Constant fluctuation of environmental conditions limits the diversity. Usually only a small number of taxa can be recorded in a single pan. Species number and diversity is negatively related to salinity (Larson & Belovsky, 2013). Human impact on water regime of soda pans can also change the salt content, consequently altering the diversity (Boros et al., 2013). Zooplankton crustacean quantities can greatly affect the composition of water bird associations (especially filter-feeding species) appearing on the pans (Boros et al., 2008; Boros et al., 2013).

Platyhelminthes species *Dendrocoelum lacteum* (O.F. Müller, 1774) (Turbellaria, Dendrocoelidae), which lives in various freshwater ecosystems, also occurs in sodic waters (Herrmann, 1986; Boros et al., 2013).

Nematoda species, *Dorylaimus stagnalis* Dujardin, 1845 (Adenophorea, Dorylaimidae) and *Hirschmanniella gracilis* (de Man, 1880) (Secernentea, Pratylenchidae) are reported from bottom sediments of brackish and salt waters (Abebe, Traunspurger, & Andrassy, 2006; Zaki, Khan, & Abid, 2012). These two species are commonly found in soda pans (Boros et al., 2013).

Mollusc fauna associated with soda pans in the Vojvodina region has not been investigated so far. It is expected to find similar species composition as in soda pans of Hungary or Austria. *Anisus spirorbis* (Linnaeus, 1758) is mentioned as a common species of soda pans, as well as several other species of Planorbidae and Valvatidae (Boros et al., 2013). Greater number of species and specimens can be found in soda pans with lower levels of salinity (Horváth, 1950; Szabó, 1993).

Various insect orders are associated with soda pans. However, knowledge on several groups, so far analyzed in this and similar kinds of habitats in Serbia, is quite scarce.

Heteroptera were investigated on several soda pans in Vojvodina. Fauna of this group is represented with numerous species from more than 25 families (Šeat, Nadaždin, Cvetković, Jovanov, & Tot, 2016). Aquatic species from genera *Corixa* Geoffroy, 1762, *Notonecta* Linnaeus, 1758, *Paracorixa* Poisson, 1957 and *Sigara* Fabricius, 1775 are fairly common in soda pans. Semiaquatic species of families Mesoveliidae and Gerridae inhabit emersed vegetation and water surface film. Most terrestrial species are generally not specifically associated with soda pans. However, certain halophilic species were found, such as *Henestaris halophilus* (Burmeister, 1835) (Geocoridae), *Conostethus hungaricus* Wagner, 1941 and *Solenoxyphus fuscovenosus* (Fieber, 1864) (Miridae) (Šeat et al., 2016). During warm periods of a year Heteroptera can be the most numerous group of insects in soda pans (Boros et al., 2013).

Aquatic species of Coleoptera are mostly represented by species from families Haliplidae, Hydrophilidae and Dytiscidae. Genus *Berosus* Leach, 1817 (Hydrophilidae) is represented with 6 species in Serbia of which *Berosus spinosus* (Steven, 1808) is a true halophilic, while *B. frontifoveatus* Kuwert, 1888 is partly halophile species. Both species were collected from several soda pans (Mesaroš & Novaković, 2015). *Dytiscus marginalis* Linnaeus, 1758 (Dytiscidae) is common in wetlands of the Vojvodina region and also occurs in soda pans. *Bidessus nasutus* Sharp, 1887 is known from ephemeral and stagnant waters (Mesaroš, 2015), and although it was not recorded from soda pans of Vojvodina, the species was found in sodic water bodies in Hungary (Boros et al., 2013).

Vertebrates

There are no vertebrates specifically associated with soda pans. Permanent fish fauna is absent in most soda pans due to the large seasonal water level fluctuation and periodic drying out. Certain fish species can sporadically occur in marshy pans with more permanent water cover and lower salt content (Boros et al., 2013). High salt content and high turbidity create unfavorable conditions for most amphibian species, negatively affecting reproduction and spawning of these groups in soda pans. Occasionally, the following species may be present: *Bufo bufo* (Linnaeus, 1758), *Bufotes viridis* (Laurenti, 1768), *Bombina bombina* (Linnaeus, 1761), *Pelobates fuscus* (Laurenti, 1768) and *Hyla arborea* (Linnaeus, 1758) (Džukić et al., 2015). Common wetland reptile species, *Natrix natrix* (Linnaeus, 1758), *N. tessellata* (Laurenti, 1768) and *Emys orbicularis* (Linnaeus, 1758) can be found in or near soda pans (Boros et al., 2013).

Bird fauna

Soda pans are characterized by a diverse avifauna, representing suitable habitats both for breeders and migratory bird species. During the period 1950–2010, a total of 210 bird species were recorded on the Rusanda Lake (Šćiban, Ružić, Radišić, Rajković, & Janković, 2010). Some of them are very rare or periodic breeders in Serbia: *Podiceps nigricollis* C. L. Brehm, 1831, *Tadorna tadorna* (Linnaeus, 1758), *Recurvirostra avosetta* Linnaeus, 1758 and *Panurus biarmicus* (Linnaeus, 1758). Considering breeders, the number of breeding pairs depends on water level fluctuations in salt lakes and can vary significantly from year to year. Two characteristic species – *Oxyura leucocephala* (Scopoli, 1769) and *Charadrius alexandrinus* Linnaeus, 1758, are regarded as extinct breeders of soda pans in the Vojvodina region.

Passage migrants, vagrants, winter or accidental visitors often prefer soda pans for feeding and resting. After breeding period populations of many bird species gather in flocks and for a large number of species, primarily from the orders Anseriformes, Charadriiformes and Passeriformes, soda pans in Vojvodina represent one of the most important migration stations in Serbia (Marčetić & Antal, 1961; Antal, Ferenbach, Mikuska, Pellem, & Szlivka, 1971; Dimitrijević, 1977, 1984; Gergelj & Šoti, 1990; Lakatoš, 1992; Lukač & Lukač 1992; Dević, 1995; Šćiban, Ružić, Radišić, Rajković, & Janković, 2010). The following rare migratory species and accidental visitors were observed in Vojvodina soda pans: *Anser erythropus* (Linnaeus, 1758) – globally endangered species; *Clangula hyemalis* (Linnaeus, 1758), *Burhinus oedicnemus* (Linnaeus, 1758), *Glareola pratincola* (Linnaeus, 1766), *Pluvialis squatarola* (Linnaeus, 1758), *Pluvialis apricaria* (Linnaeus, 1758), *Calidris canutus* (Linnaeus, 1758), *Calidris melanotos* (Vieillot, 1819), *Calidris temminickii* (Leisler, 1812), *Limicola falcinellus* (Pontoppidan, 1763), *Arenaria interpres* (Linnaeus, 1758), *Phalaropus lobatus* (Linnaeus, 1758), *Xenus cinereus* (Guldenstadt, 1775) – first record for Serbia at the Rusanda Lake, *Tringa stagnatilis* (Bechstein, 1803), *Larus melanocephalus* Temminck, 1820, *Larus fuscus* Linnaeus, 1758, etc. (Antal et al., 1971; Dimitrijević, 1977; Dimitrijević, 1984; Đeković, 2014; Gergelj, Tot, & Frank, 2000; Šćiban & Janković, 2008; Šćiban et al., 2014).

Due to the large number of shorebirds, soda pans represent an important feeding and resting sites for birds of prey (Falconiformes), such as: *Falco cherrug* Gray, 1834, *F. vespertinus* Linnaeus, 1766, *Accipiter gentilis* (Linnaeus, 1758), etc. These species usually breed in surrounding areas (Puzović, Sekulić, Stojnić, Grubač, & Tucakov, 2009). Rare species recorded at the Rusanda Lake are: *Falco eleonorae* Gene, 1839 – first record for Serbia at the Rusanda Lake,

Aquila fasciata (Vieillot, 1822), *Circaetus gallicus* (Gmelin, 1788) and *Buteo rufinus* (Cretzschmar, 1827) (DZPPS, 2016; Puzović, 2000; Šćiban, Ružić, Radišić, Rajković, & Janković, 2010).

At the Pečena Slatina a very rare egret – *Bubulcus ibis*, for long thought to be extinct in Serbia (Linnaeus, 1758) was observed in 2008 (Szymański, Szymański, & Horvat, 2008) and two years later this species breeding was confirmed nearby, at the Baranda Lake (Ham, 2010). At the Baranda fishpond two very rare species of pelicans (extinct breeders in Serbia) – *Pelecanus onocrotalus* Linnaeus, 1758 and *Pelecanus crispus* Bruch, 1832 were observed as accidental visitors (Jovanović, Stefanović, Szymański, & Szymański, 2007). At the Pečena Slatina the flock of 21 specimens of the very rare *Cygnus columbianus* (Ord, 1815) was observed in January 2016 (Rajkov, Šćiban, & Vučković, 2016).

At Slano Kopovo soda pan a total of 220 bird species were recorded (http://www.slanokopovo.com/ornitofauna/). It represents a very important migratory station for *Grus grus* (Linnaeus, 1758) and some waterfowl species (the most frequent species is *Anser albifrons* (Scopoli, 1769)). Some rare species for Serbia were recorded at Slano Kopovo: *Anser erythropus* (Linnaeus, 1758), *Branta leucopsis* (Becshtein, 1803), *Branta ruficollis* (Pallas, 1769), *Phoenicopterus roseus* Pallas, 1811, *Eudromias morinellus* (Linnaeus, 1758) and *Stercorarius longicaudus* Vieillot, 1819 (Lukač & Ternovac, 1990; Rašajski, 2004; Šćiban, 2006; Šćiban et al., 2014; Šćiban & Tucakov, 2006; Vasić, 1984).

High avian diversity of soda pans is connected with the existence of heterogeneous habitats with a sufficient amount of available food, particularly for shorebirds. Soda pans in Vojvodina are often surrounded with reed beds, steppe and shrub vegetation, orchards, planted trees and bosks providing additional source of food for non-waterbird species. Climate change and human activity have a negative impact on bird fauna of soda pans. Prolonged periods of drought (i.e. lack of water in the soda pans' beds) cause moving of flocks, particularly of wading birds, from soda pans to puddles, canals, fishponds, rivers and other nearby surface waters. Hunting, disturbance by herd pasture, and the use of chemical agents for agricultural purposes in the surrounding arable land also have a negative impact on bird communities.

Conclusions

Soda pans of the Vojvodina region show a great diversity and unique features. Characteristic elements of flora and fauna populate these habitats with specific physical and chemical properties of water and soil. Increased salinity and

alkalinity is generally a limiting factor for many organisms, and so is the water table fluctuation and periodic drying out. However, many tolerate these extreme conditions and even flourish. Among them we can find some rare and endemic species.

Soda pans in Vojvodina are insufficiently investigated and our knowledge on their biological attributes is limited. Virtually nothing is known about bacteria and protozoa, while we also lack a great deal of knowledge of many invertebrate groups (molluscs, many arthropod groups).

Soda pans of the Vojvodina region are of a great scientific interest because of their unique appearance and functional roles. Only three of them are legally protect habitats. Agriculture is a priority sector in Vojvodina and adverse anthropogenic influence on natural ecosystems is particularly strong. In the past decades many soda pans were modified and lost their natural features. Determining the state of biodiversity is necessary in order to know where to focus our research, but also to gain an understanding of what we have lost and what is left for us to protect in the future.

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