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Contents

Sulejman Redžić - memory

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Honorable Chairperson,

Respected academicians, professors, students,

Dear friends,

Today, we have gathered here to remind ourselves and to note that for 5 years now there is not among us, our dear colleague, friend, excellent scientist, great man, professor and academician Sulejman Redžić.

Our joint address (together with colleague Andraž Čarni from Ljubljana) is an expression of our deep respect for the man with whom we shared some period of joint scientific work on studying the flora and vegetation of the Balkan peninsula, pleasant socializing, botanical collegiality and sincere friendship.

More than 5 years ago, we could not believe or accept the sad news published by the media that Sulejman Redžić had been suffered in the snowy Miljacka canyon above Sarajevo on January 7, 2013. This feeling is still present, because whenever we came to Sarajevo, our first thought was to meet Suleiman first. The news of his death was also hit the participants of the symposia about the vegetation of Europe, which was held that year in Rome, where Andraž Čarni exposed several facts about his work and life. Thus one of the important and respected Balkan vegetation experts disappeared from the scientific community, which would play an important role in creating the synthesis of European vegetation, which was then in the final stage of preparation (published 2016).

I knew Sulejman and his wife Amira for over 30 years. Together, we were professional beginners as botanical assistants at the Universities in Sarajevo and Skopje.

It was a time when we met more often, cooperated and interacted during the various conferences and symposia of ecologists, biologists, biosystematics of former Yugoslavia (in Sarajevo, Budva, Ohrid, Gozd Martuljek, Ljubljana, Zabljak and other places).

Later, the disintegration of Yugoslavia and all that resulted from this decomposition, our communication never been interrupted, even during the war in Bosnia and Herzegovina. We regularly wrote to each other and sent letters in that unfortunate time through various channels. I kept his letters from the

demolished Sarajevo from that period, where Sulejman and his family suffered in that terrible period of war, an unprecedented senseless thing that happened in this region.

After everything that happened, he was optimistic that the situation in Bosnia and Hercegovina would still improve, so that his entire engagement was directed in that direction. He wanted that much lost in that unfortunate period as soon as possible upgrade, to restore cooperation between the institutions of the former Yugoslavia, organize meetings, establish interrupted contacts with colleagues, etc.

I recall that during my stay in Ljubljana (2000) at the Biological Institute "Jovan Hadži" of the Slovenian Academy of Sciences and Arts, my colleague Andraž Čarni received a mail message from Sulejman with an invitation to visit him in Sarajevo. We did not think for a long time, so we visited him with colleagues Andraž Čarni and Mitko Kostadinovski, on August 28 and 29, 2000 in Sarajevo. We slept at his house and we were one day on a fieldtrip near Sarajevo in the direction of Pale, where we collected the plants and where the minefields were marked on the field where we were botanized. On the way to Sarajevo, as Sulejman recommended to us the day before departure to Sarajevo, we started from Ljubljana to Bihać, and via Avnoj motorway to Jajce and Sarajevo.

Suleiman, knowing our botanical curiosity, warned us not to collect plants near the road, as many of the terrain was still mined. He wrote to us not to be fooled by the fact that where we see sheep in the pastures they are safe places for botanists. Because the weight of the sheep, he has been warned us sometimes it is not enough to activate the mined terrain. He took care of everything to safely we reach Sarajevo.

Later, from 18 to 24 May 2003, he successfully organized the Third Balkan Botanical Congress in Sarajevo, where the botanists from the Balkans were together again in Sarajevo and Bosnia and Herzegovina, where they formed a park of Balkan friendship in the Faculty of Natural Scences and mathematics. All botanists from the Balkans planted a tree, so we hope that this park is still being maintained.

Last time together with Sulejman we were in Žabljak, Montenegro (19-24.09.2011) at the celebration of the 50th anniversary of the Republic Institute for the Protection of Nature of Montenegro. There we spent several unforgettable days where Sulejman was the main promoter and animator of the program of that event.

Much has been said about Sulejman, but it is certainly not enough in relation to how much he deserved. He had so much energy and ideas, during the lectures, field trips, projects, and his social engagement. He was the Dean of the Faculty of Natural Sciencis and Mathematics in Sarajevo, Deputy Minister in the Ministry of Environment of Bosnia and Hercegovina, member of the Academy of Sciences and Arts of Bosnia and Hercegovina and others.

Sulejman Redžić was an engaged intellectual, patriot, but above all botanist-ecologist, founder of the Center for Ecology and Natural Resources - Faculty of Natural Sciencis and Mathematics in Sarajevo, who throughout his life studied the unique biodiversity of Bosnia and Hercegovina. He was one of the leading Balkan ecologists, a creative and tireless researcher who with the maturity of his scientific achievements contributed to the affirmation of the Bosnian and Balkan botanical science on the international scene.

With his scientific work he has made a significant contribution to the knowledge of the flora and vegetation of our area, primarily the genus Potentilla, Edrianthus, high mountain vegetation, vegetation of dry grasslands and forest vegetation. His achievements represent a significant contribution to the knowledge of the flora and vegetation in the wider Balkan region and will remain part of the remarkable knowledge of biodiversity, where researchers in the region and beyond will continue to be upgraded.

One thing is certain, people like Sulejman Redzic are very rare. We are all proud of his work.

Foto 1: Sulejman Redžić and Vlado Matevski - field trip in the surroundings of Sarajevo (29.8.2000)

Foto 2: Sulejman Redžić, Andraž Čarni and Mitko Kostadinovski - field trip in the surroundings of Sarajevo (29.8.2000)

Foto 3: Third International Balkan Botanical Congress, Sarajevo, 24.05.2003 (Andraž Čarni, Vlado Matevski, Andrija Lovrić, Zlatko Bulić, Sulejman Redžić)

Foto 4: Field trip, Posušje, Hercegovina - Participants of the Third International Balkan Botanical Congress, Sarajevo, 21.05.2003

Foto 5: Simpozium devoted to 80 anniversary of Alojz Šecelj and 70 anniversary of Mija Zupančič and Lojze Marinček, Ljubljana, 21.11.2001 (Vlado Matevski, Sulejman Redžić and Andraž Čarni)

Foto 6: Simpozium devoted to 80 anniversary of Alojz Šecelj and 70 anniversary of Mija Zupančič and Lojze Marinček, Ljubljana, 21.11.2001 (Participants: Juraj Kamenjarin, Božena Mitić, Nejc Jogan, Andraž Čarni, Urška Sodec, Sulejman Redžić

Foto 7: Žabljak, Montenegro (20.09.2011) – Vukić Pulević, Sulejman Redžić and Vasilije Bušković at the celebration of the 50th anniversary of the Republic Institute for the Protection of Nature of Montenegro (19-24.09.2011)

Checklist of Vegetation Classes of Bosnia and Herzegovina: How Much Do We Know?

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ABSTRACT

The beginnings of vegetation research of Bosnia and Herzegovina (B&H), according to Braun-Blanquet's approach, date back to early 1930s, culminated in the period of 60s-70s, and declined until the end of 20th century. Twenty years after the war B&H vegetation science hasn't still achieved the pre-war level.

The starting point for the preparation of the checklist of vegetation classes was the vegetation database of Bosnia and Herzegovina, which contains 6823 relevés, which were digitized and imported in TURBOVEG database for storage of large relevé datasets. Total of 4780 relevés were collected from 123 references (2906 regularly published, 1331 from grey literature and 543 from manuscripts), while 2043 are unpublished relevés, mainly recorded by the team of the Department of Forest Ecology at the Faculty of Forestry in Banja Luka.

Analysis of this dataset suggests that vegetation of Bosnia and Herzegovina comprises 60 classes. According to the overviews of vegetation of Bosnia and Herzegovina published so far, the vegetation dominated by vascular plants numbers 33 and 39 classes respectively. This discrepancy can be partially attributed to different syntaxonomic concepts used in these overviews compared to the latest Checklist compiled at the European level (EuroVegChecklist), which was our guideline, but also to uneven level of elaboration of different vegetation types and geographical regions in B&H.

Six classes of forest vegetation share almost 60% of the total number of relevés, while another six classes of various grasslands take another 25%. The other 15% is divided among the rest of 48 classes.

Some of the classes without relevés are, in our own opinion, present in B&H, but still need to be confirmed, while the others, even though mentioned in literature, couldn't be confirmed at the field after extensive research.

Key words: European Vegetation Survey, phytosociology, relevé database, syntaxonomy, vegetation classification.

1. INTRODUCTION

There are many different approaches to classification of vegetation (Mueller-Dombois & Ellenberg, 1974; Peet & Roberts, 2013), but Bosnia and Herzegovina (B&H) was among the first European countries to accept the method based on total floristic composition of the plant community that reflects ecological conditions and biogeographic background of the stand (Braun-Blanquet, 1928). This method, that was introduced at the beginning of the 20th century (Braun-Blanquet, 1921) is now known as Braun-Blanquet approach, the standard Central European phytosociological method or phytosociological method of Zurich-Montpelier school, and although it has been most extensively applied in Europe, important achievements have also been made throughout the world (De Cáceres et al., 2015, 2018; Guarino, Willner, Pignatti, Attorre, & Loidi, 2018). This approach provides methods for sampling (sample known as a vegetation *relevé*), describing and classifying regular groupings of plant species which are put into conceptual phytosociological units called *syntaxa* and arranged into a hierarchical

system (syntaxonomy) (Braun-Blanquet, 1964; Dengler, Chytrý, & Ewald, 2008). The basic syntaxon is called association, which are further united into alliances, orders and classes. The rules for formal description and naming of syntaxa are given in the International code of phytosociological nomenclature (ICPN) (Weber, Moravec, & Theurillat, 2000).

Vegetation research in B&H according to this method started fairly early (Horvat, 1930, 1931, 1933, 1941; Horvat & Pawlowski, 1939; Tregubov, 1941) and the number of published relevés, as well as the number of papers with at least one relevé showed steady growth until 1960s (Figures 1-2). However, after this period, the numbers showed a continuous decline, which was quite opposite to the global European trend (Chytrý et al., 2016), only to touch the bottom in the years during and after the Bosnian Civil War 1992–1995. Situation improved a little bit in the last ten to fifteen years with additional 2000 relevés being collected, but these only sums up to a total of a little bit over 6800 relevés for the entire country. Having in mind that B&H flora and vegetation are amongst the richest in Europe (Lubarda, Stupar, Milanović, & Stevanović, 2014; Redžić, 2012) this number can be considered extremely low.

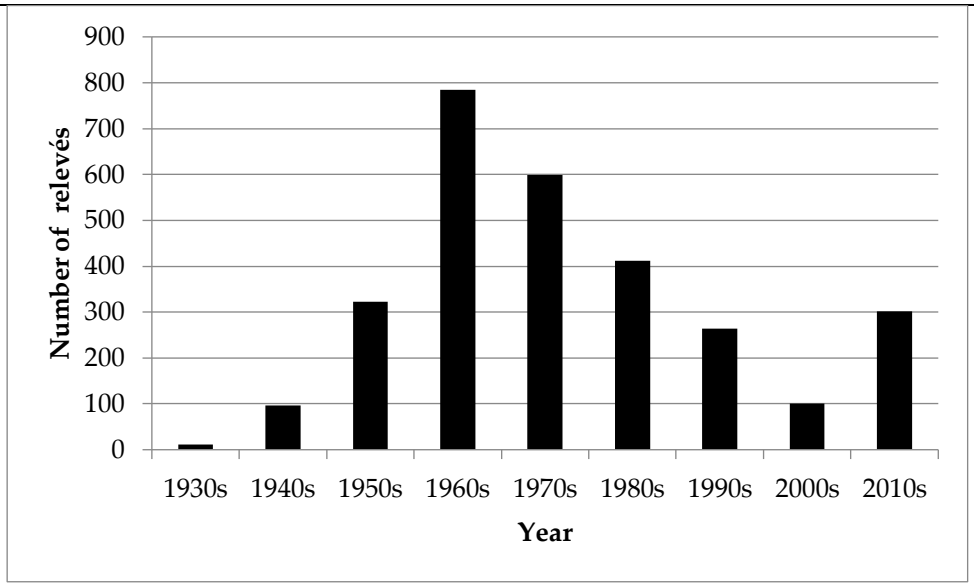

Figure 1. Number of published relevés

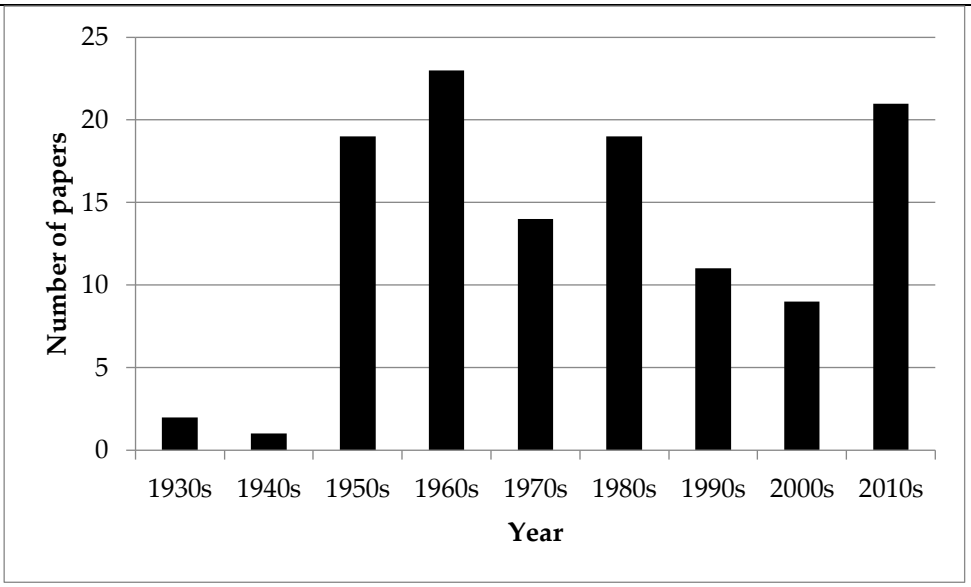

Figure 2. Number of published papers containing at least one relevé

In a meantime, an enormous quantity of phytosociological relevés has been gathered in a better part of Europe. According to Chytrý et al. (2016), as of 30 June 2015, there were more than two million presumably non-duplicated plots contained in the European databases registered in the Global Index of Vegetation-Plot Databases (GIVD; Dengler et al., 2011). There are several countries with more than 100,000 relevés (Czech Republic, France, and Germany) with Netherlands having more than 600,000 relevés, and much more countries with several tens of thousands of relevés. In B&H neighbourhood, Serbia, Croatia and Slovenia stand out with more than 10,000 relevés (Chytrý et al., 2016).

In the last two decades, thanks to the large amount of data at disposal, new syntaxonomic overviews (at least at the level of alliance) emerged for the most of European countries (Jiménez-Alfaro, Chytrý, Rejmánek, & Mucina, 2014). Furthermore, after several efforts to unify the European vegetation classification system (Mucina, 1997; Rodwell et al., 2002), the first comprehensive and consistent syntaxonomic system of alliances, orders and classes for vascular plants, bryophytes and lichens, as well as for the algal communities of Europe has been established (Mucina et al., 2016).

If we exclude the reviews of Southeast-European (Horvat, Glavač, & Ellenberg, 1974) and ex-Yugoslav vegetation (Jovanović, Lakušić, Rizovski, Trinajstić, & Zupančič, 1986) where the vegetation of B&H has been included, the first draft overview of syntaxa of B&H was given by Lakušić, Pavlović, Abadžić, & Grgić (1978). Although there were attempts by an eminent late Bosnian botanist and phytosociologist Prof. Sulejman Redžić to further develop this syntaxonomical concept (Redžić, 2007), the most comprehensive overview of B&H vegetation up to date was given by Barudanović, Macanović, Topalić-Trivunović, & Cero (2015). However, this conspectus was not in accordance with the ICPN (Weber et al., 2000) nor with the framework of the new European syntaxonomic system (Mucina et al., 2016) to which every European country will aspire to harmonize, as was the case with Croatia (Škvorc et al., 2017).

Therefore, the aims of this paper are: 1) to compile the list of vegetation classes dominated by vascular plants in B&H in accordance to new European syntaxonomic system (Mucina et al., 2016), 2) to present

the level of elaboration of every class in terms of number of relevés recorded, and 3) to identify the main problems and gaps in knowledge of the vegetation of B&H.

2. METHODS

The starting point for the preparation of this checklist were published and unpublished relevés recorded in B&H that were at our disposal. After the inspection of all available relevant literature we collected 4780 relevés. Data was collected from the total of 132 references containing at least one relevé, including published papers, books and monographs (109), PhD thesis (8), Master thesis (3), unpublished manuscripts (2), as well as unpublished studies, reports and similar (10). We also included 2043 not published relevés that were collected by the team from the Department of Forest Ecology, Faculty of Forestry in Banja Luka, during intensive field work in the last ten to fifteen years.

Total of 6823 relevés were collected, digitized and inserted into Turboveg database (Hennekens & Schaminée, 2001). A part of the database, with forest and shrub relevés, was registered in GIVD (Dengler et al., 2011) as Forest vegetation database of Bosnia and Herzegovina, with the ID EU-BA-001.

Apart from relevés database, this paper also includes information about vegetation types of B&H published in different sources, but without relevés, as well as those vegetation types occurring in B&H according to our own knowledge and experience. Classes, which are quite possible to exist in B&H but without concrete evidence, as well as those mentioned in literature but their existence is rather dubious are marked by an asterisk (*) (Table 1, Appendix).

The syntaxonomic scheme and nomenclature of classes follows the syntaxonomic system EuroVegChecklist (Mucina et al. 2016), and in particular its part for communities dominated by vascular plants (EVC1). We also used this reference for providing classes with brief descriptions and for grouping them into broad informal groups (see Appendix). Apart from accepted names of classes, whenever we found appropriate, we also gave synonyms, especially those that have been frequently used in domestic literature.

Although class *Charetea*, dominated by green algae, traditionally has been featured in syntaxonomic systems dominated by vascular plants (e.g., Barudanović et al., 2015), it is not part of EVC1, so we excluded it from this review.

3. RESULTS AND DISCUSSION

Our results suggest that the vegetation of B&H consists of 60 classes (Table 1, Appendix). This number is higher compared to most European countries (Jiménez-Alfaro et al., 2014) which is related to high floristic, macroclimatic, geological and geomorphological diversity of B&H (Redžić, 2012). This also puts B&H in line with other countries with high vegetation diversity that are divided by two biogeographical regions (Eurosiberian and Mediterranean) such as Italy, France, Spain and Croatia. But, on the other hand, the overall number of relevés is quite low, which puts B&H at the European bottom. From the countries in the region, only Macedonia, Montenegro and Albania have less relevés recorded.

This checklist comprises 27 classes more than noted by Lakušić et al. (1978) and 21 more than listed by Barudanović et al. (2015). Such large discrepancy could be explained by different syntaxonomic

concepts applied in the respective papers. For example, former class *Querco-Fagetea* was split up into five separate classes, while *Quercetea ilicis, Mulgedio-Aconitetea* and *Thlaspietea rotundifolii* were divided in two. Furthermore, largely differing concepts of classes in the group of anthropogenic vegetation have led to larger number of classes in this group. However, on the other hand, four classes have been merged into *Molinio-Arrhenatheretea*, while *Festuco-Brometea* and *Papaveretea rhoeadis* consist of two formerly independent classes.

Table 1. List of vegetation classes of Bosnia and Herzegovina with number of relevés

No	*Class*	*Number of relevés*			*%*
		Literature	*Ours*	*Total*	
1	Carpino-Fagetea sylvaticae	1610	295	1905	27.92
2	Quercetea pubescentis	389	493	882	12.93
3	Molinio-Arrhenatheretea	394	221	615	9.01
4	Vaccinio-Piceetea	406	49	455	6.67
5	Festuco-Brometea	248	113	361	5.29
6	Elyno-Seslerietea	220	38	258	3.78
7	Erico-Pinetea	176	37	213	3.12
8	Phragmito-Magnocaricetea	64	149	213	3.12
9	Asplenietea trichomanis	86	95	181	2.65
10	Quercetea robori-petraeae	124	57	181	2.65
11	Scheuchzerio palustris-Caricetea fuscae	61	99	160	2.35
12	Nardetea strictae	122	18	140	2.05
13	Alno glutinosae-Populetea albae	56	78	134	1.96
14	Mulgedio-Aconitetea	88	25	113	1.66
15	Artemisietea vulgaris	91	10	101	1.48
16	Potamogetonetea	64	29	93	1.36
17	Juncetea trifidi	78	2	80	1.17
18	Drypidetea spinosae	44	17	61	0.89
19	Roso pendulinae-Pinetea mugo	51	7	58	0.85
20	Papaveretea rhoeadis	56	0	56	0.82
21	Oxycocco-Sphagnetea	53	0	53	0.78
22	Salicetea purpureae	8	35	43	0.63
23	Thlaspietea rotundifolii	19	22	41	0.60
24	Epilobietea angustifolii	26	13	39	0.57
25	Betulo carpaticae-Alnetea viridis	37	0	37	0.54
26	Loiseleurio procumbentis-Vaccinietea	29	6	35	0.51
27	Crataego-Prunetea	23	6	29	0.43
28	Alnetea glutinosae	15	11	26	0.38
29	Bidentetea	10	13	23	0.34
30	Rhododendro hirsuti-Ericetea carneae	18	4	22	0.32
31	Isoëto-Nanojuncetea	6	13	19	0.28

32	Polygono-Poetea annuae	17	2	19	0.28
33	Montio-Cardaminetea	6	12	18	0.26
34	Sedo-Scleranthetea	8	8	16	0.23
35	Carici rupestris-Kobresietea bellardii	13	2	15	0.22
36	Digitario sanguinalis-Eragrostietea minoris	13	0	13	0.19
37	Salicetea herbaceae	11	0	11	0.16
38	Lemnetea	10	0	10	0.15
39	Lygeo sparti-Stipetea tenacissimae	1	9	10	0.15
40	Polypodietea	3	7	10	0.15
41	Quercetea ilicis	6	4	10	0.15
42	Helianthemetea guttati	0	9	9	0.13
43	Robinietea	7	2	9	0.13
44	Franguletea	0	9	9	0.13
45	Cymbalario-Parietarietea diffusae	0	8	8	0.12
46	Chenopodietea	4	3	7	0.10
47	Calluno-Ulicetea	5	1	6	0.09
48	Adiantetea	0	5	5	0.07
49	Brachypodio pinnati-Betuletea pendulae	1	3	4	0.06
50	Trifolio-Geranietea sanguinei	0	3	3	0.04
51	Ononido-Rosmarinetea	2	0	2	0.03
52	Ruppietea maritimae	1	0	1	0.01
53	Stipo-Trachynietea distachyae	0	1	1	0.01
54	Sisymbrietea	0	0	0	0.00
55	Koelerio-Corynephoretea*	0	0	0	0.00
56	Zosteretea*	0	0	0	0.00
57	Halodulo wrightii-Thalassietea testudinum*	0	0	0	0.00
58	Nerio-Tamaricetea*	0	0	0	0.00
59	Juncetea maritimi*	0	0	0	0.00
60	Crithmo-Staticetea*	0	0	0	0.00
	Total	4780	2043	6823	

The other reason for the discrepancy could be disproportion in the level of elaboration of different vegetation types, as shown in Table 1. While some classes are well represented by relevés, others simply haven't been studied enough or even noted at all. This is the case with some of the classes from the vegetation of rock crevices and screes (e.g. *Cymbalario-Parietarietea diffusae, Polypodietea*) as well as intrazonal mediterranean scrub, grasslands and herblands (*Lygeo sparti-Stipetea tenacissimae, Helianthemetea guttati, Stipo-Trachynietea distachyae*) for which we found very few or no literature data. In addition, B&H was regionally discriminated, having researchers preferring Dinaric part of the country to the south and north (Figure 3). Only lately have this issue been addressed and partially

corrected (Figure 4). At the present, the main problem seems to be the lack of financial support for this kind of research leading to small number of active researchers conducting the fieldwork.

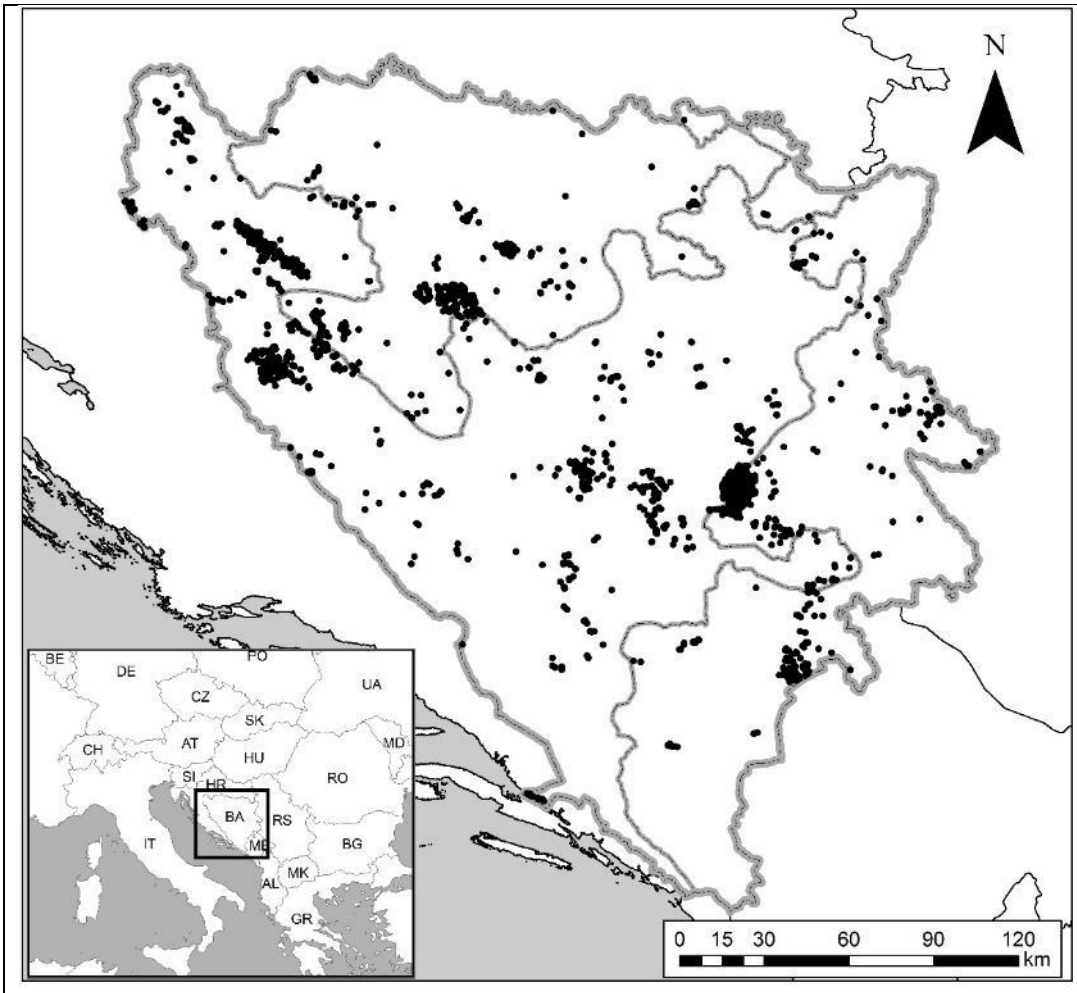

Figure 3. Relevés from literature

Disproportion in the level of elaboration of different vegetation types is clearly shown in Table 1. Only six classes of forest vegetation share almost 60% of the total number of relevés, while another six classes of various grasslands take another 25%. The other 15% is divided among the rest of 48 classes. This should serve as a road map for the future investigations of the B&H vegetation.

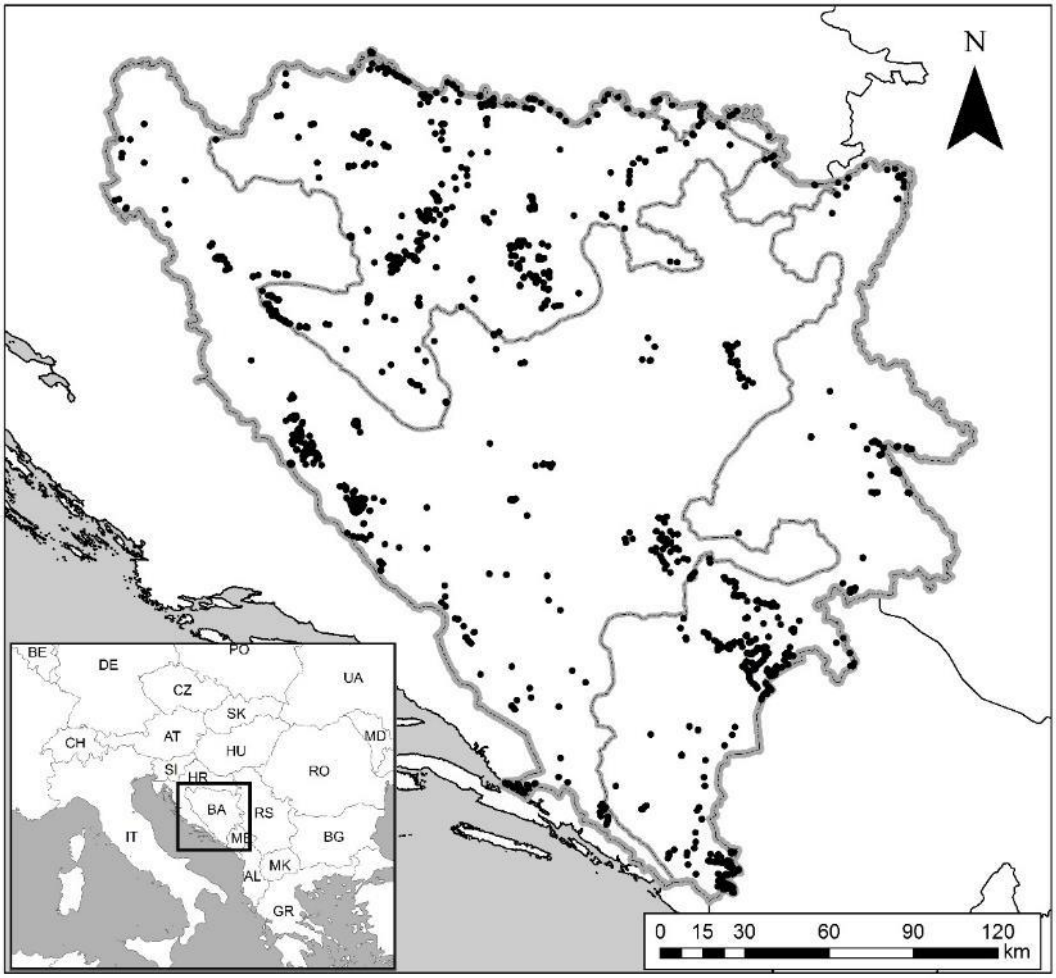

Figure 3. Unpublished relevés, mainly ours, recorded in the last fifteen years

Some of the classes without relevés and marked with an asterisk (*) are, in our own opinion, present in B&H, but still need to be confirmed (e.g., *Zosteretea, Halodulo wrightii-Thalassietea testudinum*), while the others, even though mentioned in literature, couldn't be confirmed at the field after extensive research. This is the case with *Juncetea maritimi* (Lakušić et al., 1978), *Koelerio-Corynephoretea* (Barudanović et al., 2015). In any case, the further research is needed to confirm or rule out these syntaxa.

In summary, we tried to make the checklist of vegetation classes dominated by vascular plants in B&H that is in accordance with the EuroVegChecklist (Mucina et al., 2016) and thus with the common European standards. Along the way, we pointed out at the several most conspicuous problems and gaps in B&H syntaxonomy and phytosociology, which should be dealt with in order to continue with the elaboration of the B&H vegetation. Hopefully, in the near future this will be solved and B&H will have complete and comprehensive synopsis of syntaxa at alliance and association level, which will, in turn, help facilitate broad range of activities, such as biodiversity inventory and mapping, nature conservation, spatial planning and sustainable use of natural resources, to name just a few.

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APPENDIX

List of Vegetation Classes

1. ZONAL AND INTRAZONAL VEGETATION

1.1. VEGETATION OF THE ARCTIC ZONE

1.1.1. ZONAL VEGETATION OF POLAR DESERT AND TUNDRA

***Carici rupestris-Kobresietea bellardii* Ohba 1974**

Circum-arctic fellfield and dwarf-scrub graminoid tundra, and relict wind-exposed short grasslands on base-rich substrates in the alpine and subnival belts of the European boreal and nemoral mountain ranges

***Loiseleurio procumbentis-Vaccinietea* Eggler ex Schubert 1960**

Arctic-boreal tundra scrub and relict alpine acidophilous dwarf-heath mountain tundra of Eurasia and North America

1.2. VEGETATION OF THE BOREAL AND HEMIBOREAL ZONE

1.2.1. ZONAL BOREAL AND HEMIBOREAL FORESTS

***Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939**

Holarctic coniferous and boreo-subarctic birch forests on oligotrophic and leached soils in the boreal zone and at high-altitudes of mountains in the nemoral zone of Eurasia

***Brachypodio pinnati-Betuletea pendulae* Ermakov et al. 1991**

Hemiboreal pine and birch-pine herb-rich open forests on fertile soils of the Southern Urals and Southern Siberia, and relict birch-poplar forests of Europe

1.3. VEGETATION OF THE NEMORAL FOREST ZONE

1.3.1. ZONAL TEMPERATE BROAD-LEAVED FORESTS

***Carpino-Fagetea sylvaticae* Jakucs ex Passarge 1968**

(syn. *Querco-Fagetea sylvaticae* Br.-Bl. et Vlieger in Vlieger 1937)

Mesic deciduous and mixed forests of temperate Europe, Anatolia, the Caucasus and Southern Siberia

***Quercetea pubescentis* Doing-Kraft ex Scamoni et Passarge 1959**

Oak, mixed deciduous and conifer woods of warm regions in the cool-temperate nemoral zone of Central and Southern Europe and in the supramediterranean belt of the Mediterranean, Asia Minor and Middle East

***Quercetea robori-petraeae* Br.-Bl. et Tx. ex Oberd. 1957**

Acidophilous oak and oak-birch forests on nutrient-poor soils of Europe

1.3.2. INTRAZONAL SCRUB AND WOODLANDS OF THE NEMORAL ZONE

***Crataego-Prunetea* Tx. 1962 nom. conserv. propos.**

(syn. *Rhamno-Prunetea* Rivas Goday et Borja Carbonell 1961)

Scrub and mantle vegetation seral or marginal to broad-leaved forests in the nemoral zone and the submediterranean regions of Europe

***Robinietea* Jurko ex Hadač et Sofron 1980**

Seral forest-clearing and anthropogenic successional scrub and thickets on nutrient-rich soils of temperate Europe

1.3.3. INTRAZONAL BOREO-TEMPERATE

GRASSLANDS AND HEATH

***Calluno-Ulicetea* Br.-Bl. et Tx. ex Klika et Hadač 1944**

Heath on acidic nutrient-poor soils in the lowland to montane belts of the temperate and boreal zones of Europe

***Nardetea strictae* Rivas Goday et Borja Carbonell in Rivas Goday et Mayor López 1966 nom. conserv. propos.**

Secondary mat-grass swards on nutrient-poor soils at low and mid-altitudes of the temperate, boreal and subarctic regions of Europe

Koelerio-Corynephoretea* Klika in Klika et Novak 1941

Dry grasslands on sandy soils and on rocky outcrops of the temperate to boreal zones of Europe, the North Atlantic islands and Greenland

***Sedo-Scleranthetea* Br.-Bl. 1955**

Pioneer vegetation on shallow soils on rocky siliceous outcrops on siliceous rocks of temperate and boreal Europe

***Trifolio-Geranietea* sanguinei T. Müller 1962**

Thermophilous forest fringe and tall-herb vegetation in nutrient-poor sites in the submediterranean to subboreal zones of Europe and the Macaronesia

***Molinio-Arrhenatheretea* Tx. 1937**

(syn. *Arrhenatheretea* Br.-Bl. ex Br.-Bl. et al. 1952, *Molinio-Juncetea elatioris* Br.-Bl. ex Br.-Bl. et al. 1952, *Agrostietea stoloniferae* Oberd. in Oberd. et al. 1967, *Plantaginetea majoris* Tx. et Preising in Tx. 1950 p.p.)

Anthropogenic managed pastures, meadows and tall-herb meadow fringes on fertile deep soils at low and mid-altitudes (rarely also high altitudes) of Europe

1.3.4. VEGETATION OF THE NEMORAL OROSYSTEMS

Erico-Pinetea Horvat 1959

Relict pine forests and related scrub on calcareous and ultramafic substrates of the Balkans, the Alps, the Carpathians and Crimea

Roso pendulinae-Pinetea mugo Theurillat in Theurillat et al. 1995

Pine krummholz in the subalpine belts of the nemoral mountain ranges of Europe

Rhododendro hirsuti-Ericetea carneae Schubert et al. 2001

Supramontane to subalpine low heath on calcareous skeletal soils, rocky outcrops, lapiés and boulders of the Alps, the Apennines and the Dinarides

Betulo carpaticae-Alnetea viridis Rejmánek ex Bœuf, Theurillat, Willner, Mucina et Simler in Bœuf et al. 2014

Subalpine and subarctic herb-rich alder and willow scrub and krummholz of the Alps, the Carpathians, the Hercynicum, the Balkans, the Caucasus, Northern Europe and Greenland

Mulgedio-Aconitetea Hadač et Klika in Klika et Hadač 1944

(syn. *Betulo-Adenostyletea* Br.-Bl. et Tx. 1943 p.p.)

Tall-herb vegetation in nutrient-rich habitats moistened and fertilized by percolating water at high altitudes of Europe, Siberia and Greenland

Juncetea trifidi Hadač in Klika et Hadač 1944

Acidophilous grasslands in the alpine belt of the nemoral zone of Europe, the Caucasus and in the boreo-arctic and arctic zones of Northern Europe and Greenland

Elyno-Seslerietea Br.-Bl. 1948

Alpine and subalpine calcicolous swards of the nemoral mountain ranges of Europe

1.4. VEGETATION OF THE STEPPE ZONE

1.4.1. ZONAL STEPPE GRASSLANDS

Festuco-Brometea Br.-Bl. et Tx. ex Soó 1947

(syn. *Thero-Brachypodietea* Br.-Bl. in Br.-Bl. et al. 1947 p.p.)

Dry grassland and steppe vegetation of mostly base- and colloid-rich soils in the submediterranean, nemoral and hemiboreal zones of Europe

1.5. VEGETATION OF THE MEDITERRANEAN ZONE

1.5.1. ZONAL MEDITERRANEAN FORESTS AND SCRUB

Quercetea ilicis Br.-Bl. ex A. Bolòs et O. de Bolòs in A. Bolòs y Vayreda 1950

Thermo-mesomediterranean pine and oak forests and associated macchia of the Mediterranean

Ononido-Rosmarinetea Br.-Bl. in A. Bolòs y Vayreda 1950

(syn. *Erico-Cistetea* Trinajstić 1985)

Mediterranean scrub (tomillar, espleguer, romeral, garrigue, phrygana, batha) on base-rich substrates

1.5.2. INTRAZONAL MEDITERRANEAN SCRUB

Nerio-Tamaricetea* Br.-Bl. et O. de Bolos 1958

Circummediterranean and Macaronesian riparian scrub

1.5.3. INTRAZONAL MEDITERRANEAN GRASSLANDS AND HERBLANDS

***Lygeo sparti-Stipetea tenacissimae* Rivas-Mart. 1978 nom. conserv. propos.**

(syn. *Thero-Brachypodietea* Br.-Bl. in Br.-Bl. et al. 1947 p.p.)

Circum-mediterranean pseudosteppes on calcareous rocky substrates and relict edaphic steppes on deep clayey soils

***Helianthemetea guttati* Rivas Goday et Rivas-Mart. 1963**

Mediterranean and submediterranean-atlantic annual low-grown ephemeral herb- and grass-rich vegetation on acidic substrates

***Stipo-Trachynietea distachyae* S. Brullo in S. Brullo et al. 2001**

Mediterranean calciphilous annual and ephemeroid swards and grasslands

2. AZONAL VEGETATION

2.1. ALLUVIAL FORESTS AND SCRUB

***Alno glutinosae-Populetea albae* P. Fukarek et Fabijanić 1968**

Riparian gallery forests of the Eurosiberian and Mediterranean regions

***Salicetea purpureae* Moor 1958**

Willow and tamarisk scrub and low open forests of riparian habitats in the temperate to arctic zones of Europe and Greenland

2.2. SWAMP FORESTS AND SCRUB

***Alnetea glutinosae* Br.-Bl. et Tx. ex Westhoff et al. 1946**

European mesotrophic regularly flooded alder carr and birch wooded mires

***Franguletea* Doing ex Westhoff in Westhoff et Den Held 1969**

Willow carr of Western Europe, Fennoscandia and the subatlantic regions of Central Europe

2.3. VEGETATION OF COASTAL CLIFFS AND DUNES

Crithmo-Staticetea Br.-Bl. in Br.-Bl. et al. 1952

Rupicolous vegetation of salt-sprayed coastal cliffs of the Atlantic and Mediterranean seaboards of Europe, North Africa and Middle East

2.4. VEGETATION OF ROCK CREVICES AND SCREES

Adiantetea Br.-Bl. et al. 1952

Relict chomophytic and chasmophytic vegetation in the shaded and water-splashed habitats of the Mediterranean, the Atlantic islands, North Africa and Middle East

Polypodietea Jurko et Peciar ex Boşcaiu, Gergely et Codoreanu in Raţiu et al. 1966

Chomophytic, chasmophytic and epiphytic vegetation of fern- and moss-rich communities in crevices and on the surface of rocky cliffs of temperate and mediterranean Europe

Asplenietea trichomanis (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. 1977

Chasmophytic vegetation of crevices, rocky ledges and faces of rocky cliffs and walls of Europe, North Africa, Middle East, the Arctic archipelagos and Greenland

Cymbalario-Parietarietea diffusae Oberd. 1969

Thermophilous chasmophytic vegetation of walls of the Mediterranean and the winter-mild atlantic to subcontinental regions of temperate Europe, Middle East and North Africa

Thlaspietea rotundifolii Br.-Bl. 1948

Vegetation of scree habitats and pebble alluvia of the temperate, boreal and oromediterranean Europe and the Arctic archipelagos

Drypidetea spinosae Quézel 1964

Vegetation of scree habitats and pebble alluvia of in the submediterranean montane and supra-oromediterranean belts of the Central and Eastern Mediterranean and the Black Sea seaboards

2.5. VEGETATION OF ARCTIC-ALPINE VEGETATION OF SNOW-RICH HABITATS

Salicetea herbaceae Br.-Bl. 1948

Arctic and alpine-subnival snow-bed vegetation at high altitudes of the mountain ranges of Eurasia and the Arctic Ocean islands

2.6. VEGETATION OF SALINE AND BRACKISH WATERS AND SWAMPS

Zosteretea Pignatti 1953

Vegetation of sea-grass meadows on muddy and sandy submerged substrates of the temperate and subarctic seas surrounding Europe

Halodulo wrightii-Thalassietea testudinum Rivas-Mart. et al. 1999

Vegetation of eel-grass swards on muddy and sandy substrates of subtropical and tropical seas fringing Atlantic Ocean

***Ruppietea maritimae* J. Tx. ex Den Hartog et Segal 1964**

Submerged rooted herbaceous vegetation of brackish waters of the World

Juncetea maritimi* Br.-Bl. in Br.-Bl. et al. 1952

Perennial grasslands and herb-rich vegetation of coastal and inland salt-marshes and sea-cliffs of the Mediterranean Sea and the Atlantic and Arctic Oceans

2.7. FRESHWATER AQUATIC VEGETATION

***Lemnetea* O. de Bolòs et Masclans 1955**

Free-floating duckweed vegetation of still and relatively nutrient-rich freshwater bodies of the Holarctic

***Potamogetonetea* Klika in Klika et Novák 1941**

Vegetation of rooted floating or submerged macrophytes of stagnant mesotrophic, eutrophic and brackish freshwater bodies and slowly flowing shallow streams of Eurasia

2.8. VEGETATION OF FRESHWATER SPRINGS, SHORELINES AND SWAMPS

***Montio-Cardaminetea* Br.-Bl. et Tx. ex Klika et Hadač 1944**

Vegetation of water springs of Europe, the European Arctic archipelagos and Greenland

***Isoëto-Nanojuncetea* Br.-Bl. et Tx. in Br.-Bl. et al. 1952**

Pioneer ephemeral dwarf-cyperaceous vegetation in periodically freshwater flooded habitats of Eurasia

***Phragmito-Magnocaricetea* Klika in Klika et Novák 1941**

Reed swamp, sedge bed and herbland vegetation of freshwater or brackish water bodies and streams of Eurasia

2.9. VEGETATION OF BOGS AND FENS

***Scheuchzerio palustris-Caricetea fuscae* Tx. 1937**

Sedge-moss vegetation of fens, transitional mires and bog hollows in the temperate, boreal and Arctic zones of the Northern Hemisphere

***Oxycocco-Sphagnetea* Br.-Bl. et Tx. ex Westhoff et al. 1946**

Dwarf-shrub, sedge and peat-moss vegetation of the Holarctic ombrotrophic bogs and wet heath on extremely acidic soils

3. ANTHROPOGENIC VEGETATION

***Papaveretea rhoeadis* S. Brullo et al. 2001 nom. conserv. propos.**

(syn. *Stellarietea mediae* Tx. et al. in Tx. 1950, *Secalinetea* Br.-Bl. in Br.-Bl. et al. 1952)

Annual weed segetal vegetation of arable crops, gardens and vineyards in the cool-temperate and boreal zones of Eurasia

Sisymbrietea Gutte et Hilbig 1975

Zoo-anthropogenic and modern anthropogenic vegetation of animal shelters and disturbed ruderal sites in cool- and cold-temperate regions of Eurasia

Chenopodietea Br.-Bl. in Br.-Bl. et al. 1952

Winter-annual weed segetal and ruderal vegetation of man-made habitats of the Mediterranean, the mild-winter Atlantic seaboards and Macaronesia

Digitario sanguinalis-Eragrostietea minoris Mucina, Lososová et Šilc 2016

Thermophilous grass-rich anthropogenic vegetation rich in summer-annual C4 species in the southern nemoral, mediterranean, steppe and semi-desert zones of Europe

Polygono-Poetea annuae Rivas-Mart. 1975

(syn. *Plantaginetea majoris* Tx. et Preising in Tx. 1950 p.p.)

Subcosmopolitan therophyte-rich dwarf-herb vegetation of trampled habitats

Artemisietea vulgaris Lohmeyer et al. in Tx. ex von Rochow 1951

(syn. *Agropyretea intermedio-repentis* T. Müller et Görs 1969)

Perennial (sub)xerophilous ruderal vegetation of the temperate and submediterranean regions of Europe

Epilobietea angustifolii Tx. et Preising ex von Rochow 1951

Tall-herb semi-natural perennial vegetation on disturbed forest edges, nutrient-rich riparian fringes an in forest clearings in the temperate and boreal zones of Eurasia

Bidentetea Tx. et al. ex von Rochow 1951

Summer-annual pioneer vegetation of seasonally flooded nutrient-rich river alluvia, lacustrine banks and heavily nutrient-loaded anthropogenic habitats of boreo-temperate Europe and North Africa

Two Species of Genus *Carex* sect. *Spirostachyae* (*Cyperaceae*) New to Bosnia and Herzegovina

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ABSTRACT

During systematic field research of genus Carex in Bosnia and Herzegovina in the period of 2014-2018. two species from sect. Spirostachyae Drejer ex L. H. Bailey *have been recorded for the first time in the flora of the country: Carex extensa* Gooden. *and Carex punctata* Gaudin*. While C. punctata is a quite common species growing in damp and wet habitat types over serpentine substrates in Central Bosnia, C. extensa is recorded as very rare along the Adriatic sea coast on Klek Peninsula (southern Bosnia and Herzegovina), and recognized as critically endangered (CR) in the country.*

Key words: Bosnia and Herzegovina, *Carex extensa*, *Carex punctata*, conservation status, new floristic records.

1. INTRODUCTION

The genus *Carex* L. (Cyperaceae) is one of the most diverse and widely distributed angiosperm, especially in the temperate regions of the Northern Hemisphere (Reznicek, 1990). It consists of more than 2000 species, which are colonizing a great range of habitats (Frodin, 2004). Five subgenera (*Carex*, *Kreczetoviczia*, *Psillophora*, *Vignea* and *Vigneastra*) are recognized based on a comprehensive taxonomic account (Egorova, 1999). Section *Spirostachyae* Drejer ex L.H. Bailey belongs to the subgenus *Carex* and mostly occurs in mesic places across Eurasia and N. Africa (Egorova, 1999). There are about 26 species of the section *Spirostachyae* occurring across Eurasia and N Africa, with 13 representatives distributed in Europe (Escudero et al., 2008). Of these species only three are distributed in the Balkan Peninsula: *Carex distans* L., *Carex extensa* Gooden. and *Carex punctata* Gaudin.

In the flora of Bosnia and Herzegovina (BiH) the presence of 75 taxa of genus *Carex* at subspecies level have undoubtedly been recorded so far (Milanović, 2014a, 2014b, 2017). Only *Carex distans* L. was previously known from the section *Spirostachyae* (Beck-Mannagetta, 1903).

2. MATERIAL AND METHODS

The research area occupies the salt-sprayed coastal zone of Klek Peninsula in the extreme south of BiH, and serpentine habitats of wider area of Central Bosnia as well. The specimens were collected and stored into the Herbarium of the National Museum of Bosnia and Herzegovina (SARA) (voucher numbers: 51866, 51867) and Herbarium of the Faculty of Forestry University of Banja Luka (voucher numbers:

22/01-205, 22/01-206, 22/01-254). Identification was performed using the identification keys and descriptions provided by Chater (1980), Jermy et al. (2007) and Schou (2006). The nomenclature follows Jiménez-Mejías & Luceño (2011). The distribution of target species is shown on the map using standard UTM grid 10x10 km.

3. *RESULTS AND DISCUSSION*

Carex extensa Gooden. and *Carex punctata* Gaudin belongs to Subgenus *Carex*, section *Spirostachyae* Drejer ex L. H. Bailey (Figure 1). Generally, the main morphological characteristics of the section *Spirostachyae* are: primary rhizomes with short internodes, presence of leaf anteligule, lowest bract of the inflorescence leaf-like, sheathing, three stigmas, glabrous and smooth utricles, epidermal cells of utricles with red crystalloid bodies, bifid or bidentate utricle beak and ellipsoid achenes (Chater, 1980; Escudero & Luceño, 2009).

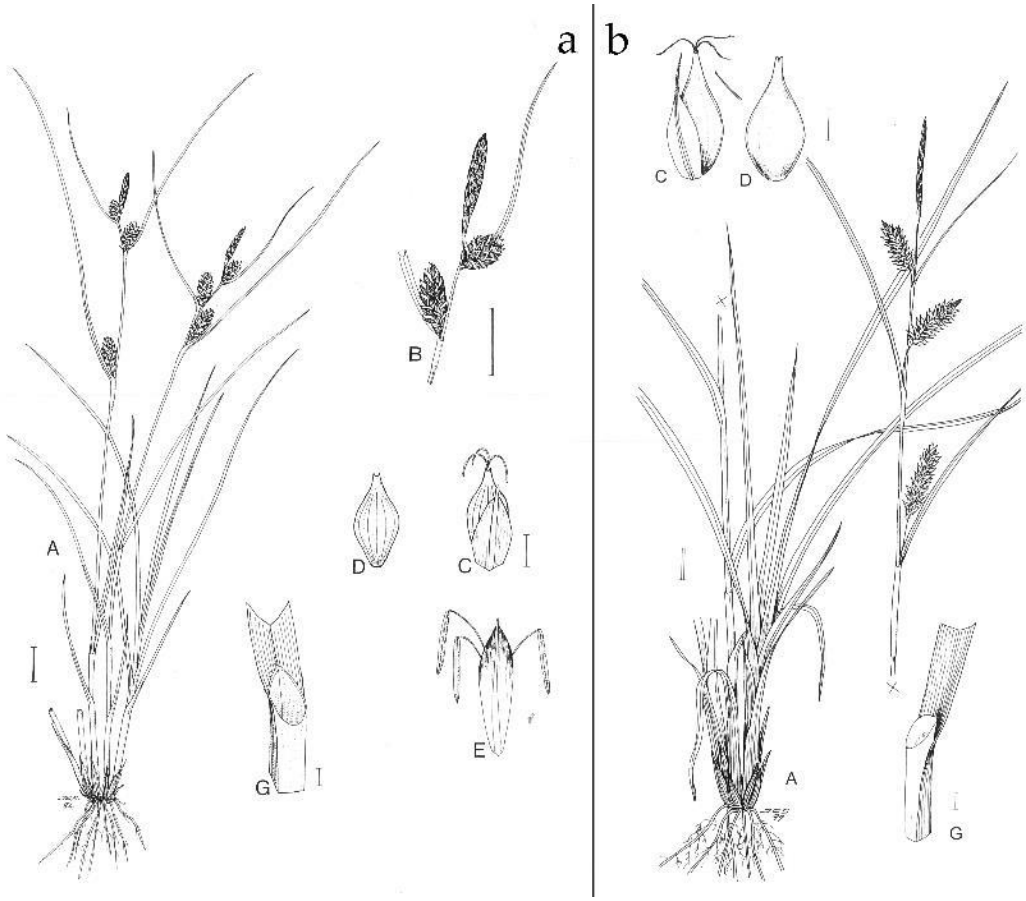

Figure 1. (a) *Carex extensa* Gooden. *and* ***(b)*** *Carex punctata* Gaudin
A. habitus B. inflorescence C. female glume D. utricle E. male glume G. ligule
(Drawing from the book Danmarks halvgræsser, by Jens Christian Schou with permission of author)

In order to clarify the diagnostic characteristics of the target species within the section *Spirostachyae*, and its relation with morphologically similar section *Ceratocystis* Dumort. as well, the identification key is provided here, following Chater (1980) and Jermy et al. (2007):

1. The pistillate spikes generally ovoid or globose and approximate, on relatively short peduncles; achenes distinctly obovate ..... section *Ceratocystis*
1. The pistillate spikes short-cylindric, distant, the lower are often conspicuously pedunculate; achenes elliptic in outline ..... section *Spirostachyae*
   2. Utricles indistinctly nerved ..... *C. punctata*
   2. Utricles distinctly nerved *3*
      3. The pistillate spikes far separated. Leaves of flowering stems flat, pure green ..... *C. distans*
      3. The pistillate spikes usually clustered near stem apex. Leaves of flowering stems channelled or involute, glaucous to grayish green..... *C. extensa*

3.1. Carex punctata Gaudin 1811, Agrost. Helv. 2: 152.

C. punctata (synonym: *Carex laevicaulis* Seub., Fl. Azor.: 21. 1840) (Figure 1b) is a caespitose perennial with shortly creeping rhizomes. Culms are erect, 15-100 cm tall, trigonous. Leaves are 10-50 cm x 2-5 mm, usually as long as the stem, flat or shallowly keeled, pale or yellow-green. Ligule is 3 mm long, obtuse and tubular. Inflorescence is about ½ length of stem. Bracts are leaf like, at least one usually but not invariably exceeding the inflorescence. Male spike 1, 10-30 mm. Male glumes 3-4 mm, oblong-obovate, orange-brown; apex mucronate, often fimbriate. Female spikes 2-4, upper contiguous, lower distant, 5-25 mm, ovoid-cylindric. Female glumes 2.5-3.5 mm, obovate, yellowish or pale brown with green midrib, margin hyaline; apex acuminate or obtuse and mucronate. Utricles 3-4 mm, obovoid-ellipsoid, inflated, indistinctly nerved, shiny, pale green, often reddish-spotted, inserted at an angle of 75-80° to the stem axis and therefore strongly patent, narrowing abruptly into a beak, widely bifid; stigmas 3 (Jermy et al., 2007). Chromosome numbers, 2n=68. (Escudero et al., 2008).

Recent floristic researches in the region of Balkan Peninsula show that this species has been overlooked in most of the neighbouring countries, probably due to morphological similarity to *C. distans*. Just in the last ten years it was first recorded in Montenegro (Stešević & Drescher, 2010), Croatia (Koopman & Topić, 2011) and Albania (Barina et al., 2013). Within the region *C. punctata* is registered also in Macedonia, Slovenia, Bulgaria and Greece (Maly, 1931-32; Chater, 1980; Martinčić, 2007).

The species is quite common in damp, grassy or rocky places near the sea in W. & S. Europe, extending locally north-eastwards to S.W Sweden, N. Poland and S.E. Austria (Chater, 1980). It is also known from sandy patches of marine marshes, sheltered rock ledges on sea-cliffs, and wetlands of siliceous substrates (Preston et al., 2002). Opposite to that, excluding only the record from Velika Ulcinjska beach (Stešević & Drescher, 2010), in the Western Balkans it occurs only in inland habitats, colonizing wet meadows, alkaline fens, degraded swamps, and wet road verges and ditches (Koopman & Topić, 2011; Kocjan, 2014). In Bosnia and Herzegovina it has been recorded only over serpentine substrates in Central Bosnia (Figure 2). Here it grows in wet habitats alongside small serpentine watercourses and around water sources, in damp places on the edge of forests, and in ditches, wet verges and swards along

macadam roads and skidding trails, where it occurs as quite common species in numerous populations. According to that, *C. punctata* probably occurs in the area more widely than the new records indicate.

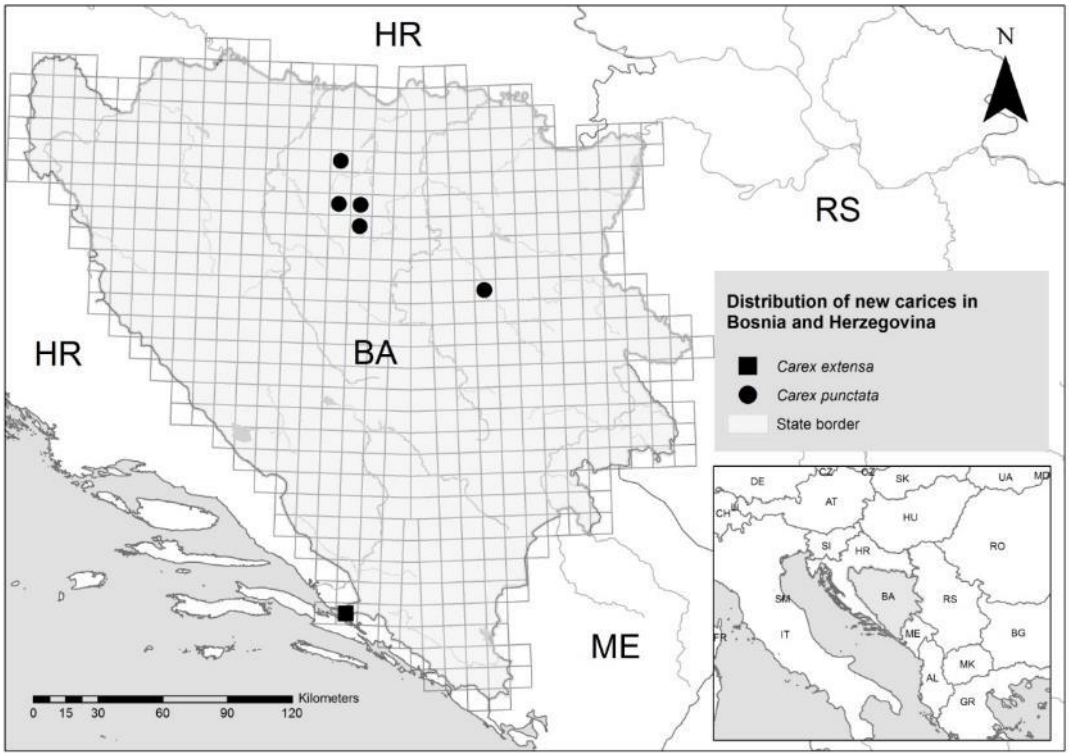

Figure 2. Distribution of Carex extensa and Carex punctata in Bosnia and Herzegovina

The researches of flora and vegetation of maritime marshes indicates that *C. punctata* and *C. extensa* often grow together. In addition to that, at all here stated finding places *C. punctata* grows together with similar *C. distans*. So, it can be overlooked with both similar species. But, the mature plants of *C. punctata* can be easily distinguished from both due to its light female glumes with green midrib and hyaline margin, as well as a bit smaller, shiny utricles, with indistinct nerves (Figure 3), particularly in fresh specimens. Contrary to *C. distans*, *C. punctata* has the lowest bract exceeding the inflorescence, which is flat, while in *C. extensa* this bract is involute (Figure 4 a-b).

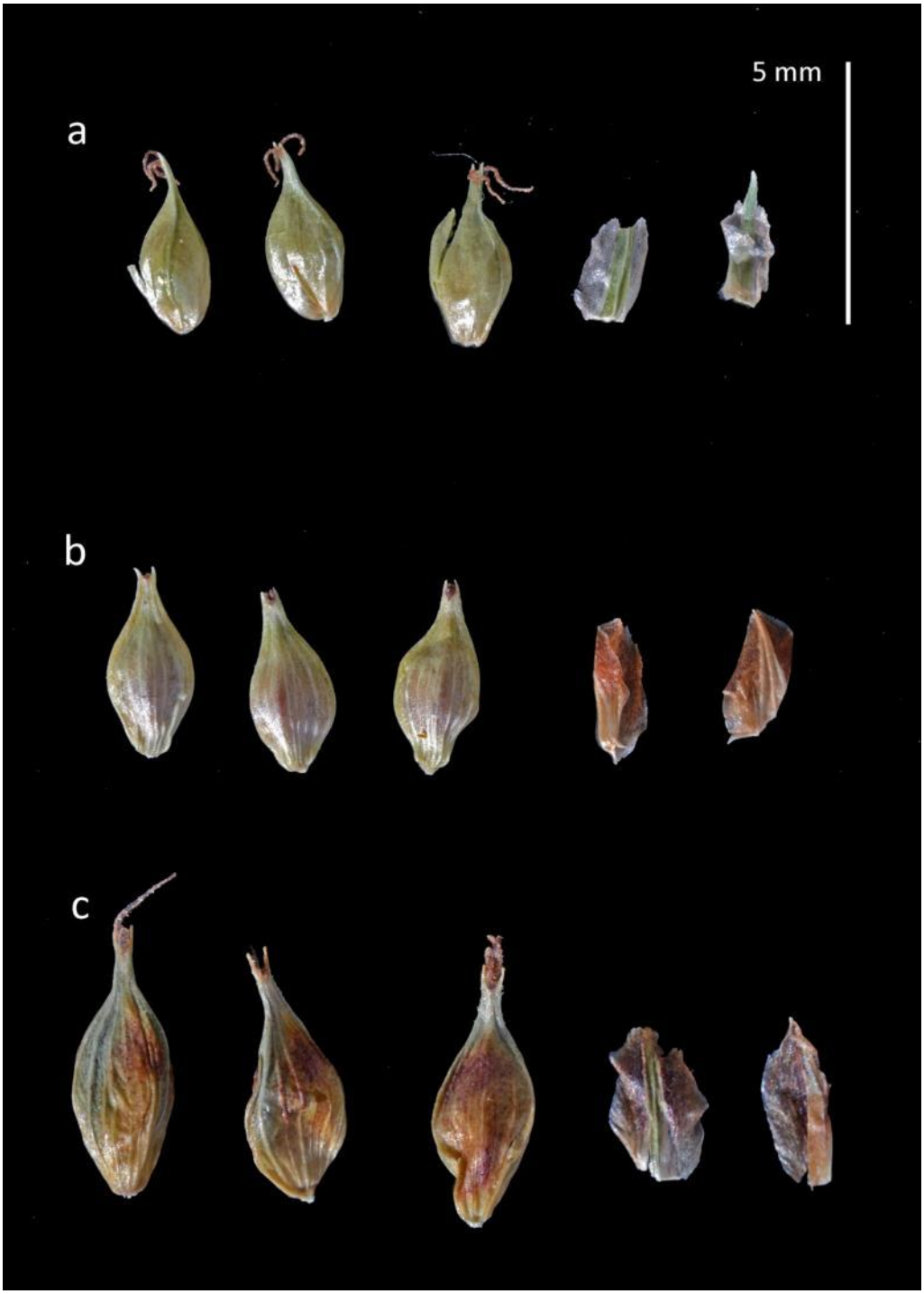

*Figure 3. Utricles and female glumes of three similar species of the section Spirostachyae from Bosnia and Herzegovina: **(a)** C. punctata, **(b)** C. extensa, **(c)** C. distans (© Đ. Milanović)*

Figure 4. Carex punctata (a) habitus (b) female spike, and Carex extensa (c) habitus (d) female and male spike (© Đ. Milanović and Š. Šarić)

3.2. Carex extensa Gooden. 1794, in Trans. Linn. Soc. London 2: 175.

C. extensa (Figure 1a, 4 c-d) is a densely tufted perennial with short rhizomes. Culms are erect, 5-45 cm tall, rigid and bluntly trigonous. Leaves are 5-35 cm x 2-3 mm, rigid, thick, keeled, often inrolled, grey-green or glaucous. Ligule 2 mm, rounded. Inflorescence is about 1/3 or ½ length of stem. Bracts are leaf

like, usually reflexed, far exceeding the inflorescence. Male spike usually 1, rarely 2-3, 5-25 mm. Male glumes 3-4 mm, obovate-elliptic, red-brown, with paler midrib; apex obtuse. Female spikes 2-4, contiguous or lower sometimes distant, 5-20 mm, subglobose to cylindric. Female glumes 1.5-2 mm, broadly ovate, red-brown with pale midrib, margin hyaline; apex mucronate. Utricles 3-4 mm, ovoid or ellipsoid, weakly ribbed, grey-green or brownish with purplish blotches, beak smooth, notched; stigmas 3 (Jermy et al., 2007). Chromosome numbers, 2n=60. (Escudero et al., 2008).

As opposed to *C. punctata*, *C. extensa* is a typical coastal sedge, occurs inland only along salt marshes (Preston et al., 2002). It grows along the European coast from the Baltic Sea via the Atlantic coast and the Mediterranean Basin to the Black Sea. It has been recorded in all Balkan countries which generally have coastal habitats: Montenegro, Albania, Bulgaria, Greece, Slovenia and Croatia (Rohlena, 1942; Chater, 1980; Martinčič, 2007; Nikolić, 2000).

As Bosnia and Hercegovina have only 24 km of the Adriatic sea shore and doesn't have salt marshes at all, the Klek Peninsula and the surrounding of the town of Neum are only potential finding places for the typical flora of maritime habitats. Although the flora and vegetation of Klek Peninsula were systematically investigated in the past (Kutleša & Lakušić, 1964), *C. extensa* hasn't been recorded so far. During research of the flora of Klek Peninsula carried out in the period of October 2017-July 2018, the species was found as very rare, with less than 30 characteristic tufts, in a small bay under the locality of Izbroće in the southern part of the Peninsula, near an abandoned mussels farm. Considering that this species has a very restricted area of occupancy, and count very small numbers of adult plants (criteria D), it has to be included into the Red List of endangered plant species for Bosnia and Herzegovina, as critically endangered (CR) (IUCN, 2001).

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The Syntaxonomic and Species Diversity of the Class *Festuco-Brometea* Br.-Bl. Ex Klika & Hadač 1944 in the Area of Prečko Polje

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ABSTRACT

The ecosystems of the class Festuco-Brometea in Bosnia and Herzegovina play an important role in the overall biological diversity. They are distinguished by a large number of vegetation units, as well as by significant number of rare, endemic or relict plant species. The study area, Prečko polje, covers 1.27 km² at 1100 m a.s.l., and takes place in the heart of mountain complex Treskavica-Visočica-Bjelašnica. We analised thermophylous meadows of Prečko polje after method of phytocoenological relevé. The class Festuco-Brometea in study area is being differentiated into the alliances Xerobromion erecti (with suballiance Fumano-Scabiosenion leucophyllae) and Mesobromion erecti (with suballiance Eu-Mesobromenion). In general, thermophylous meadows are characterized by high degree of species diversity. Moreover, within thermophylous meadows of Prečko polje we have identified nine species which are considered to have certain conservation status, according to the national and/or international legislation. Our study has shown that investigated area should be considered as potential Natura 2000 site for it is inhabited by a significant number of rare and/or endangered orchid species.

Key words: thermophylous meadows, diversity, orchid site, protection measures.

1. INTRODUCTION

The results of numerous ecological studies have shown that vegetation of the Balkan peninsula expresses high heterogeneity in respect of both its floristic composition and syntaxonomy. This is especially the case for xerophyllous vegetation of the class *Festuco-Brometea* (Redžić, 1999). There is investigation continuity regarding this vegetation type in Bosnia and Herzegovina (Lakušić, 1975; Lakušić et al., 1984; Redžić, 1984; Redžić et al., 1984; Redžić, 1997, 1999; Riter-Studnička, 1956, 1974). In the area of Balkan, thermophylous meadows have secondary character, for they were formed by degradation of climax communities, such as *Carpinion orientalis* Blečić & Lakušić 1966, *Ostryo-Carpinion orientalis* Horvat 1954 emend. 1958, *Quercion farnetto* Horvat 1954 in the supramediterranea area, and *Seslerio-Ostryon* Lakušić, Pavlović & Redžić 1982, *Quercion petraeae-cerris* (Lakušić, 1976) Lakušić & B. Jovanović 1980, *Quercion pubescentis-petraeae* Br.-Bl. 1931, *Fagion moesiacae* Blečić & Lakušić 1970 and *Fagion illyricum* Horvat (1938) 1950 in the supramediterranean-mountain and partially mountain belt (Redžić, 1999). The phytocoenoses of the class *Festuco-Brometea* develop on limestone, dolomite, dolomitized limestone, silicate, diabase or serpentine, whereby the soil can be calcomelanosol, eroded calcomelanosol, rendsine or deeper type of soil which is physiologically dry. The pH value of soil varies between 6,5 and 7,5. The phytocoenoses of the class *Festuco-Brometea* develop under warm and dry habitat conditions, frequently on

southern, southeastern or southwestern slopes. Mean annual temperature varies between +12°C and +5°C. Absolute minimum is -20°C, whereas absolute maximum reaches +45°C. Mean annual air humidity varies between 60 and 40%. The phytocoenoses encompass species which are typical heliophytes (Barudanović *et al.*, 2015). From the ecological point of view, they are being differentiated into alliances: *Mesobromion erecti* and *Xerobromion erecti* (Redžić, 1999). Due to its origin and distribution range of characteristic species, thermophylous meadows play an important role when it comes to maintenance of endemic genpool on global scale (Barudanović *et al*., 2015). Comparative analises have shown that class *Festuco-Brometea* on the Balkan is characterized by high species and syntaxonomic diversity with 1000 recorded taxa, and more than 100 described phytocoenoses. Average number of species per association varies between 90 and 230, which places them among the ecosystems with the highest species diversity level (Redžić, 1999).

Investigated Area

Geographic position. The Prečko polje is situated at 1100 m a.s.l., in the heart of mountain complex Treskavica-Bjelašnica-Visočica, covering the area of 1.27 square kilometers. It is determined by coordinates N 43°42'7.34" E 18°19'57.43" (Fig. 1).

Figure 1 – Position of Prečko polje in Bosnia and Herzegovina (Google Earth, 2018)

Geology. The Prečko polje is built of thick deposits from the Triassic period. The early Triassic deposits are arenites and conglomerates of fine granulation, whereas the late Triassic is represented by limestone, dolomite and sedimentary rocks of breccia type. The most significant geological feature is presence of reddish silicate from the early Perm, which is covered by limestone layers with fossilized remains of brachiopods, Echinodermata and red algae (Hrvatović, 2006).

Pedology. In the area of Prečko polje occur automorphous soils of the humus-accumulative class, whose pedological profile is A-C. Soil types are calcomelanosol and rendsine depending on the type of parental rocks.

Climate. The investigated area is characterized by mountainous climate with harsh winter conditions and short, warm summer. Mean annual precipitation amounts 1202,4 mm, and mean annual temperature is +7,3°C. The absolute maximum is +35°C, whereby minimum is -30°C (*Strategija održivog razvoja Općine Trnovo za period 2012-2106. Općina Trnovo, 2012*).

2. MATERIALS AND METHODS

Investigation in the field was conducted according to the method of SIGMA (Braun-Blanquet, 1964), whereby plant material was collected for further identification purposes. For the identification of taxa we used Domac (1989) and Javorka and Csapody (1979). The nomenclature is given after Tutin et al. (1964-1980). In order to evaluate microclimate conditions for the investigated phytocoenoses, we analised floral elements and life forms according to Oberdorfer (1979). The syntaxonomy is given after Lakušić et al. (1978).

3. RESULTS AND DISCUSSION

The analysis of species and syntaxonomic diversity of thermophylous meadows in Prečko polje was based on twelve reléves that were made in spring, summer and autumn aspects, in the year 2017. According to our results, thermophylous meadows in Prečko polje differentiate as follows:

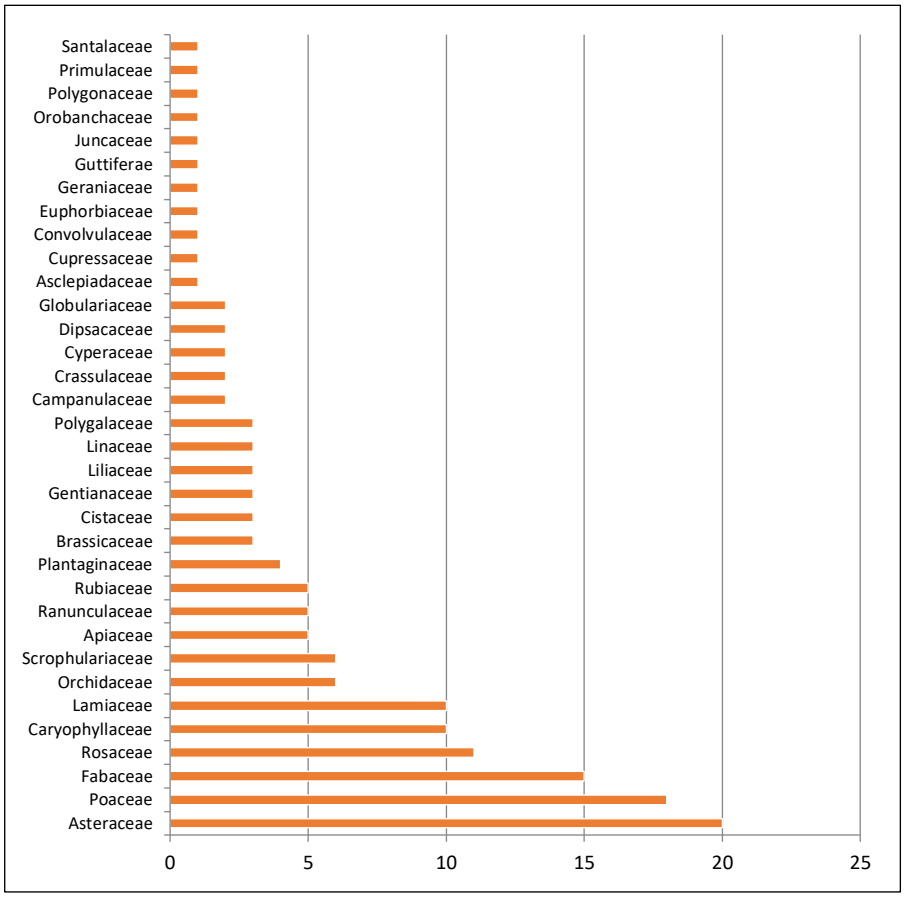
Class: Festuco-Brometea Br.-Bl. Ex Klika & Hadač 1944
Order: Brometalia erecti (W. Koch 1926) Br.-Bl. 1936
Alliance: Xerobromion erecti (Br.-Bl. & Moor 1938) Moravec in Holub et al. 1967
Sub-alliance: Fumano-Scabiosenion leucophyllae Redžić 1991
Association: Potentillo-Scabiosetum leucophyllae Redžić 1991
Association: Scabiosetum leucophyllae Abadžić 1973
Association: Globulario-Scabiosetum leucophyllae Redžić, Lakušić et al. 1984
Alliance: Mesobromion erecti (Br.-Bl. et Moor 1938) Oberd. 1957
Sub-alliance: Eu-Mesobromenion Oberd. 1957 (= *Cirsio acauli-Bromenion* Redžić 1991)
Association: Bromo-Brachypodietum pinnate Petkovsek 1977
Association: Bromo-Plantaginetum mediae Horvat (1931) 1949

The phytocoenoses of the alliance *Xerobromion erecti* occur on northern slopes of Prečko polje. The inclination of localities, with southern aspect, spans from 5 to 20°. The parental rocks are limestone, and soil is shallow, rocky calcomelanosol. The vegetation coverage varies between 90 and 95%. In the floristic composition were identified 104 species, of which the most frequent

were: *Scabiosa leucophylla* Borbás, *Teucrium chamaedrys* L., *Cirsium acaulon* (L.) Scop., *Plantago media* L., *Anthyllis vulneraria* L., *Veronica jacquinii* Baumg., *Euphorbia cyparissias* L., *Potentilla tommasiniana* F. W. Schultz, *Prunella laciniata* (L.) L., *Leontodon crispus* Vill., *Juniperus communis* L. and *Lotus corniculatus* L.

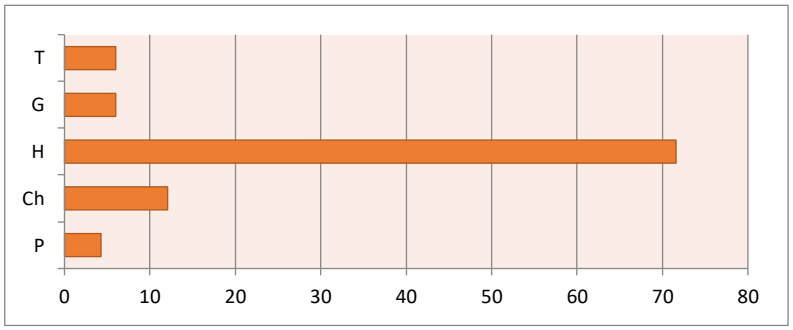
The phytocoenoses of the alliance *Mesobromion erecti* occur in southern slopes of Prečko polje. The inclination of localities reaches up to 30°, whereas the aspect is northeast or west. Inspite of unfavorable aspect, thermophylous meadows occur here due to the great inclination and partially dolomite ground. In the floristic composition were identified 121 species, of which the most frequent were: *Scabiosa leucophylla* Borbás, *Teucrium chamaedrys* L., *Filipendula hexapetala* Gilib., *Thymus serpyllum* L., *Cirsium acaulon* (L.) Scop., *Plantago media* L., *Centaurea pannonica* (Heuff.) Simonk., *Galium verum* L., *Bromus erectus* Huds. *Inula britannica* L. and *Trifolium montanum* L.. Differential species in relation to the alliance *Xerobromion erecti* are: *Galium verum* L., *Bromus erectus* Huds., *Inula britannica* L., *Trifolium montanum* L., *Festuca heterophylla* Lam., *Agrimonia eupatoria* L, *Brachypodium pinnatum* (L.) P. Beauv. and *Ononis spinosa* L.

In total, thermophyllous meadows of Prečko polje encompass 155 species belonging to 35 plant families (Graph 1). Average number of species per association is 42. Since thermophyllous meadows are distinguished by much higher level of species diversity (Redžić, 1999), the obtained result in Prečko polje reflects harsh environmental conditions caused by mountainous climate in the investigated area. The highest proportion of species belongs to the families *Asteraceae* (20), *Poaceae* (18), *Fabaceae* (15), *Rosaceae* (12), *Caryophyllaceae* (10), *Lamiaceae* (10). With five or six species represented were families: *Orchidaceae, Scrophulariaceae, Apiaceae, Ranunculaceae* and *Rubiaceae*. Remaining families have much lower proportion in the floristic composition of thermophylous meadows of Prečko polje. The most frequent species were: *Scabiosa leucophylla* Borbás, *Teucrium chamaedrys* L., *Cirsium acaulon* (L.) Scop., *Plantago media* L., *Anthyllis vulneraria* L., *Veronica jacquinii* Baumg., *Euphorbia cyparissias* L., *Filipendula hexapetala* Gilib., *Genista sagittalis* L., *Potentilla tommasiniana* F. W. Schultz, *Centaurea pannonica* (Heuff.) Simonk., *Leontodon crispus* Vill. and *Prunella laciniata* L..



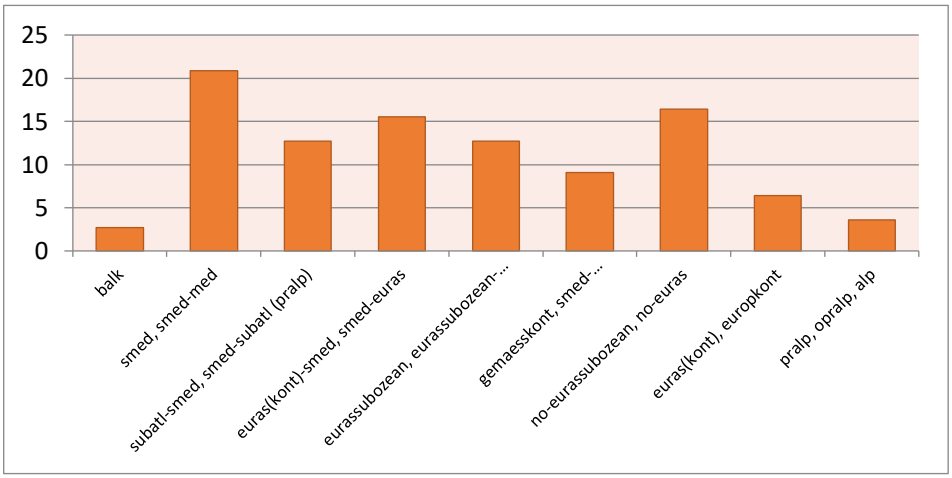
Graph 1 – Proportion of plant families in the composition of thermophylous meadows in Prečko polje

By analyzing the spectrum of life forms according to Raunkier (Graph 2), hemicryptophytes (H) prevail in the flora of thermophylous meadows in Prečko Polje, indicating climate conditions of wider macro-region. Relatively high proportion of chamaephytes (Ch) is caused by mountain microclimate. On the other hand, geophytes (G) and therophytes (T) represent life forms that are characteristic for steppe and desert areas and indicate thermophylous and xerophylous habitat conditions.



Graph 2 – Spectrum of life forms of thermophylous meadows in Prečko polje

According to the spectrum of floral elements (Graph 3), thermophylous species with a center of distribution in the sub-Mediterranean belt play a dominant role in the floristic composition of thermophylous meadows in Prečko polje (21%). A relatively high proportion of species of sub-oceanic and sub-atlantic floral elements (26%) indicates the perhumide character of the climate. Despite the large amount of rainfall, xerophilic conditions in Prečko polje occur due to the water-permeable character of the parental rocks (limestone and dolomite). Species of which ecological optimum is in the area of northeast Europe (no-euras) and the species of prealpine (pralp) and alpine (alp) floral elements also have high proportion in the spectrum (20%). Such a significant proportion of frigoriphic species is the function of altitude, i.e. the mountain climate in the area of Prečko polje. From the aspect of natural values for the investigated area, it is important to highlight the species of Balkan floral element (3%).



Graph 3 – Spectrum of floral elements of thermophylous meadows in Prečko polje

Considering the fact that we have found six species from the familiy *Orchidaceae*, there is a possibility of designating the area as a priority in terms of protection. According to the "Management of Natura 2000 Habitats" (2008), habitat is considered as a protection priority (6210*) if it represents a significant orchid site. Significant habitats of orchids are determined on the basis of one or more of the following criteria:
(a) the habitat covers a rich suite of orchid species;
(b) habitat covers an important population of at least one orchid species which is considered not very common in the national territory;
(c) one or more orchid species that are considered rare, very rare or exceptional on the national territory are present on the habitat.
The orchids recorded in the area of Prečko polje are *Orchis tridentata* Scop., *Orchis morio* L., *Orchis ustulata* L., *Anacamptis pyramidalis* (L.) Rich., *Listera ovata* (L.) R. Br. and *Cephalanthera ensifolia* Rich., of which three have defined conservation status according to national and/or international legislation. In addition, the widespread ecological significance of the class *Festuco-Brometea* is reflected through the presence of predatory bird populations for which these meadows represent hunting grounds in the mating period. There are also many migratory birds nesting on thermophylous meadows. In addition, thermophylous meadows represent a significant habitat for butterfly fauna.

4. CONCLUSIONS

Numerous studies have highlighted the complexity of the structure and dynamics of vegetation, and especially the problems in syntaxonomy and ecological differentiation of xerophilic and rocky meadows in the Balkans. Floristic and ecological analyzes show that the communities of the class *Festuco-Brometea* in Balkans are significantly different from the ones in Western, Central and Eastern Europe through the presence of Balkan, Illyrian and Southeast European floral elements. This emphasizes the need for additional revision of the status of the class *Festuco-Brometea* and its phytocoenologycal differentiation as well as their connection with the most relative rocky meadows (Redžić, 1999). According to the clear differentiation of alliances *Xerobromion* and *Mesobromion* in the area of Prečko polje, the result of the floristic-vegetation research represents a contribution in context of the observation for all ecological specificities of lower syntaxonomic categories of the class *Festuco-Brometea*. In order to raise ecological awareness of the specificity and significance of the ecosystems of Prečko polje and to create the prerequisites for the establishment of measures for the protection of local populations of orchids, and taking into account the principles of ecosystem approach, it is necessary to investigate the structure and dynamics of all vegetation types in the investigated area.

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State of peatland ecosystems in Bosnia and Herzegovina

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ABSTRACT

Peatland ecosystems in Bosnia and Herzegovina represent a relict remain of the vegetation, flora and fauna from the glaciation periods. Peatlands are widespread on the North, where they occupy large areas of northern Europe, Asia and Canada. Occurrence of this type of ecosystems in Bosnia and Herzegovina contains an indication of nature conservation in general and represents an extraordinary natural value. The status of peatland ecosystems in the Balkans should be carefully monitored especially today, at the time of the already recognizable effects of climate change. The preserved structure and functionality of these ecosystems might indicate satisfactory degree of resilience to climate change, but adverse state warns on the need to take appropriate actions. Multiply drivers as overexploitation of natural resources, water, air and soil pollution and spread of invasive alien species, also have a negative effect on peatland ecosystems. In order to assess the conditions of peatland ecosystems in Bosnia and Herzegovina, researches were carried out on Vranica and Zvijezda mountain in central Bosnia. Researches was conducted including the following communities: Sphagno-Piceetum montanum Stef 1964, *Sphagnetum recurvo-subsecundi* Grgić et al. 1991, *Menyanthi-Sphagnetum* Grgić et al. 1991 *Scirpetum silvatici* Ht et H-ić, *Calthaetum rostratae* Lakušić et al. 1991, *Abieti-Piceetum Illyricum Fuk. 1960 Stef. 62 s.l ect. To investigate existing conditions state of the peatland ecosystems, floristic elements and life forms were determined for every plant species. A comparison of previous and today's state of these communities was conducted, associated with analysis of Ellenberg's indices for temperature, light, soil reaction etc. According to Lakušić et al., 1991 these type of ecosystems in Bosnia and Herzegovina was satisfactory. However, today's finding shows severe changes. The loss of peatland habitats was recorded in the entire area of research. The main identified drivers are deforestation, habitat conversion and drainage of watercourses. In order to protect this type of ecosystems and important indicator species it is necessary to implement different conservation and restoration activities.*

Key words: peatland ecosystems, degradation, biodiversity, conservation, restoration, pressures.

1. INTRODUCTION

Peatland ecosystems represent a specific type of vegetation that at the global level makes up only 3% of the earth's surface (Houghton et al. 1990), and whose significance is particularly emphasized in the carbon cycle processes (Gorham, 1991, 1995; Roulet, 2000). This role is even greater today, which is especially important in the period of intense climate change due to

the capability of carbon retention and storage (Houghton et al. 1990). Besides the important role in the key processes of the geobiosphere, these ecosystems also represent very important habitats of many plant species of specific life forms. In accordance with environmental conditions they developed a set of morphological, anatomical, physiological and phenological characteristics that represent the type of organization of the species and their adaptive behavior. The belonging to a certain life form is also reflected in a specific habitus, the use of certain resources and the speed of physiological processes, etc. (Stevanović & Janković, 2001). Particular role in peatlands have species of the genus *Sphagnum* which, thanks to their morphological and physiological properties, imitate sponges. They retain a large amount of water in their inter- and intracellular spaces (Rydin & Jeglum, 2013; Rice et al., 2008) which is a special characteristic of these ecosystems. To the specificity of peatlands also contribute other types of mosses and sedges, whose productivity varies. In bogs where the main species are mosses, there is a lower intensity of photosynthesis compared to fens. However, sedge develop later, so the duration of photosynthesis intensity is much longer in bogs with mosses (Glenn et al., 2006). Beside specific plant and animal species, peatlands are unique in their formation processes. It is considered that they were mostly formed by processes of paludification (71%) and terestrialization (28%)(Wider & Vitt, 2006).

Peatland ecosystems in Bosnia and Herzegovina occupy small areas and make specific habitats for many indigenous species. They were researched last time 30 years ago when knowledge about them was very scarce. At that time, their structure and dynamics were examined for the first time in detail, focusing on ecological, pedological and microclimatic factors and the composition of flora and fauna. According to the aforementioned researches, areas in which these peatland ecosystems are described are known today. They include mountain areas of Romanija (locality Han Kram), Zvijezda Mountain (locality Ponikve; Šimin Potok and Bijambare), Jahorina Mountain (locality Dugo polje), Vranica Mountain (surroundings of Prokoško Lake) and greater area of Livanjsko polje (locality Ždralovac) (Lakušić et al., 1991).

Peatland ecosystems at the mentioned sites are formed by different processes. Those, in areas of Bijambare and Šimin Potok (Zvijezda mountain), were formed by the process of terestrialization. In terms of supply of mineral matter they belong to minerotrophic type of peatland. On the other hand, the peatlands on mountains Vranica and Zvijezda were formed by the process of paludification. They are supplied with water only from precipitation and, according to the content of nutrients, they are classified ombrotrophic type (Barudanović et al., 2016).

The researched peatland areas represent significant centers of endemism in BiH. The Vranica Mountain as a unique silicate massif is especially distinguished. Beside a large number syntaxonomic units of vegetation, in this area, according to the research of Kulijer (2015) in the coastal belt of Prokoško Lake an endemic species was found, *Sympetrum flaveolum* (Linnaeus, 1758) from the order Odonata.

Peatland ecosystems are valuable ecosystems in BiH. Their status should be continuously researched and protected through various monitoring mechanisms. Unfortunately, today they are exposed to intense pressures mostly derived from human activities such as: logging, drainage (Figure 1, a-b), abstraction of water, land exploitation, illegal waste dumps, etc. Due to the more intense influence of pressures, their condition is gradually being disrupted, which was the main reason for the implementation of new researches, but in already known sites in order to determine the changes that occurred in their structure.

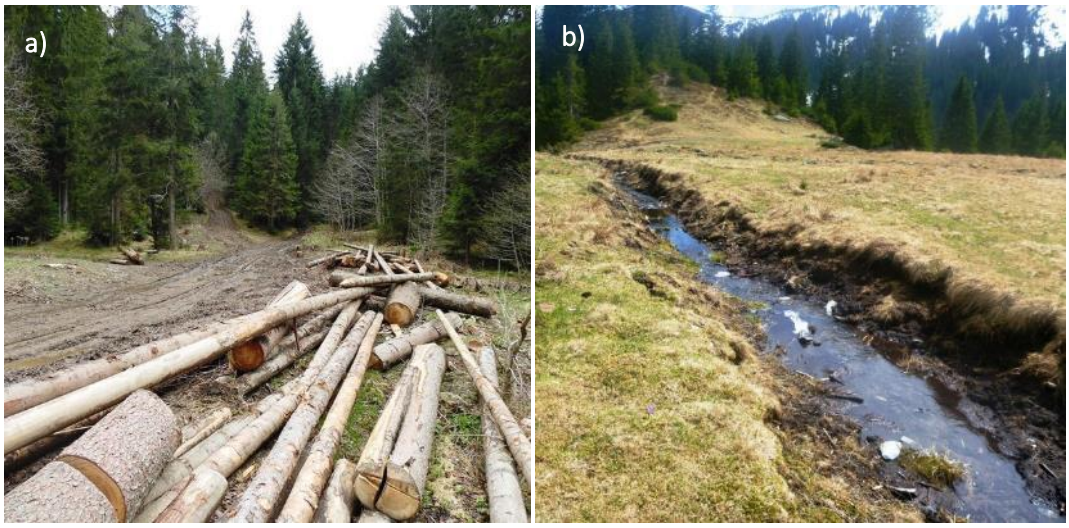


Figure 1. Pressures on peatland ecosystems (a) logging on Zvijezda Mountain; (b) drainage channels on Vranica Mountain

2. MATERIALS AND METHODS:

The specific diversity of species identified through previous researches (Lakušić et al. 1991, Đug, 2004, Barudanović et al. 2016), was the subject of this paper. A repeated researches of peatland ecosystems were carried out in 2016 and 2017 in various aspects of the vegetation season. The surveys were conducted according to the Br.-Bl. 1964. phytosociological method. The plant material was sampled and subsequently herbarized. Determination of mosses and Cormophyta was carried out using relevant literature (Pavletić, 1968; Javorka & Csapody, 1979; Daniels & Eddy, 1990; Domac, 2002; Atherton, Bosanquet & Lawley, 2010). Synthetic tables were prepared according to localities, separately for each research period (1985-1986 (I), 2002 (IIA) and 2016 (II)) and established associations. Plant species are associated with life forms, floristic elements, and spectra of associations were prepared (Oberdorfer, 1979; Landolt et al., 2010). Then, a comparison of life forms and floristic elements of the plant composition was made between separate periods and association in order to determine changes in their structure. The results of the analyzes are presented in tables and in graphic. This approach sought to establish the existence of phytosociological and ecological changes at selected localities of peatland ecosystems in the past 30 years.

3. *RESULTS AND DISCUSSION:*

In the area of the Bosnian mountains habitats with peatland ecosystems are today still preserved. Their structure and floristic composition largely depend on the biotic and abiotic component, but also on the hydrological network. The research that was carried out included seven already known peat associations, located in the greater area of Zvijezda and Vranica mountains.

In the vicinity Zvijezda Mountain, at Bijambare locality, peatlands are surrounded by primary climatogenous forest phytocoenoses in which, according to the spatial and ecological distance from the bogs, plant species can be found with their optimum in associations of high or low mires. The following associations have been described: *Sphagnetum recurvo-subsecundi* Grgić et al.1991 (Figure 1a) and *Sphagno-Piceetum montanum* Stef. 1964. The community ***Sphagno-Piceetum montanum* Stef. 1964** is particularly preserved (Figure 1b). It develops in the phytocoenosis of spruce forests at a height of 930m, on ravine terrains above silicates, or on distric cambisol alternated with luvisol. The general coverage is about 100%. The species that have the dominant role in the arboreal and shrub layer is *Picea abies,* and sporadically *Abies alba*. The most important differential species are: *Luzula pilosa, Potentilla erecta, Carex canescens, C. echinata, Juncus effusus, Lysimachia nummularia, Ranunculus ophioglossifolius* and *Agrostis stolonifera.* Among short shrubs are present populations of the following species: *Vaccinium myrtillus, Betula pubescens, Picea abies* and *Salix cinerea.*

According to the latest research, the floristic composition is as follows: *Agrostis capillaris, Ajuga reptans, Anemone nemorosa, Angelica sylvestris, Arabis hirsuta, Aremonia agrimonoides, Asarum europaeum, Athyrium filix-femina, Blysmus compressus, Callitriche palustris, Caltha palustris, Cardamine pratensis, Carex muricata, C. pallescens, C. pendula, C. rostrata, C. sylvatica, Marchantia polymorpha* etc. The differential species in the moss layer are *Rhitidiadelphus squarosus, Plagiomnium affine, Dicranum scoparium, Eurhynchium striatum, Sphagnum girgensohnii, S. palustre, S. robustum* etc.

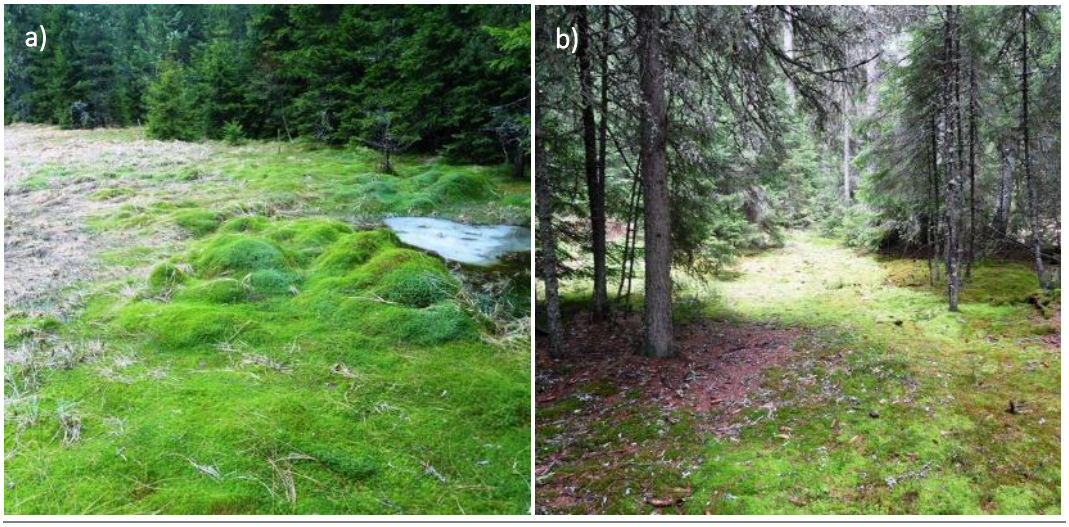


Figure 2. Researched plant communities: (a) Sphagnetum recurvo-subsecundi* Grgić et al., 1991*; locality: Bijambare *(b) Sphagno-Piceetum montanum* Stef. 1964 *locality: Bijambare*

Beside Bijambare, in the greater area of Zvijezda Mountain the peatlands are represented by associations: *Abieti-Piceetum illyricum* Fuk. 1960 em. Stef. 1962 s.l.., *Calthaetum rostratae* Lakušić et al. 1991, *Menyanthi-Sphagnetum* Lakušić et al. 1991., *Scirpetum sylvatici* Ht et H-ić prov. (in Ht et al. 1974). The geological substrate is made of marl and sandstone, and the soil is marshy gley.

On the locality Ponikve the association ***Abieti-Piceetum illyricum* Fuk. 1960 em. Stef. 1962 s. l.** is present. It develops at altitudes of 1060 m and slopes inclined 10-20°. The general coverage reaches 100%, and the dominant species in the layer of tall trees are: *Picea abies, Abies alba* and *Fagus sylvatica.* The moss and lichens layer is made by: *Sphagnum squarrosum, S. girgensohnii, S. subsecundum, Dicranum scoparium, Brachythecium rivulare, Ptychostomum capillare, Atrichum undulatum, Plagiochila asplenioides, Eurhynchium striatum, Fegatella conica, Metzgeria conjugata* etc. The spectrum of life forms od certain association shows some differences in the distribution of individual groups. The largest number of plant species belongs to the group of hemicriptophytes, followed by phanaerophytes and geophytes.

The association ***Calthaetum rostratae* Lakušić et al. 1991** is present at the same locality and it develops in wet habitats along mountain sources and streams. The physiognomy of the association is determined by *Caltha palustris* and few differential species such as: *Veronica beccabunga, Valeriana dioica, Lysimachia nemorum, Carex brizoides, Leersia sp., Poa palustris* and *Montia palustris.* The moss layer is made by: *Sphagnum girgensohnii, S. palustre, S. recurvum, Brachythecium rivulare, Ptychostomum capillare, Dicranum scoparium, Eurhynchium striatum* and others.

The association ***Scirpetum sylvatici* Ht et H-ić (in Ht et al. 1974)** on Zvijezda Mountain, develops at the locality of Ponikve at a higher altitude of 1,050 m. Its characteristic is that it occurs next to calm waters and on flat terrain (Figure 3, a). The physiognomy of the association is determined by: *Scirpus sylvaticus*, followed by *Eleocharis palustris, Alisma plantago-aquatica, Carex canescens* and *Juncus lampocarpus*. Other significant species are: *Myosotis palustris, Calliergon stramineum, Rhizomnium punctatum, Galium palustre, Ranunculus repens* etc. The moss layer is made by: *Brachythecium rivulare, Calliergon stramineum, Plagiomnium elatum, Plagiochila asplenioides* and *Polytrichum commune.*

The association ***Menyanthi-Sphagnetum* Grgić et al. 1991** at an altitude of 1050 m, on a flat and slightly inclined slope. Phytosociological analyzes showed the highest number and coverage of species of the genus *Sphagnum* L. such as: *Sphagnum recurvum, S. palustre*, while *S. subsecundum, S. squarrosum* (Figure 3, b), *S. quinquefarilum* and *S. girgensohnii* are less represented. Among other plant species the following are present: *Angelica sylvestris, Caltha palustris, Carex muricata, C. flava, Cirsium palustre, Crepis paludosa, Dactylorhiza maculata*

subsp. *transsilvanica, Deschampsia cespitosa, Epilobium palustre, Eriophorum latifolium, Festuca rubra, Filipendula ulmaria.* The moss layer is made by*: Bryum capillare, Calliergonella cuspidata, Drepanocladus sp., Rhizomnium punctatum, Polytrichum commune, Scapania irrigua, Thuidium tamariscinum* etc. The largest number of plant species belongs to the group of hemicriptophytes (H).

Figure 3. Researched plant communities: (a) Scirpetum sylvatici* Ht. et Hi-ič (in Ht et al 1974)*; (b) habitat of the species Sphagnum squarrosum

According to previous researches, on Vranica Mountain there is a high degree of diversity of peatland ecosystems. Associations like: ***Sphagno-Piceetum montanum* Stef. 1964, *Sphagnum russowii-Pinus mugo* prov., *Saxifrago-Sphagnetum* Đug 2003 prov. and *Eriophoro-Pinguiculetum* Đug 2003 prov**. have special status. Associations develop on limestone and silicate (metariolites and riolites) (Đug, 2006). The floristic cover develops according to the specific habitat conditions where species adapted to conditions of increased humidity and low air temperatures are present. Those species are: *Sphagnum russowii* Warnst., *Sphagnum subsecundum* Nees, *Ctenidium molluscum* (Hedw.) Mitt., *Climacium dendroides* (Hedw.) F. Weber & D. Mohr, *Plagiomnium affine* (Blandow ex Funck) T.J. Kop., *Empetrum nigrum* subsp. *hermaphroditum* (Hagerup) Böcher etc.

The association that develops along streams and springs is ***Sphagno-Piceetum montanum* Stef. 1964**. In the shrub layer present are *Picea abies* and *Abies alba*. The herbaceous layer is made by: *Agrostis rupestris, Alchemilla xanthochlora, Angelica sylvestris, Carex leporina, C. pilulifera, Crocus imperati, Galium palustre, Luzula maxima, L. pilosa, Mentha aquatica, Oxalis acetosella, Parnassia palustris* etc. In this vegetation type the following mosses are present: *Climacium dendroides, Marchantia polymorpha, Pseudotaxiphyllum elegans, Rhizomnium punctatum, Sphagnum subsecundum* and *Cladonia pyxidata.*

The association ***Sphagnum russowii-Pinus mugo*** **prov.** develops at an altitude of 1660-2100 m on different exposures. The geological substrate is mostly made of limestone, sometimes silicates, and soil type is riolite, metariolite or calcomelanosol. The characteristic species are: *Pinus mugo, Calamagrostis villosa, Asarum europeum, Polygonatum verticillatum, Myosotis sylvatica* and *Geranium sylvaticum*. A peculiarity of the association is reflected in the presence of the species *Sphagnum russowii* which occurs in the habitat of spruce or Heldreich's pine. According to new research, the composition of the vegetation of this association has not changed significantly. The species with the highest number and coverage are: *Pinus mugo, Juniperus communis, Rosa pendulina, Rhododendron hirsutum, Agrostis rupestris, Alchemilla hybrida, Carex leporina, C. palescens, Cerastium arvense, Eriophorum latifolium, Homogyne alpina, Nardus stricta, Ranunculus platanifolius* etc.

Figure 4. Researched plant communities: (a) Shagno-Piceeetum montanum; (b) Sphagnum rusowii mugo prov.

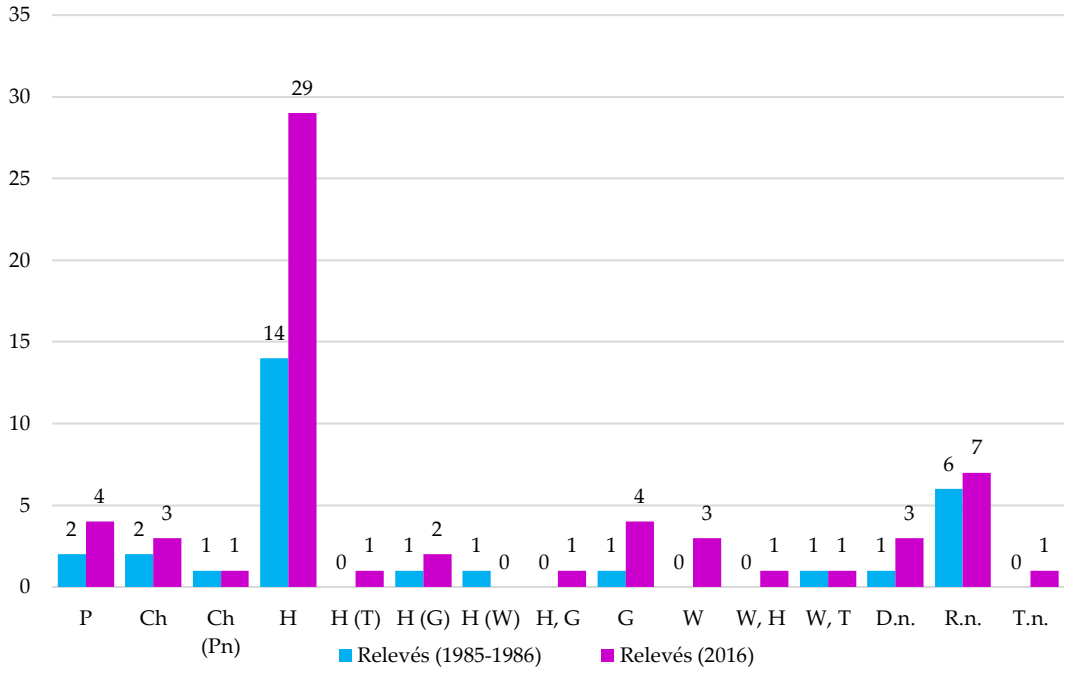
Analysis of the spectrum of life forms and floristic elements in two separate periods clearly indicates the presence of plant elements adapted to the specific conditions of the subalpine belt. The largest number of plant species belongs to the life form of hemicriptophytes (H). Plants of this form have permanent parts that survive in the layer close to the soil. They are usually covered with leaves which protects from low temperatures, snow and ice. Those species are: *Eriophorum latifolium* Hoppe, *Luzula campestris* (L.) DC., *Pinguicula leptoceras* Rchb., *Potentilla crantzii* (Crantz) Beck ex Fritsch itd. The spectrum of floristic elements shows the dominance of species of Eurasian distribution, but there is a high proportion of species with Alpine and Subatlantic-Mediterranean distribution.

The results of the comparative analysis of life forms and floristic elements in both research periods are presented in Table 1 and 2, and graphs 1, 2 and 3.

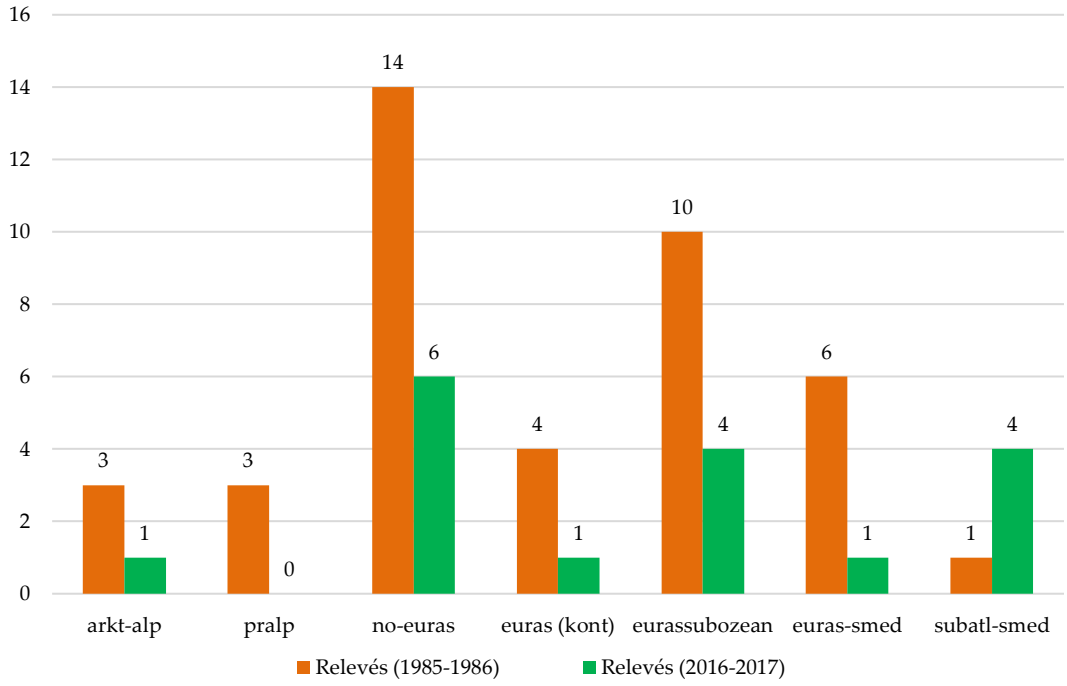
Spectra of life forms show that the biggest changes occurred in the group of hemicriptophytes. So, for example, a significant increase in the proportion of hemicriptophytes in associations was recoreded *Sphagno-Piceetum montanum* (Bijambare, graph 1) and *Abieti-Piceetum illyricum* (Zvijezda, graph 3). In the association *Sphagnetum recurvo-subsecundi* (Bijambare) a lower proportion of hemicriptophytes in recent studies was recorded. Here, the question arises whether the observed increase in hemicriptophytes indicates a changed water regime in the soil of these associations. In any case, the change in the floristic composition in favor of hemicriptophytes can lead to a smaller amount of available water for species of mosses the researched communities.

Changes in the proportion of geophytes and therophytes in the researched associations have also been observed. The share of plants of these life forms in peatland associations is generally low. However, it should be noted that in the associations *Abieti-Piceetum illyricum, Sphagno-Piceetum montanum,* but also in *Calthaetum rostratae* is observed the increase in geophytes and therophytes in the spectrum of life forms. It can be assumed that their increase points to the same situation as in the analysis of hemicriptophytes, and further research of these associations in Bosnia and Herzegovina should be done.

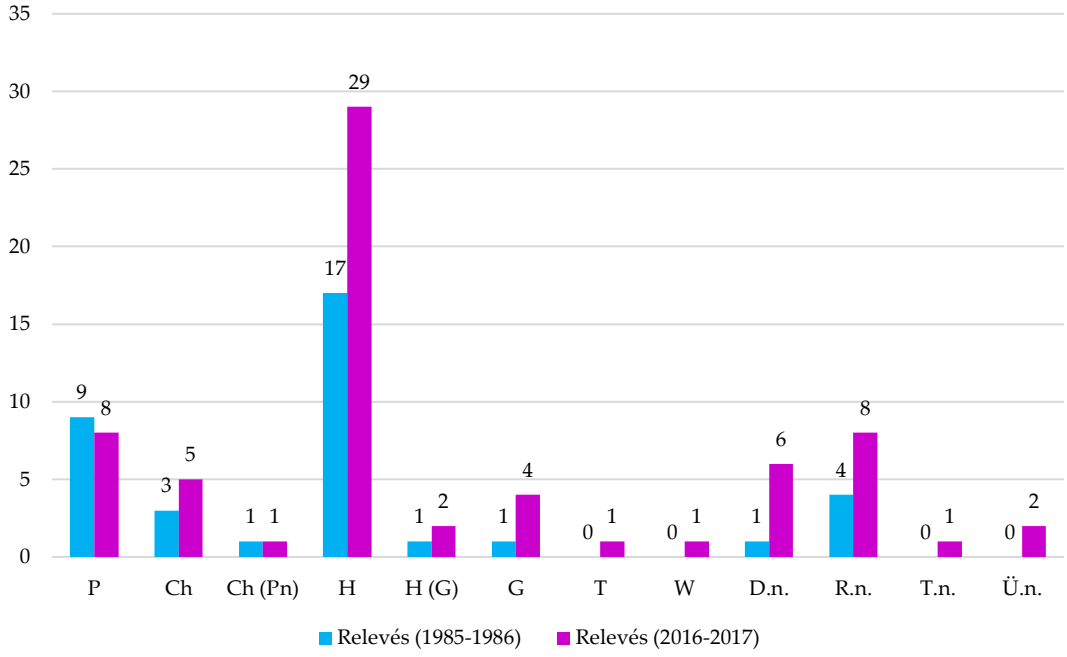
The analysis of the spectra of floristic elements shows the trend of the increase of the proportion of species whose areal of distribution center is in the sub-Mediterranean area. In contrast, there was also a reduction in the proportion of species originating from the Alpine, Subalpine and Northern Eurasian areas. The most obvious changes are visible in the association *Sphagnetum recurvo-subsecundi* in Bijambare, the best preserved peatland ecosystem in Bosnia and Herzegovina (Graph 2).



Graph 1. Spectrum of life forms in Sphagno-Piceetum montanum Stef. 1964 *(Bijambare) (by* Raunkier, 1934; Landolt et al., 2010*) (Legend: P-Phanerophyte; Ch-Chamaephyte; H-Hemicriptophyte; G-Geophyte, T-Therophyte; W-Water plants)*



Graph 2. Spectrum of floristic elements in Sphagnetum recurvo-subsecundi Grgić et al. 1991 *(Bijambare) (by* Oberdorfer, 1979)



Graph 3. Spectrum of life forms in Abieti-Piceetum illyricum Fuk. 1960 em. Stef. 62 *s.l (Zvijezda) (by* Raunkier, 1934; Landolt et al., 2010*) (Legend*: *P-Phanerophyte; Ch-Chamaephyte; H-Hemicriptophyte; G-Geophyte, T-Therophyte; W-Water plants)*

Table 2. Spectrum of life forms of researched plant communities

Researched associations	*Sphagno-Piceetum montanum* Stef. 1964		*Sphagnetum recurvo-subsecundi* Grgić et al. 1991		*Calthaetum rostratae* Lakušić et al. 1991		*Abieti-Piceetum illyricum* Fuk. em. 1960 Stef. 62 s.l		*Menyanthi-Sphagnetum* Grgić et al. 1991	*Scirpetum sylvatici* Ht et H-ić prov. (in Ht et al. 1974)	*Saxifrago-Sphagnetum* Đug 2003 prov. Stef. 1964	*Eriophoro-Pinguiculetum* Đug 2003 prov.	*Sphagno-Piceetum montanum*	*Sphagnum russowii-Pinus mugo* prov.
Life form	RESEARCH PERIOD													
	I	II	I	II	I	II	I	II	I	I	IIA	II	II	II
P	2	4	2	0	1	4	9	8	2	1	0	1	4	8
Ch	2	3	2	1	2	3	3	5	1	1			3	3
Ch (Pn)	1	1			1	1	1	1					2	2
Ch (H)											1	0	0	1
H	14	29	27	15	29	29	17	29	27	24	0	29	23	21
H (Ch)			2	0							0	2	0	1
H (G)	1	2			0	2	1	2			0	1	1	0
H (W)	1	0	2	0	1	1			0	2	0	1	1	1
H, G	0	1			1	0								

G	1	4	1	0	1	4	1	4	2	2	0	1	1	1
G, W											0	1		
G (H)					0	1							1	0
T			1	0	0	1	0	1						
T (H)			1	0	1	0								
W	0	3	3	0	1	0	0	1	1	4				
W (H)					1	0								
W (T)					0	1								
W, H	0	1			1	1					0	1	1	1
W, T	1	1			1	0								
D.n	1	3	1	3	1	1	1	6	1	1	0	2		
R.n	6	7	6	6	5	5	4	8	8	1	1	2	4	3
T.n	0	1			1	1	0	1					1	1
B.n			0	1							0	1	1	1
U.n					1	1	0	2	1	1				

***Legend**: **I**- research period from 1985 to 1986 year; **II**-research period 2016; **IIA** - research period 2002*

Table 3. Spectrum of floristic elements of researched plant communities

Researched associations	***Sphagno-Piceetum montanum* Stef. 1964**		***Sphagnetum recurvo-subsecundi* Grgić et al. 1991**		***Calthaetum rostratae* Lakušić et al. 1991**		***Abieti-Piceetum illyricum* Fuk. 1960 Stef. 62s.l**		***Menyanthi-Sphagnetum* Grgić et al. 1991**	***Scirpetum sylvatici* Ht et H-ić prov. (in Ht et al. 1974)**	***Saxifrago-Sphagnetum* Đug 2003 prov. Stef. 1964**	***Eriophoro-Pinguiculetum* Đug 2003 prov.**	***Sphagno-Piceetum montanum***	***Sphagnum russowii-Pinus mugo* prov.**
	RESEARCH PERIOD													
	I	II	I	II	I	II	I	II	I	I	IIA	II	II	II
arkt	**2**	**6**			**2**	**11**	**2**	**2**			**2**	**2**	**4**	**2**
arkt-no									2	3				
arkt-alp			3	1										
alp													3	3
alp-pralp											11	1		
pralp	1	2	3	0	4	5			3	2			3	7
pralp-alp							4	3						
no-euras	7	18	14	6	12	11	8	19	13	14	17	4	18	16
eurass							7	7	12	9				
euras-kont	2	4			3	4	1	5					2	1
euras (kont)			4	1										

eurassubozean	2	7	10	4	11	16							3	3
subatl	1	6			4	3			3	2	3	0		
subatl-smed			1	4			8	10					5	7
euras-smed	1	4	6	1							5	0		
smed	1	3			3	5	3	2	1	4				
total	**17**	**50**	**41**	**17**	**39**	**47**	**33**	**48**	**34**	**34**	**38**	**7**	**38**	**39**

***Legend**: **I**- research period from 1985 to 1986 year; **II**-research period 2016; **IIA** - research period 2002*

Legend:

P	*Phanerophyte*
Ch	*Chamaephyte*
H	*Hemicriptophyte*
G	*Geophyte*
T	*Therophyte*

R. n	*turf form more or less loosely growing, erect shoots; "normal" i.e. perennial without particular strategy*
D. n	*relatively large and essentially plagiotropic shoots in deep mat; "normal" i.e. perennial without particular strategy*
B. n	*more or less dendroid, mostly with creeping "rhizome" and erect shoots; "normal" i.e. perennial without particular strategy*
Ü. n	*more or less mat of small, creeping shoots; "normal" i.e. perennial without particular strategy*
T. n	*thalloid, forming rosette or more or less branched bands; "normal" i.e. perenial without particular strategy*

4. CONCLUSIONS:

By analyzing the spectra of life forms and floristic elements in two separated periods, changes in the proportion of previously identified groups were observed. The changes in the spectra are due to changes in the floristic composition, indicating a possible change in ecological conditions in habitats of peatland associations. The increasing trend of the share of plant species with life forms of hemicriptophytes (H), geophytes (G) and therophytes (T) is observed. It has also been observed a decreasing trend in species originating from the Alpine, Subalpine and Northern Eurasian regions, and increasing of the species with the distribution center in the sub-Mediterranean area.

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Biodiversity of Fruit-Bearing Forest Species in the Protected Landscape "Konjuh"

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SUMMARY

The area of the protected landscape "Konjuh" is distinguished by quality forest ecosystems, featuring diverse fruit-bearing forest species, which contributes to the conservation of biodiversity of the protected landscape "Konjuh". The aim of the paper is to assess the state of biodiversity of fruit-bearing species in the forest ecosystems of the study area, with the emphasis on determining the genus richness as a basis for conservation (in/ex situ), breeding and economic use. During the vegetation season in 2015 and 2016, several relevés (phytosociological plot) were made in the Protected Landscape "Konjuh". The results of the research indicate the high level of variability for most of the species according to characteristics of biology, pomology, and ecology. The fruit trees, like the noble hardwood, are wild cherry, (Prunus avium L.), wild pear (Pyrus communis L.), wild apples (Malus sylvestris Mill.), Breccia (Torminalis clusii M.Roem.), Sorbus aria L. et all, Wild cherry, Vrapcarka (Prunus avium L.) is the most famous forest fruit grower, occurs as a single tree or in smaller groups (Noćajević, 2009). The benefit *of* fruit-bearing forest species *are emphasized in the bloom and the fruiting time, when "decorated" forest provide a rich bee pasture and feeding nutriment for forest fauna (Orešković et al. 2006). Fruit-bearing forest species are significant as the genera of the varieties and as a basis for the grafting for high-grade varieties. Also, they are important for humans from the aspect of ecology, nutrition, dietotherapy, pharmacology, and bioenergy balance.*

***Keywords**: Biodiversity, Fruit-bearing forest species, Protected landscape "Konjuh", relevé (phytosociological plot), distribution.*

1. *INTRODUCTION*

According to ecologic-vegetative reionization (STEFANOVIĆ, et al. 1983), the area of the Konjuh mountain belongs to the area of the inner Dinarides. In the area of the Konjuh Mountain, there is the area of the protected landscape "Konjuh" belonging to the parts of the municipalities Banovići, Kladanj, and Živinice. The protected landscape "Konjuh" is the matrix of orchards, pastures, arable land, deciduous and coniferous forests, mixed forests, stony and scarce surfaces, scrubs. Fruit-bearing forest species are an important source of flora in these habitats. Protected landscape "Konjuh" has the potential and the opportunity to develop as the eco and the mountain tourism site, as well as strengthening the production of healthy/organic food. Forest is a fundamental natural resource in which the natural laws prevail. Often, it is under

negative pressure of the anthropogenic influence that disturbs the balance of biocenosis, time and biodiversity. Protected areas are not excluded from this process. Forest, because of its polyvalence, is the most complex and most universal integral ecological system that includes other ecosystems BOJADŽIĆ (2001). Although subject to various harmful effects, forests still represent the healthiest natural framework on earth, and nonwood products can be used in nutrition like extremely healthy foods. The primary ecological services of the forest are the oxygen production, food, and raw materials source, habitats for various plants and animals species, and various more benefit outside the mentioned spheres. In "Forest as a Factor of Development of Bosnia and Herzegovina" ŠAKOVIĆ (1996) said: "The poliversity of the forest as a natural resource is reflected in ecological, aesthetic, socioeconomic and other values". According to the statistics, the area of Bosnia and Herzegovina has about 1% of the protected areas. Protected Landscape "Konjuh" occupies about 2.9% of the territory of the Tuzla Canton. This paper observes significant biological diversity of the fruit-bearing forest species in this relatively small area (8.139,77 ha). Fruit-bearing forest species have enormous importance for the living world and their conservation in natural habitats is the general conservation interest in the Protected Landscape "Konjuh". *The* benefit *of* fruit-bearing forest species *are emphasized in the bloom and the fruiting time, when "decorated" forest provide a rich bee pasture and feeding nutriment for forest fauna* OREŠKOVIĆ et al. (2006). In order to maintain the biodiversity of fruit-bearing forest species, the primary task is to determine the richness of their genus as a basis for implementing further measures for its conservation (*in/ex situ*), breeding and economic use.

2. MATERIALS AND METHODS

The monitoring of the fruit-bearing forest species biodiversity in the area of the protected landscape "Konjuh" is an input for further conservation activities. For this purpose, we made relevé (phytosociological plot), according to the principles of the **Zurich–Montpellier school of phytosociology** (BRAUN-BLANQUET, J 1964, WESTHOFF, V. & E. VAN DER MAAREL 1973), in the period of 2015 and 2016. Plot area was 20x20 m (400m^2). As a sample of a wider area, we analyzed five (5) siteswithin the protected landscape "Konjuh" (northeast Bosnia): Mačkovac, Zlaći, Zobik, Bebrava, and Tisca. Each relevé contain set of general data: the identifying number, the date, the site's location, biogenic and physiognomic characteristics, the record of a responsible person, the plot size, and index of coverage and sociality for founded fruit-bearing forest species. Taxonomic keys were used to determine plant species ROTMAHLER (2000), HEGI (1906-1974), OBERDORFER (1994), DOMAC (1994), JAVORKA and CSAPODY (1991) Monitoring of ecological conditions was carried out at the plot sites. Location data were taken by Garmin GPSMAP 60CSx. The study area geological background is characterised by a eutric cambisol with serpentinites and peridotites. Particular emphasis is placed on orographic conditions (relief, altitude, exposition, slope). The orographic conditions modify the variation of climatic conditions in the investigated areas.

2.1 THE AIM OF THE RESEARCH

- To assess the state of biodiversity of fruit-bearing forest species in the Protected Landscape "Konjuh".

- To make an inventory of fruit-bearing forest species in the study area with data on quantitative participation of each plant species in the forest stand with the recommendation of conservation of founded biodiversity

2.2 SPECIFIC AIMS OF THE RESEARCH

- To make relevé (phytosociological plot) on fruit-bearing forest species in the part of the Protected Landscape "Konjuh", based on the principles of the **Zurich–Montpellier school of phytosociology** (Braun-Blanquet, 1964).

- To valorise the biodiversity of fruit-bearing forest species in the Protected Landscape of Konjuh (northeast Bosnia).

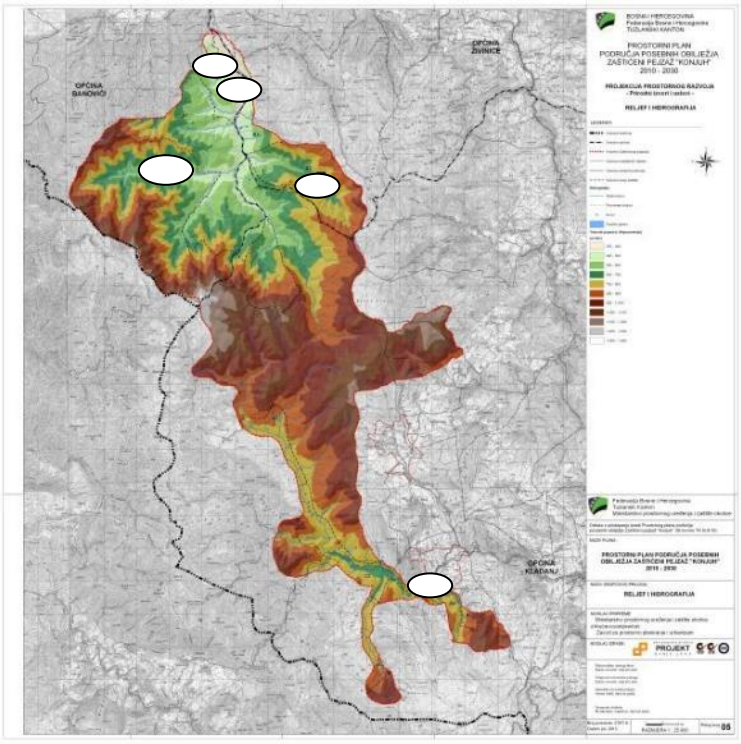


Figure 1: Map of the site on which research was conducted in Protected Landscape (ZP) Konjuh (source: http:// www.vladatk.kim.ba)

The possibility of separating ecotypes or autochthonous varieties from the aspect of conservation of fruit and biodiversity ex-situ, breeding and economic use of fruits is monitored. Priority was given to small-scale farmers, vulnerable and economically important.

3. *RESULTS AND DISCUSSIONS*

In the past, The Konjuh Mountain has been slightly floristically explored, and previous researchers have found only one floral association, Fagetum sylvaticae montanum. According to the syntaxonomic examination of Bosnia and Herzegovina, most of the founded plant species from The Konjuh Mountain belong to the Central European floral elements, i.e. class Querco-fagetea, the association Fagetum sylvaticae montanum, Qverco-Carpinetum illyricum (HORVAT et al.1974). Heterogeneous floral composition, especially within noble hardwood, shows significant ecological differences at the level of individual sites and indicates that The Konjuh Mountain should not be covered only by one floral association. According to ecologic-vegetative reionization (STEFANOVIĆ, et al., 1983), the area of The Konjuh Mountain belongs to the area of the inner Dinarides. The protected landscape ‘’Konjuh’’ belongs to the northern temperate geographical zone, with favourable ecological conditions and rich plant diversity (NOĆAJEVIĆ et al., 2011). At the surface of 8.139,77 ha and at the altitude of 300 - 1.328 meters, the Protected Landscape "Konjuh" occupy the 2,9% of the Tuzla Canton territory, and consist mainly of forests within the municipalities of Banovići, Kladanj and Živinice (source: http: /www.zpkonjuh.ba/). The area is abundant with fruit-bearing forest species. In 2015 and 2016, we found, in the form of individual trees, groups of trees, several plantations of fruit trees, scattered over the protected landscape "Konjuh". About 20 different fruit-bearing forest species have been identified by this research: Malus sylvestris (Mill), Pyrus pyraster (L.) Burgsd. Prunus avium (L.), Aesculus hippocastanum, Juglans regia, Sorbus torminalis (L.), *Sorbus aria* (L.), Sorbus aucuparia , Sorbus domestica , Prunus cerasifera (Ehrh.), Corylus avellana (L.), Cornus mas, Prunusspinosa, Cratacgus oxyacantha (L.) , Vaccinium myrtilus (L.), Rubus caesius (L.), Rubus idaeus (L.), Fragaria vesca (L.), Rosa canina (L.), Sambucus nigra.

Figure 2: Fruit trees in the fruiting phase

Table 1. Phytocenological record in five (5) explored sites in ZP Konjuh

Number of recording	I	II	III	IV	V
Region	**Mačkovac**	**Zlaća**	**Zobik**	**Bebrava**	**Tisovac**
Surface of recording (m)	20 x20	20 x20	20 x20	20 x20	20 x20
Elevation	450m	330m	550m	610m	500m
Exposition	SW/S-E	SE/N-E	SW/S-E	S/S-W	SE/N-E
Tilt (°)	13°	9°	15°	16°	17°
Geological background	peridot	serpenit	eutrični kambisol	Serpent	peridot
Coverage (%)	65	70	71	80	60
Prunus avium L.	3.3	4.3	3.2	1.2	2.3
Malus sylvestris Mill.	1.2	1.2	1.3	3.3	2.1
Pyrus pyraster (L.) Burgsd.	1.1	2.1	3.1	2.2	+
Aesculus hippocastanum	+	+	+	+	+
Sorbus torminalis (L.)	+	+	+	+	+
***Sorbus aria* (L.)**	+	+	+	1.1	+.1

Sorbus aucuparia	1.1	1.1	1.2	1.2	1.2
Sorbus domestica	+	+	+	+	+
Prunus cerasifera Ehrh.	3.3	2.2	2.1	3.1	3.2
Corylus avellana L.	3.4	3.3	3.3	3.2	2.1
Juglans regia	2.2	3.2	1.2	+	1.1
Cornus mas	1.1	+	+	2.1	2.2
Prunus spinosa	2.3	2.3	+	2.1	1.1
Cratacgus oxyacantha L.	4.3	3.2	4.2	4.3	2.1
Vaccinium myrtilus L.	1.2	2.1	4.3	4.3	3.3
Rubus caesius L.	3.3	3.4	4.2	4.2	3.1
Rubus idaeus L.	3.2	3.3	*3.4*	3.1	3.4
Fragaria vesca L.	3.4	4.3	3.3	4.3	4.3
Rosa canina L.	1.2	2.1	2.1	+.2	2.2
Sambucus nigra	2.2	3.1	3.2	3.2	2.1
2015/2016	*Klasa QUERCO-FAGETEA, asocijacija Fagetum sylvaticae montanum,Qverco-Carpinetum illyricum (Horvat et al.1974)*				

These fruit trees grow in a moderate continental climate, just as they are in the study sites localities. It belongs to the Cfb climate group. The main characteristic is annual air temperature fluctuations with a sharp rise from January to July, and a gradual fall to December. Vegetation period lasts from 180 to 190 days, as it is in Kladanj region. The forest layers are clearly expressed at study sites with a clear difference between the layers: the trees - the shrub – the herbaceous plants. The fruit - bearing trees as forest species contribute to the of the biodiversity of forest ecosystems. The tree and shrub species are represented by 19 plant species, and dominant is the wild cherry (Prunus avium L.), which is widespread in The Konjuh mountain, occurs as a single tree along the roads or in smaller groups NOĆAJEVIĆ (2009), (see Chart 1. for details).

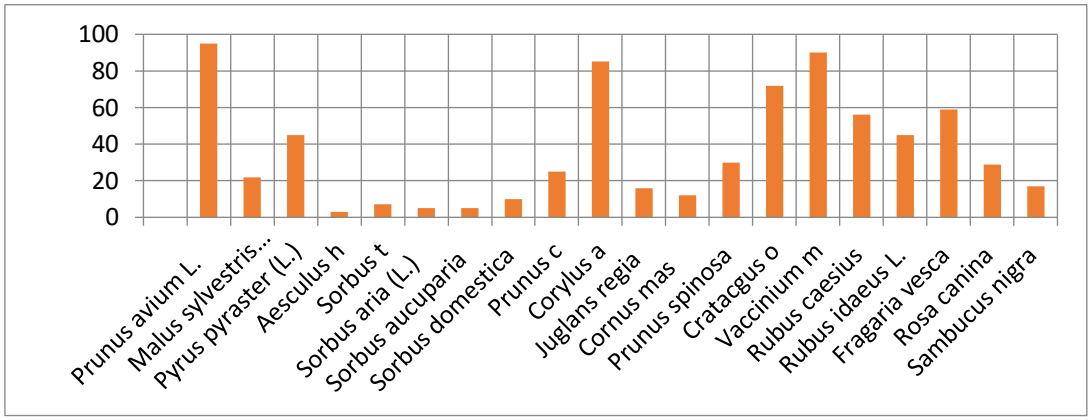


Chart 1: Numerical presentation of forest fruit trees in ZP Konjuh, 2015

It can be easily see in Ctart 2. that The most frequent found fruit plant is the blueberry (Vaccinium myrtillus L.) as it is suitable for sour and moderately wet soil.

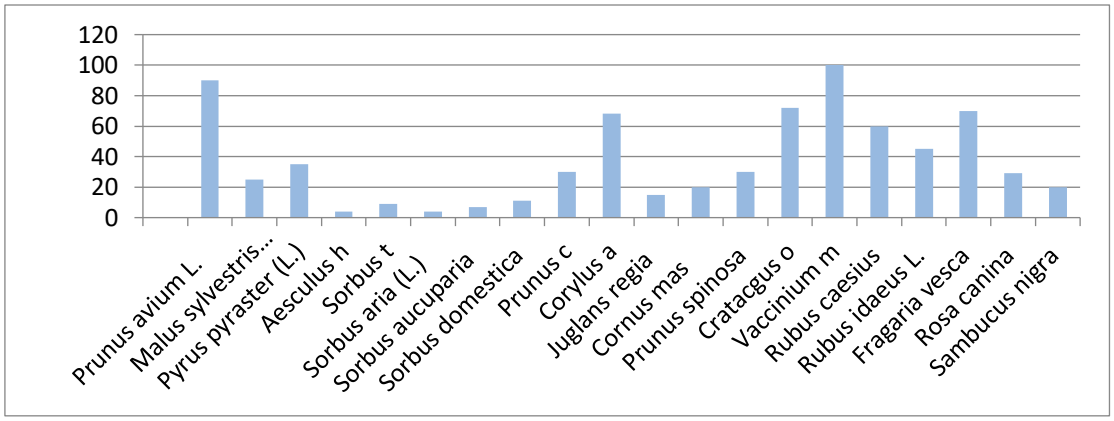
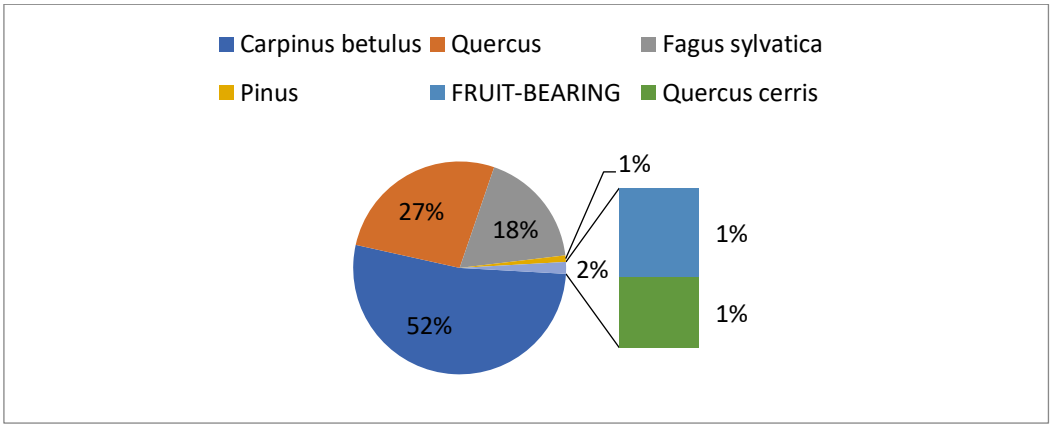


Chart 2: Numerical presentation of forest fruit trees in ZP Konjuh, 2016

Also in two years of research, wild cherry is among the most common fruit trees in the protected landscape "Konjuh". It is an important autochthonous species of Bosnian forests and as such, it can be considered as the moist favor material for the creation of many varieties of cherries in fruit growing. Wild cherry is very important for the conservation of biodiversity. It is why the wild cherry is called "tree of the future" BALLIAN (2002). This is confirmed by the high price of technical wood in the world market. We have found seedling nearby several full growth mother trees, which are in the full fruiting phase (wild cherries, wild pears, wild apples, dwarfs, hawthorn, scabies, and walnut trees). It can be considered as natural rejuvenation mechanism what is particularly important for conservation issues. The fruit trees are mostly found in the

forest edges, along the forest roads, and at the opening. Not so frequent, but also found deep in the forest (see Chart 3. for details).



Graph 3: Representation of wood mass in Bosnia and Herzegovina

All mention above shows us the significant biodiversity level of primordial ecosystems and taxa in the area of the Protected Landscape "Konjuh". It is necessary to use this area on the principles of maximum protection and sustainability of existing natural values.

3.1 Cherry Wild, Prunus (Prunus avium) – is important in preserving biodiversity and is also the earliest seasonal forest fruit at the same time as stone fruit. Wild cherry is red to blackish, it is very healthy fruit. The fruit is smaller and slightly more acidized than the homemade cherry, but very sophisticated. It eats fresh, suitable for the preparation of jams, compotes, etc. It contains 80% water, levoose, pectin, organic acid (apple, citrus, wine), vitamins C, B and carotene, rich in potassium. Especially abounds with phenols and polyphenols, and can be used as natural antioxidants.

3.2 Blueberries (*Vaccinium myrtilus**)*** are a significant part of biodiversity in ZP "Konjuh", they are classified into a group of berry fruits characterized by its intense red and purple color. Carriers of this color are pigments from the group of bioflavonoids, more precisely anthocyanins, and the color of the fruit is more intense means that the fruits are richer in these healing substances. The nutritionists put it at the level of the healthiest fruit.

3.3 Wild apple (*Malus sylvestris)* – a significant contribution to the biodiversity of ZP "Konjuh", contains sugar, pectin, tannin, gallotanin, vitamins A, B and C, essential oil, phosphorus, geraniol, acetaldehyde, apple, ant, carnese and citric acid . The fruit tastes very sour.

3.4 Wild pear (*Pyrus pyraster*) – a part of the floristic richness in ZP "Konjuh" contains proteins, sugar, starch, pectin, tannin, silicic and phosphoric acid (ideal brain food), mucus and ballast.

3.5 Dwarf (*Prunus cerasifera*) – the fruits are smaller, red, orange or other colors, of the egg shape. Contains minerals: potassium, phosphorus, magnesium, vitamins: A (beta-carotene), B group and vitamin C. Medicinal properties: acting laxative.

3.6 Scrub(*Sorbus domestica*) – Representatives of this genus are characteristic of forest biodiversity, they are found as soliter trees in the investigated areas and the fruit contains sugar, pectin, tannin, carotenoid, vitamin C, organic acids (apple, wine and citrus) and rubber. Ethnobotanical research in the Bosnian-Herzegovinian region shows that the products of wild cherry, wild apples and pears were used in the treatment and prevention of metabolic diseases (diabetes) REDŽIĆ et al. (2007). As far as the Pyrus pyraster fruits are produced, well-known dried hoshaph (used for compote) with very high stability, and today, from the ripe fruits of Malus sylvestris, found in clean ecological environments such as forests, they produce delicious compotes, juices (apple vinegar), sour jam that represents top quality healthy food in the prevention of all diseases (including metabolic diseases). This fruit juice is a natural high-value multivitamin drink. Excellent fruit tea JASIC (2007) is prepared from mixed fruits of dry wild fruit.

3.7 Wild scrub (Sorbus torminalis) is a slow-growing deciduous tree, at the same time the strongest tree in Europe, grows up to 25 meters in height, and sometimes more. It has a rounded, much branched, dense crochet and erecting branches. After the first cold, the fruits become edible and tasty. The plant propagates with seed and vegetative. The rocks have a strong firing force from the roots, so that the trees of the same genotype can be found around the tree.

3.8 Wild strawberries (*Fragaria vesca***)** abound in phytochemical compounds from the group of antioxidants, such as procyanidine, elaginic acid and elagitinin, and pelargonidine, the main compound from the group of anthocyanins, which is responsible for the characteristic red strawberry color.

Forestry fruit trees as an integral part of forest ecosystems also contribute significantly to the polyvalent functions of the forest. Distribution of fruit trees in forest habitats significantly contributes to feeding animals. From the original name of the cherry tree, bird cherries (sparrows) can be concluded that most of the birds contributed to its distribution. In the studied areas of the Konjuh mountain, it was noticed that there are mostly wild cherries, and very few breeders (Sorbus torminalis) and Torminalis clusii and if their habitats are suitable. Genofond breeds, mussels and scabies should be preserved as noble herbivores and provide seedling production in order to create highly valuable crops with stems of favourable biomorphological properties IDŽOJTIĆ (2004).

4. CONCLUSIONS

- About 20 different fruit-bearing forest species have been identified by this research: Malus sylvestris (Mill), Pyrus pyraster (L.) Burgsd. Prunus avium (L.), Aesculus hippocastanum, Juglans regia, Sorbus torminalis (L.), Sorbus aria (L.), Sorbus aucuparia , Sorbus domestica , Prunus cerasifera (Ehrh.), Corylus avellana (L.), Cornus mas, Prunusspinosa, Cratacgus oxyacantha (L.) , Vaccinium myrtilus (L.), Rubus caesius (L.), Rubus idaeus (L.), Fragaria vesca (L.), Rosa canina (L.), Sambucus nigra.

- In the studied areas of the Konjuh Mountains, there are mostly individuals with wild cherries (Prunus avium), blueberries (Vaccinium myrtilus) and a very small number of breeders (Sorbus torminalis) and Torminalis clusii and their habitats.
- Forest fruit trees as rare and endangered species should be left in the group in which they are in natural habitats, and in particular mother trees, ie, in this way natural reproduction and distribution would be preserved, and certainly better quality biodiversity in forest ecosystems would be ensured.
- The biodiversity of forest fruit trees in ZP Konjuh is important and can contribute to the implementation, management tools and define guidelines for further monitoring and specific conservation measures, focusing on sustainable management and improvement of this area and its overall biodiversity.

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The Macrophyte Flora and Vegetation of the Paučko Lake (Mt. Konjuh)

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ABSTRACT

The study presents the first data on biodiversity of macrophyte flora and vegetation of Paučko Lake, which is recognized as an area of great natural, landscape and hydrological value in the Protected Landscape "Konjuh". Paučko Lake has a small surface and it's located at 711 m a.s.l. in the catchment area of the Drinjača River. The aquatic and marsh vegetation was studied during spring and summer in 2018 using the traditional Zürich-Montpellier approach. The vegetation of Paučko Lake is comprised of aquatic and marsh associations of the classes Potamogetonetea Klika in Klika et Novák 1941 and Phragmito-Magnocaricetea Klika in Klika et Novák 1941. The following aquatic and marsh plant associations were identified: Myriophyllo-Potametum Soó 1934, Scirpo-Phragmitetum australis W. Koch 1926, Thelypterido palustris-Phragmitetum australis Kuiperex van Donselaar et al. 1961, Schoenoplectetum lacustris Chouard 1924, Typhetum latipholiae Lang. 1973 and Scirpetum silvatici Ht et H-ić prov. (in Ht et al.1974). Rare vulnerable taxa Thelypteris palustris Schott and Menyanthes trifoliata L. were recorded in emerged littoral communities, whose habitats are under successional changes caused by excessive macrophyte overgrowth by competitor species. Restoration measures are necessary to be taken to preserve the habitats of endangered species of the Paučko Lake.

Key words: biodiversity, flora, Konjuh, macrophytes, Paučko Lake, vegetation

1. INTRODUCTION

Macrophytes play an important structuring role in shallow freshwater bodies by reducing water turbidity, competing with phytoplankton by taking up nutrients from the water, enhancing the density of surface-associated organisms, changing oxygen conditions, having a significant impact on phosphorus and nitrogen dynamics and pH. Macrophytes have an importance for the food web interactions and environmental quality of lakes (Scheffer & Jeppesen, 1998). Studies of the aquatic and marsh communities in Bosnia and Herzegovina have been known for the Hutovo blato Natural park (Jasprica & Carić, 2002; Jasprica et al., 2003), Bardača (Kovačević & Stojanović, 2008), Sava river basin floodplains (Redžić et al., 2009), Velika Tišina (Bjelčić, 1954), karstic rivers (Lasić et al., 2014) and several mine pit lakes (Kamberović & Barudanović, 2011; 2012; Kamberović et al., 2014). Shallow mountain lakes of Bosnia and Herzegovina are often densely overgrown with macrophytic vegetation. Paučko Lake, which is recognized as an area of natural, landscape and hydrological value of the Protected Landscape Konjuh in north-eastern Bosnia and Herzegovina (Vujatović et al., 2013) is a good example of this process. The previous research of the Paučko Lake as a wider locality site is known from the initial study on

biodiversity of the Protected Landscape "Konjuh" (Public Institution Protected Landscape Konjuh, 2017), whilst detailed data on the floristic diversity and vegetation of this lake is missing. Previous floristic research on the Konjuh Mountain was conducted by Ritter-Studnička (1963) focusing on the vegetation on serpentines and peridotites, and by Kamberović (2015), and Kamberović et al. (2016) focusing on algae and macrophytes in spring ecosystems. The objective of this paper is to describe floristic composition of the aquatic and marsh plant communities of the Paučko Lake, with a special emphasis on the conservation status of the plants and associations.

2. MATERIALS AND METHODS

2.1 Methods

Phytocenological relevés were carried out using the Zűrich–Montpellier approach in two vegetation seasons in 2018 (Braun-Blanquet, 1964). Determination of plants was done according to the following literature: Tutin et al., eds. (1964-1993), Domac (2002) and Javorka & Csapody (1979).

The nomenclature of syntaxa follows Barudanović et al. (2015), Mucina et al. (2016) and Šumberová et al. (2011). Sociability of plant species and environmental factors (temperature, humidity, soil acidity, nitrification, light, continentality, and salinity) are given according to Ellenberg (Borhidi, 1993). Threatened plant species of the investigated sites are determined in accordance with Đug et al. (2013).

2.2 Study area

Paučko Lake is a small lake located at 711 m a.s.l. in the catchment area of the Drinjača River in the Protected Landscape Konjuh, north-eastern Bosnia and Herzegovina (N 44°14´01.61´´, E 18°36´05.51´´). It's fed from two streams and its surface is 0.44 km2 (Vujatović et al., 2013). The area is characterized by moderate-continental climate (Stefanović at al., 1983). Phytocoenological researches were done on nine locations, marked on the Figure 1 as L1-L9.

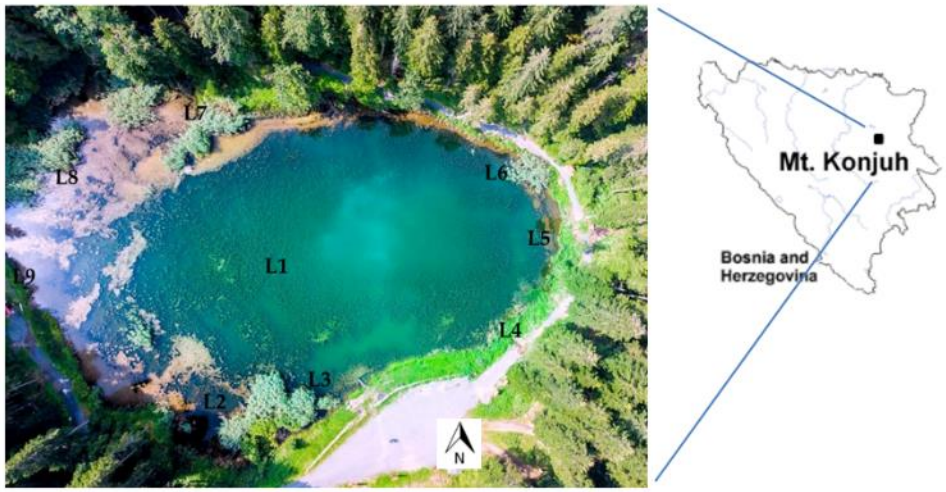

Figure 1. Study area – Paučko Lake (photy by Almir Čamdžić)

RESULTS AND DISCUSSION

2.3 Flora and vegetation of the Paučko Lake

The macrophyte flora is comprised of 30 taxa in total. The dominant aquatic submerged macrophyte is the eurasian water-milfoil Myriophyllum spicatum L., which covers almost the entire bottom of the lake in the summer aspect. It is a competitive species, which forms a mono-dominant plant community at the Paučko Lake. Besides the above mentioned species, very abundant were the following taxa: Typha latifolia L., Phragmites australis (Cav.) Steud, Scirpus sylvaticus L., Carex paniculata L. and Solanum dulcamara L. A total of two identified taxa are listed as threatened, Menyanthes trifoliata L. and Thelypteris palustris Schott (a vulnerable threat category). Both taxa are recorded on the southern shore of the lake. Menyanthes trifoliata has a declining population size trend in neighbouring countries Hungary, Italy and Croatia where it is classified as an endangered species (http://www.iucnredlist.org/details/ 163993/0). According to Đug et al. (2013), this species had been recorded in Bosnia and Herzegovina in several karst fields and peats. The species Thelypteris palustris typically grows on fine substrates, peat bogs, shores of ponds and alluvial deposits along the river. It comes in a reed community at the Paučko Lake in an islet plant community.

During the investigation, we recorded only one endemic species Knautia sarajevensis (Beck) Szabó. The most common macrophyte taxa are shown on the Figure 2.

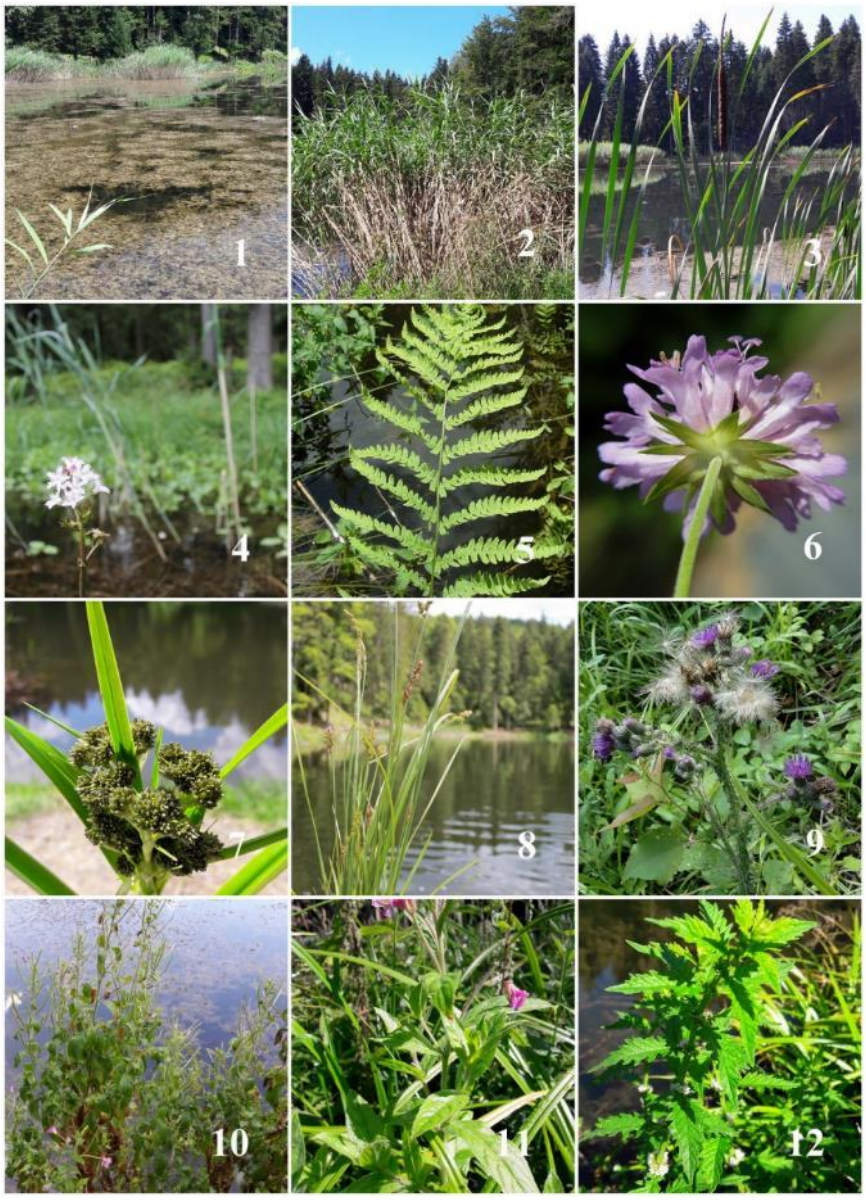

Figure 2. The common macrophyte taxa of the Paučko Lake 1 - Myriophyllum spicatum L., 2 - Phragmites australis (Cav.) Steud., 3 - Typha latifolia L., 4 - Menyanthes trifoliata L., 5 - Thelypteris palustris Schott, 6 - Knautia sarajevensis (Beck) Szabó., 7 - Scirpus sylvaticus L., 8 - Carex paniculata L., 9 - Cirsium palustre (L.) Scop., 10 - Epilobium parviflorum Schreber., 11 - Epilobium hirsutum L., 12 - Lycopus europaeus L

The vegetation of the Paučko Lake is comprised of six plant associations within two classes.

Class: POTAMOGETONETEA Klika in Klika et Novák 1941

Order: Potamogetonetalia Koch 1926

Alliance: *Potamogetonion* Libbert 1931

1. Ass. *Myriophyllo-Potametum* Soó 1934

Class: PHRAGMITO-MAGNOCARICETEA Klika in Klika et Novák 1941

Order: Phragmitetalia Koch 1926

Alliance: *Phragmition communis* Koch 1926

2. Ass. *Scirpo-Phragmitetum australis* W. Koch 1926

3. Ass. *Typhetum latifoliae* Lang. 1973

4. Ass. *Schoenoplectetum lacustris* Chouard 1924

Order: Magnocaricetalia Pignatti 1953

Alliance: *Magnocaricion elatae* Koch 1926

5. Ass. *Scirpetum silvatici* Ht et H-ić prov. (in Ht et al.1974).

Alliance: *Carici-Rumicion hydrolapathi* Passarge 1964

6. Ass. *Thelypterido palustris-Phragmitetum australis* Kuiperex van Donselaar et al. 1961

The following taxa are characteristic for vegetation classes Potamogetonetea and Phragmito-Magnocaricetea: *Myriophyllum spicatum* L., *Phragmites australis* (Cav.) Steud., *Typha latifolia* L., *Menyanthes trifoliata* L., *Schoenoplectus lacustris* (L.) Palla, *Sparganium erectum* L., *Thelypteris palustris* Schott, *Solanum dulcamara* L., *Carex paniculata* L., *Scirpus silvaticus* L., *Lycopus europaeus* L., *Veronica beccabunga* L., *Epilobium hirsutum* L., *Epilobium parviflorum* Schreber., *Hypericum tetrapterum* Fr., and *Cirsium palustre* (L.) Scop..

Species compositions of all recorded communities are summarised in the Table 1.

Table 1. The phytocenological relevés of aquatic and marsh vegetation of the Paučko Lake

Associations	**1**		**2**		**3**		**4**				**5**		**6**	
Relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Localities	1	1	6	8	5	5	7	7	2	2	3	3	4	9
Date 2018	17.5.	14.8.	14.8.	14.8.	17.5.	14.8.	17.5.	14.8.	17.5.	14.8.	17.5.	14.8.	14.8.	14.8.
Water depth (cm)	90	90	30	50	30	20	20	20	30	30	-	-	-	-
Area of relevé (m^2)	50	50	50	50	20	20	50	50	20	20	100	100	50	50
Density (%)	60	70	80	100	70	60	70	70	40	50	100	100	100	100
Taxa														
Characteristic species of the ass. of the alliance *Potamogetonion*														
Myriophyllum spicatum L.	4.5	4.5	2.2					2.2	1.2	1.2				
Characteristic species of the ass. of the alliance *Phragmition communis*														
Phragmites australis (Cav.) Steud.			5.5	5.5					1.2		4.4	4.5		
Typha latifolia L.					1.2	+.1	4.4	4.5	1.1	2.2	+.1	1.2		+.1
Menyanthes trifoliata L.									3.2	2.1	+.1	+.1		
Schoenoplectus lacustris (L.) Palla					3.3	3.3								
Sparganium erectum L.								+.1						
Characteristic species of the ass. of the alliance *Carici-Rumicion hydrolapathi*														
Thelypteris palustris Schott											2.2	2.3		
Solanum dulcamara L			+.1	+.1	2.3	1.1	1.1		1.1	+.1	1.1	+.1	+.1	+.1
Characteristic species of the ass. of the alliance *Magnocaricion elatae*														
Carex paniculata L.			1.3		1.3	+.3	3.3	2.3	1.3	1.3			+.3	+.2
Scirpus silvaticus L.				1.3				+.1					4.5	5.5
Characteristic species of the ass. of the class *Phragmito-Magnocaricetea*														
Lycopus europaeus L.			+.1			+.1	1.2	+.1	1.1	+.1			1.1	+.1
Veronica beccabunga L.								+.1					+.1	
Epilobium hirsutum L.						+.1		+.1					+.1	+.1
Epilobium parviflorum Schreber.													+.1	
Hypericum tetrapterum Fr.													+.1	
Cirsium palustre (L.) Scop.								+.1						

Accessory species								
Athyrium filix-femina (L.) Roth.								+.1
Salix cinerea L.						1.2	2.3	1.1
Eupatorium cannabinum L.			+.1				+.1	+.1
Angelica sylvestris L.				+.1		1.1	+.1	
Galeopsis speciosa Mill.								1.2
Juncus effusus L.							+.2	+.1
Juncus inflexus L.							+.2	
Lysimachia nummularia L.					1.2		+.1	1.1
Mentha longifolia (L.) L.							1.1	
Pteridium aquilinum (L.) Kuhn								+.1
Ranunculus repens L.						+.1	+.1	
Sonchus asper (L.) Hill ssp. Asper.							+.1	
Urtica dioica L.							+.1	
Knautia sarajevensis (Beck) Szabó.								+.1

Associations:

1- *Myriophyllo-Potametum* Soó 1934
2- *Scirpo-Phragmitetum australis* W. Koch 1926
3- *Schoenoplectetum lacustris* Chouard 1924
4- *Typhetum latifoliae* Lang. 1973.
5- *Thelypterido palustris-Phragmitetum australis* Kuiperex van Donselaar et al. 1961
6- *Scirpetum silvatici* Ht et H-ić prov. (in Ht et al.1974)

Ass**.** ***Myriophyllo-Potametum*** Soó 1934 comprises vegetation of rooted macrophytes of mesotrophic and eutrophic freshwater bodies at low and mid-altitudes of temperate Eurasia (Mucina et al., 2016). The floristic composition of this association at Paučko Lake is made of only one species - *Myriophyllum spicatum,* indicating low diversity and a disturbed ecosystem function of the lake (Figure 3a). Similar to the situation on the Paučko Lake, Eurasian water milfoil took a dominant role in the colonization processes of macrophytes in pit lakes in north-eastern Bosnia (Kamberović & Barudanović, 2012).

Ass. ***Scirpo-Phragmitetum australis*** W. Koch 1926 comprises reed swamp vegetation of mesotrophic and eutrophic standing freshwater bodies of boreo-temperate Eurasia (Mucina et al., 2016). It grows on coastal areas in the northern and north-eastern shores of the lake with the water depth of 0.3 - 0.5 m. The floristic composition is made of dense stands of *Phragmites australis*, and several less abundant taxa (*Carex paniculata, Myriophyllum spicatum*), or pioneer species of secondary successions (*Solanum dulcamara, Lycopus europaeus*). Due to the small depth of the lake, the community penetrates into the open water surface and has a high potential of causing an overgrowth of the lake (Figure 3b). In comparison with stands on Natural park Hutovo Blato (Jasprica et al., 2003) with 12 to 20 taxa, and those on the shores of pit lakes (Kamberović et al., 2014), with 8 to 26 taxa, communities on the Paučko Lake are less diverse (5 taxa).

Ass. ***Schoenoplectetum lacustris*** Chouard 1924 is dominated by *Schoenoplectus lacustris*, a leafless species that forms sparse stands. It occurs on the eastern shore of the lake in water depths of 0.3 m. It forms a discontinuous zone between the open water and littoral sedge vegetation. The community has poor floristic composition with only seven taxa (Figure 3c).

Ass. ***Typhetum latifoliae*** G. Lang 1973 was observed at two sites on the Paučko Lake - on the southern and northern coast, in shallow water. It's dominated by *Typha latifolia*. The community at the southern shore is important for conservation, as it is inhabited with vulnerable species in B&H - *Menyanthes trifoliata* L.. On the other hand, high overgrowing potential of cattail community on the northern shore was observed (Figure 3d).

Ass. ***Scirpetum silvatici*** Ht et H-ić prov. (in Ht et al.1974) is a sedge-bed marsh vegetation on oligotrophic to mesotrophic organic sediments of temperate Europe. It grows on almost the entire coastal area of the lake and relies on reed or cattail communities at the Paučko Lake. The community consists of the highest number of taxa compared to the other described communities, dominantly *Scirpus silvaticus* and *Carex paniculata* (Figure 3e).

Ass. ***Thelypterido palustris-Phragmitetum australis*** Kuiperex van Donselaar et al. 1961 belongs to the alliance *Carici-Rumicion hydrolapathi* Passarge 1964., or herbland vegetation on non-stabilized organic substrates in mesotrophic waters of boreal and temperate Eurasia. The association grows on an islet of 50 m^2 on the Paučko Lake (Figure 3f). It is dominated by *Phragmites australis*, with participation of the wetland fern. It is a rare vegetation type of mesotrophic fishponds in northern and southern Bohemia (Czech Republic) where it occurs as floating islets in 30–100 cm deep water. This marsh type has not been recorded earlier in Bosnia

and Herzegovina, and it is valuable because of the plant species, e.g. *Menyanthes trifoliata* and *Thelypteris palustris*.

Figure 3 . Identified plant associations at the Paučko Lake – a) Myriophyllo-Potametum Soó 1934, b) Scirpo-Phragmitetum australis W. Koch 1926, c) Schoenoplectetum lacustris Chouard 1924; d) Typhetum latifoliae G. Lang 1973 , e) Scirpetum silvatici Ht et H-ić prov. (in Ht et al.1974), f) Thelypterido palustris-Phragmitetum australis Kuiperex van Donselaar et al. 1961

2.4 Ecological analysis of associations

Ecological indexes of plant species from the analyzed communities indicate that studied communities appear on alkaline (R=6.5-8), non-salinated (S<1), well exposed to sunlight or shaded occasionally (L=5.7-7.25), briefly flooded or submerged (W=7.9-12) and mesotrophic soils (N=5-7) with moderate heat requirements of their habitats (T=5.1-5.8). Communities are characterized by a large proportion of sub-oceanic species which find their main areal in Central Europe (K=3-4) (Figure 4). In comparison with other studied communities, ass. *Myriophyllo-Potametum* has the lowest requirement for light, whilst ass. *Schoenoplectetum lacustris* has the highest requirement for nitrogen in soil. Results of ecological analysis of identified marsh communities are very similar to the research of Kamberović et al. (2014) on marsh communities of pit lakes in north-eastern Bosnia.

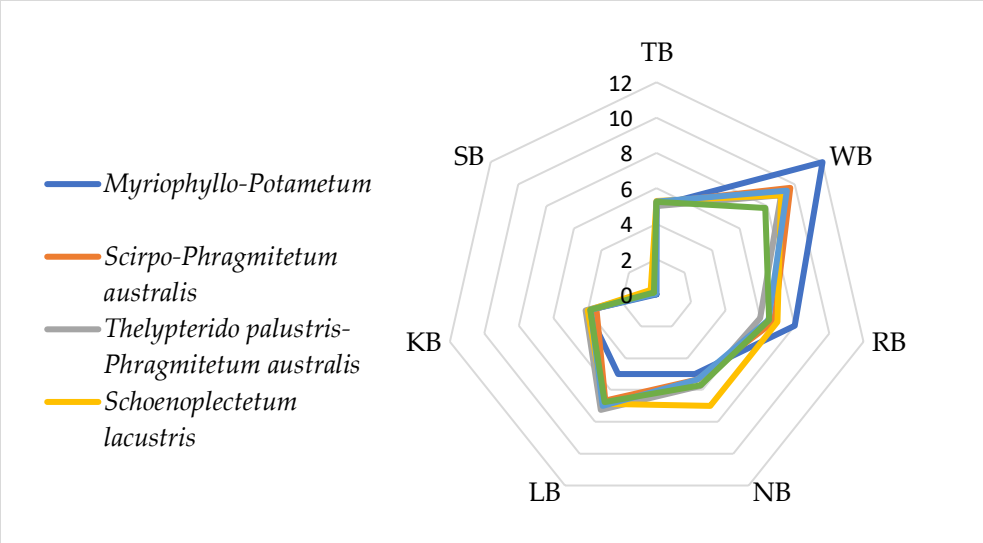

Figure 4. Ecological analysis of the studied associations (T - temperature, W - humidity, R - soil acidity, N - nitrification, L - light, K - continentality, S - salinity)

2.5 . Biological spectrum and sociability of plant species

The most dominant life forms are hydrophytes and hemicriptophytes. Geophytes, chamaephytes, and especially therophytes had the lower contribution (Figure 5). Comparing the biological spectrum, the studied communities are more similar to the stands in Serbia studied by Polić (2006), and Croatia (Stančić, 2010), than those on artificial pit lakes in north-eastern Bosnia (Kamberović et al., 2014), due to the high contribution of therophytes in pit lake marsh communities.

Analyzing the spectrum of sociability of the plant species, the most frequent are competitive taxa and pioneering elements of secondary successions (Figure 6). Associated plant species had less contribution. Several taxa belong to the group of sensitive indicators (Thelypteris palustris, Menyanthes trifoliata, Veronica beccabunga). On the other hand, competitor species such as Phragmites australis, Typha latifolia and submerged Myriophyllum spicatum play an important role in the intense process of plant owergrowth of the lake.

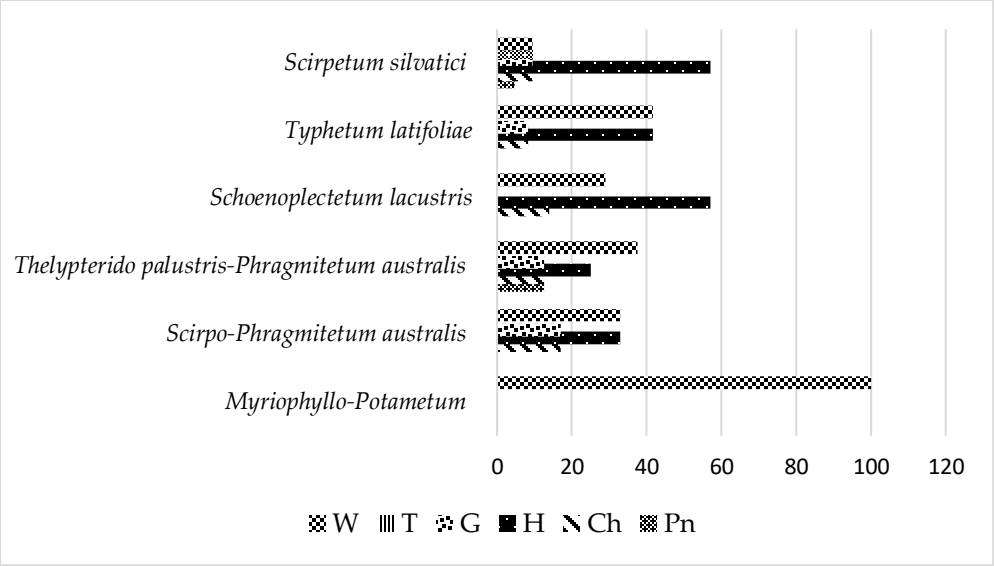

Figure 5. The biological spectrum of the studied associations: W – hydrophytes, T - therophytes, G - geophytes, H – hemicriptophytes, Ch - chamaephytes, Pn – phanerophytes

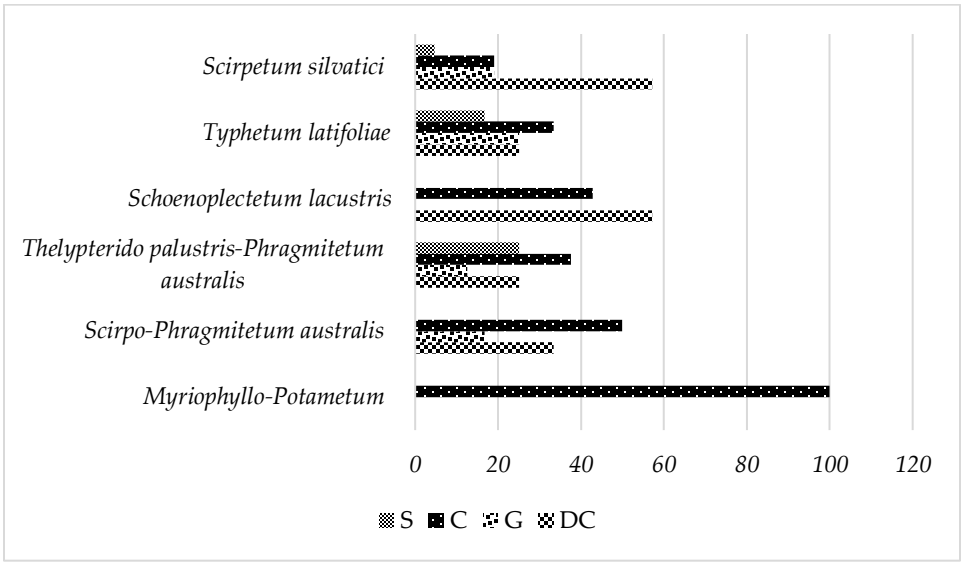

Figure 6. The social behaviour types spectrum of the studied associations

S - sensitive species, C - competitors, G - associated plant species, DC - pioneer species of secondary successions

Exploring the possibility of using helophytes as bioindicators of lake overgrowth based on long-term changes, Lawniczak-Malińska and Achtenberg (2018) concluded that lakes which currently exhibit the highest degree of overgrowth were shown to have been affected by intensive littoral growth for over 100 years. Overgrowth of helophytes on the Paučko Lake, followed by the production of submerged plants have a tendency of reducing the water surface and gradual succession of the lake into a swamp ecosystem. High productivity plants characterized by a fast growth rate, lead to the large coverage of vegetation with low taxonomic differentiation (Liira et al. 2010). This process is observed on the Paučko Lake, where the common reed, cattail and

eurasian water-milfoil dominate in plant communities, and can gradually lead to the disappearance of the rare and vulnerable taxa.

3. CONCLUSION

Paučko Lake is under high pressure caused by gradual shallowing and overgrowth by competitor species. All the while the high proportion of emerged and submerged macrophytes characterizes lake overgrowth. Six plant associations were recognized, within which a rare community Thelypterido palustris-Phragmitetum australis is observed. Rare vulnerable taxa were recorded in emerged littoral communities, whose habitats are under successional changes caused by excessive macrophyte overgrowth. Restoration measures are necessary to be taken in order to prevent the gradual disappearance of the lake.

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The Diversity of Trematodes in Fishes from the Middle Course of the River Sava (Bosnia and Herzegovina)

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ABSTRACT

The prevalence and intensity of trematodes ectoparasites in freshwater fish are presented in this paper. Parasitology researches were conducted during 2017 in the middle course of the river Sava near Orašje. All results from this study were tested with the use of nonparametric tests (χ2, Kruskal-Wallis test and Spearman test of corellation) in the statistical package STATISTICA 7. The total of 400 sampled specimens of different fish species were parasitologically tested. The trematodes from the class Monogenea (Dactylogyrus, Gyrodactylus and Eudiplozoon nipponicum) and Digenea (Posthodiplostomum cuticola) were found on the skin and the gills of the fish. The genus Dactylogyrus was found on 27 specimens, or 6.75%. Intensity of the infection for the genus Dactylogyrus did not show any significant deviations during different seasons. Parasites from the genus Gyrodactylus were found on the skin and the gills of 40 infected specimens, dominantly found on the gills. The species Eudiplozoon nipponicum was found in low prevalence in the total ichthyo sample of 1.75%. The presence of the species Posthodiplostomum cuticola is established in 18 specimens and the prevalence of the infection in total sample was 4.5%.

Key words: The Sava River, biodiversity, trematodes, fish

1. INTRODUCTION

Ichthyofauna researches of river Sava have shown that it is a typical cyprinid fish river flow (reference). Parasite researches of fish living in river Sava have shown an enormous biodiversity, still data regarding fish trematodes in our freshwater are scarce. Important contribution in study of trematodes in fish from our big rivers was provided by Čanković (1963) who discovered the presence of 17 species of digenetic trematodes.

Parasitological studies enable us evaluate the value of fish as nutritional products, and to identify the parasites that are dangerous to people and animals. Because of that, study of trematodes represents a special interest, because there are species of parasites, especially trematodes that can be transferred to humans (reference). Researches of fish parasites living in river Sava have shown the presence of trematode species from classes: Monogenea and Digenea (reference). In order to analyse the current state of diversity and ecological characteristics of fish populations of river Sava, it is necessary to determine the fish species diversity in river Sava, presence of parasites in researched fish species and the seasonal dynamic of parasite appearance.

2. MATERIAL AND METHODS

In order to determine the presence of trematodes in fish in the middle flow of river Sava, parasitological researches was conducted on 400 fish specimens that were collected in 2017. Sampling of fish was performed on the area of middle flow of river Sava on two locations, marked as: Tolisa (45°3'42.44"N; 18°38'14.07"E) and Orašje (45°2'29.53"N; 18°41'26.37"E). Full length of longitudinal profile of research was around 15 kilometers from West towards East.

In the research, trawling nets with eyelet diameter of 25 mm and 100x100 cm dimensions were used, as well as stationary nets with eyelet diameter of 50 mm, and dimensions up to 12 meters. The parasitological researches were performed on the spot, on fresh material, because vegetative forms of trematodes die very quickly after the death of a host. Researches were focused on study of skin, fins and gills of fish.

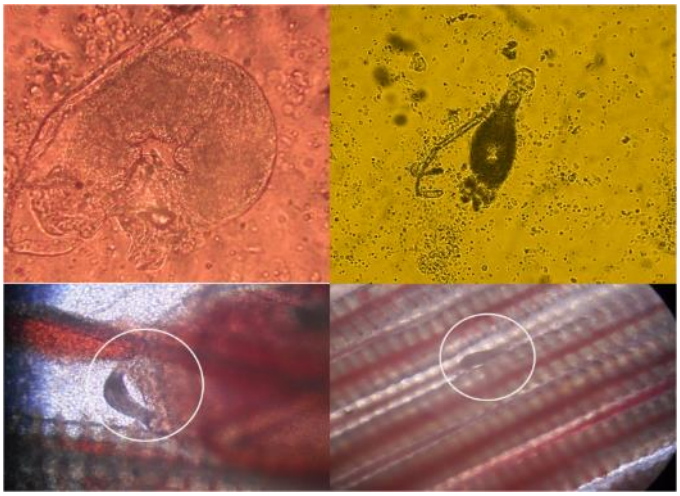
Field researches were performed by microscope (MC50 BAT and Karl Zeiss), by taking the mucus smears from body surface from caught fish specimens and by forming the native preparations on slide glass. Samples of gill filaments for determining of ectoparasite presence were also taken. After the skin and gill samples analysis, trematode infection intensity was stated and their taxonomic affiliation was determined. Determination of trematodes found on the skin and gills was performed by using the standard methods for determination according to the literature (Bychovskaya-Pavlovskaya et al, 1962; Fijan, 2006). After the sampling, part of material was preserved in ice and transported to laboratory for further analysis (Faculty of Biology in Belgrade, Laboratory for Zoology at Faculty of Science in Tuzla). In the laboratory samples were conserved in 70% ethanol solution. The data of the water quality of the Sava river were taken from the agency for water management of Bosnia and Herzegovina. The data were analysed by using non-parametric statistical test (hi - square test, Kruskal - Wallis test and Spearman correlation test) of statistical software STATISTICA 7.

3. RESEARCH RESULTS AND DISCUSSION

Ichthyoparasitological researches of middle flow of river Sava were performed during four seasons in 2017. Researches were performed on 400 specimens of different fish species. According to taxonomic affiliation, most of sampled fish (13) were of Cyprinidae family. Other species participate less in the sample. Three species are from Percidae family, two are from Ameiuridae family and other species in the sample are: Esocidae, Gobiidae, Siluridae and Thymallidae families with one species each. Research has proven presence of ectoparasites from Monogenea and Digenea classes from Trematoda group in the researched specimens of fish.

In Monogenea class, presence of parasites from Dactylogyrus, Gyrodactylus genera and Eudiplozoon nipponicum species was proven, while from Digenea class, Posthodiplostomum cuticola species was determined. These parasites, which were found on skin and gills, can cause negative consequences to fish health, such as increased mucus production on skin and gills, which can cause serious metabolical problems ot the host (Fijan, 2006; Skenderović, 2015).

From total of 400 researched different species fish specimens, Dactylogyrus genus parasites were determined on bodies of 27 specimens of fish, which relates to 6.75% of ichthyo sample, whereby it is not possible to determine that fish population of researched region are highly infected by parasites from this genus. (Picture 1.). By parasitological research of gills and skin of fish, Dactylogyrus genus parasites were found in following fish species: Abramis brama, Ballerus sapa, Barbus barbus, Blicca bjoerkna, Carassius gibelio, Cyprinus carpio, Silurus glanis, Rutilus virgo and Vimba vimba.



Picture 1. Dactylogyrus sp.

A representation of prevalence and infection intensity of sampled fish specimens which had the determined parasites (Table 1.). In analysis of Abramis brama species, parasite was found on skin and gills in same ratio, as well as in species Ballerus sapa. Infection analysis in common barbel and white bream shows parasite infection on the gills. On prussian carp, parasite occurs on skin and gills in the same ratio, while on the infected specimens of common carp parasite was found only on skin. In infected catfish specimens parasite was found on the skin. On specimens of heckel and vimba bream, parasite was found only on the gills.

*Table 1. Prevalence and infection intensity by species from Dactylogyrus genus in total ichthyosample (*species is excepted from statistical analysis due to low sample number)*

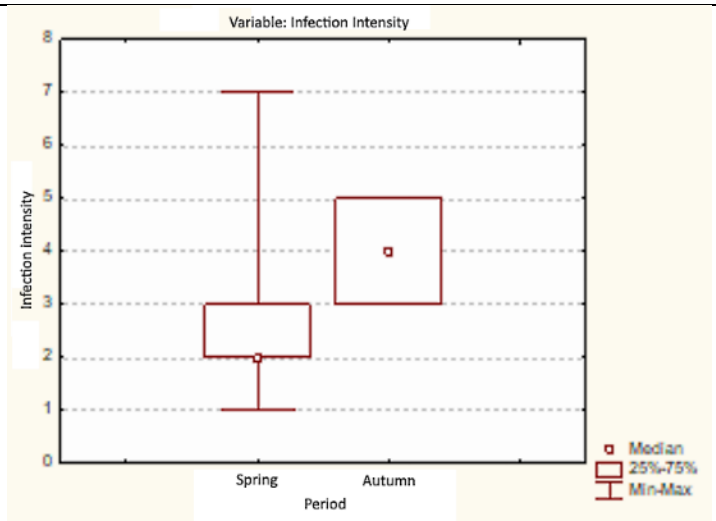
No:	Fish species	Total	Infected	Prevalence %	Infection intensity
1.	*Abramis brama*	35	8	22,85	1-7
2.	*Ballerus sapa*	17	2	11,76	5-12
3.	*Barbus barbus*	37	1	2,7	3
4.	*Blicca bjoerkna*	25	2	8	1-3
5.	*Carassius gibelio*	86	8	9,3	1-5
6.	*Cyprinus carpio**	4*	1*	25*	2
7.	*Silurus glanis**	8*	2*	25*	7-10
8.	*Rutilus virgo**	7*	2*	28,5*	2
9.	*Vimba vimba**	3*	1*	33,3*	1

By analysing the infection prevalence, it was determined that prevalence was uneven, meaning that infection of Abramis brama species was statistically much higher when compared to other values of infection prevalence ($x2=20,30$; $p<0,05$) (Picture 2).

Infection intensity in season periods did not show statistically significant deviations. As analysis models, two statistically interesting species were chosen: Abramis brama and Carassius gibelio because these two species had the highest number of infected specimens. In analysis of

infection intensity of species Abramis brama no statistically significant deviations were determined in autumn and spring periods when the infection was determined (H=1,45; p>0,05) (Picture 2).

In analysis of species Carassius gibelio, results have also shown that there are no differences in infection intensity in seasons when infection was determined (H=1,14; p>0,05).



Picture 2. Infection intensity by species from genus Dactylogyrus over the season of reserach for Abramis brama species

In analysis of infection intensity and water temerature for species Abramis brama no statistically significant correlation was found between these parameters (R=0,456; p>0,05). Infection was determined on temperatures of 17,2°C and 18°C. In analysis of infection intensity and temperature for species Carassius gibelio negative, statistically insignificant correlation was determined (R=-362; p>0,05). Infection was determined in a very wide temperature values spectrum, from 10,3°C to 27,1°C.

Species from Gyrodactylus genus, Nordmann, 1832, represent parasites form Monogenea class which are common causers of fish diseases called gyrodactylosis. Gyrodactylosis is a gill and skin disease. These species reproduce quickly and they can have up to 2000 offspring in a single month. Bad environmental conditions in the hydro ecosystem serve to the development of these parasites, especially in fish spawn but also in adult fish (Fijan, 2006).

Out of total 400 sampled fish, Gyrodactylus parasites were determined in 40 fish specimens, whereby the prevalence of infection of total sample is 10%, which means that significantly higher number of specimens was not infected by parasites from this genus.

Picture 3. Gyrodactylus sp.

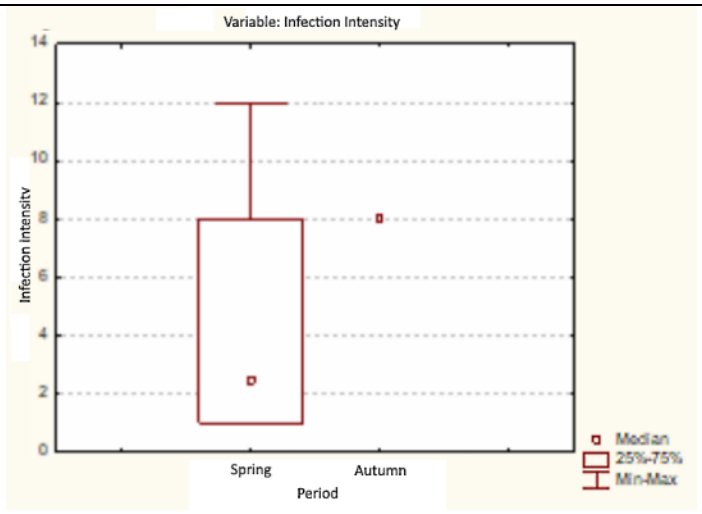
Gyrodactylus parasites are determined of following fish species: Abramis brama, Ballerus sapa, Alburnus alburnus, Barbus barbus, Blicca bjoerkna, Carassius gibelio, Chondrostoma nasus, Esox lucius, Rutilus virgo, Sander lucioperca and Vimba vimba. Parasites were found on skin and gills of infected fish specimens, where the higher number is found on gills.

*Table 2. Prevalence and infection intensity by Gyrodactylus genus parasites in total ichthyosample (*species is excepted from statistical analysis due to low sample number)*

No:	Fish species	Total	Infected	Prevalence %	Infection intensity
1.	*Abramis brama*	35	5	14,28	1-12
2.	*Ballerus sapa*	17	2	11,76	4-5
3.	*Alburnus alburnus*	57	3	5,26	1-7
4.	*Barbus barbus*	37	4	10,81	1-13
5.	*Blicca bjoerkna*	25	4	16	1-5
6.	*Carassius gibelio*	86	13	15,11	1-5
7.	*Chondrostoma nasus*	48	4	8,33	2-6
8.	*Esox lucius*	12*	2*	16,66*	2
9.	*Rutilus virgo**	7*	1*	14,28*	1
10.	*Sander lucioperca*	6*	1*	16,66*	2
11.	*Vimba vimba**	3*	1*	33,33*	1

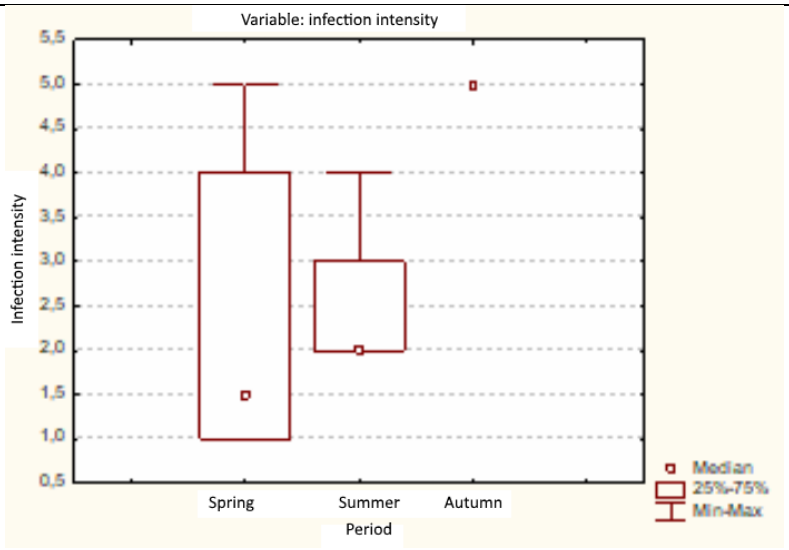
Based on microscopical analysis of skin and gills of fish, prevalence and infection intensity is shown for each infected species (Table 2). By infection prevalence analysis of optimal samples for statistical testing, equal infection distribution in all tested species was determined ($x^2=7,75$; $p>0,05$).

In analysis of infection intensity according to research season, no statistical significance was proven for Abramis brama species, whereby it can be claimed that infection is present in same intensity in spring and autumn. ($H=0,52$; $p>0,05$) (Picture 4).



Picture 4. Infection intensity by parasites from Gyrodactyus genus for Abramis brama species for periods when the infection was determined

Similar results were determined for infected specimens of Carassius gibelio species. Equal distribution of infection intensity was determined in periods when the infection was determined. (H=2,75; p>0,05) (Picture 5). There was no statistically significant correlation between the mentioned ecological factors and infection intensity parameters (R=0,230; p>0,05). Infection was determined in temperature range from 10,3°C to 27,1°C, which represents a wide range of variation in temperature. Infection of abramis brama species, was determined in temperature range from 17,2°C to 18°C.

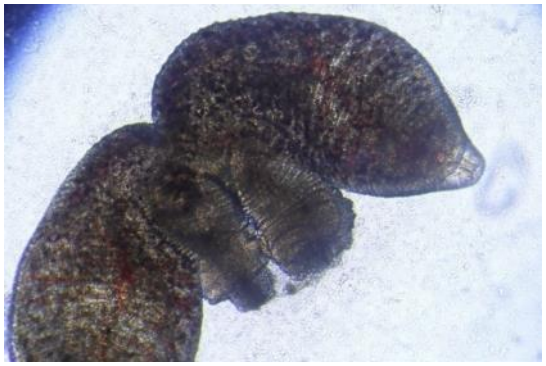


Picture 5. Infection intensity by parasites from Gyrodactylus for Carassius gibelio species for periods when infection was determined

Species from Gyrodactylus and Dactylogyrus genera occur with with highest frequency in the researched fish, these parasites are interesting because of their vivipary and polyembryony, but the factor that triggers the sudden appearance of these parasites is still not known. (Scholz, 1999; Bakke and affiliates., 1990; Lund and Heggeberget, 1992). Eudiplozoon nipponicum (Goto, 1891) is a parasite species from Monogenea class. It causes fish disease called Diplozoonosis.

Cycle of life of these parasites happens in three phases; free swimming organism phase, the phase where parasite attaches itself to gills of the host fish, and the phase where male and female merge into one individual creating a special structure called "living X".

This species is widely spread freshwater fish parasite, which damages gill apparatus by sucking blood, which consequentially causes fish anemia (Fijan, 2006). Eudiplozoon nipponicum species was determined in a very low prevalence in total ichthyo sample, 1.75%. This species was found in following host fish species: Abramis brama, Barbus barbus, Ameiurus nebulosus and Blicca bjoerkna. Discovery of this species is significant because it is the first time that this species was found in river Sava. (Nedić and affiliates, 2016).



Picture 6. Eudiplozoon nipponicum

*Table 3. Prevalence and infection intensity by Eudiplozoon nipponicum species in total ichthyo sample (*species is excepted from statistical analysis due to low sample number)*

No:	Species	Sampled	Infected	Prevalence %	Infection intensity
1.	*Abramis brama*	35	3	8,57	1-2
2.	*A. nebulosus**	5*	1*	6,66*	1
3.	*Barbus barbus*	37	1	2,70	2
4.	*Blicca bjoerkna*	25	2	8	1-2

By analysing the infection prevalence, no statistical significance was determined (x2=3,26; p>0,05). Infection intensity analysis, as well as the analysis of temperature relation as an ecological factor was not performed due to very low prevalence and intensity of infection.

Posthodiplostomum cuticola, Nordmann, 1832 is a fluke species systemised in Digenea class. It causes disease, scientifically marked as postodiplostomosis. Transitional hosts in its life cycle are snails from Planorbis and Anisus genera, and other transitional hosts are Cyprinidae (Fijan, 2006).

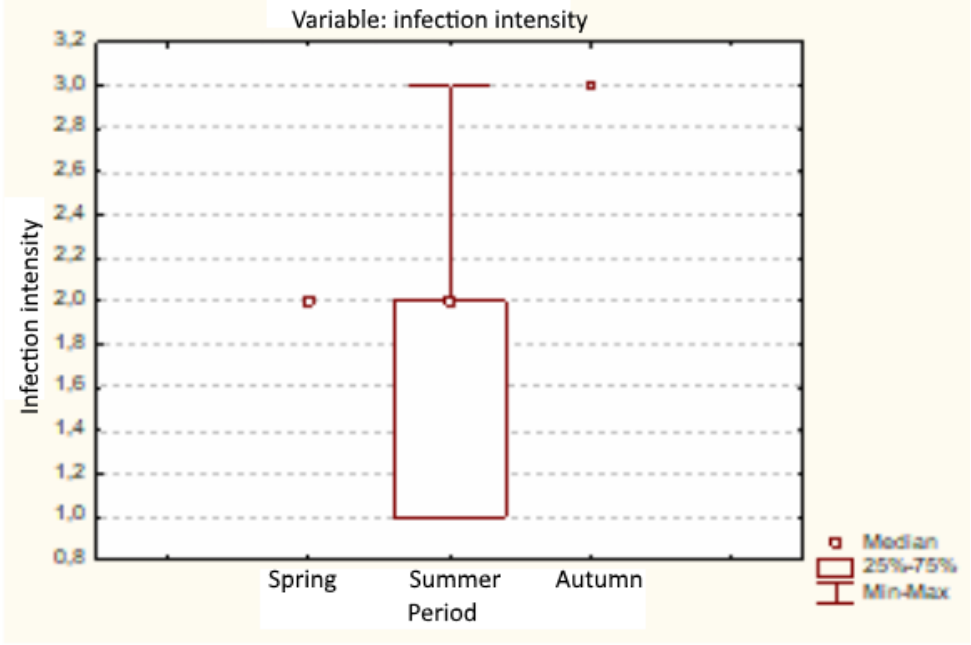
In total ichtyo sample, presence of Posthodiplostomum cuticola species was determined in 18 specimens, with prevalence of 4.5%, whereby the significance between infected and noninfected specimens was determined. By microscopical analysis, presence of parasites was determined predominantly on gills of infected specimens and in lesser quantity on skin of following species: Abramis brama, Ballerus sapa, Barbus barbus, Blicca bjoerkna and Carassius gibelio.

The prevalence and infection intensity of infected species by Posthodiplostomum cuticola is shown in Table 4.

Table 4. Prevalence and infection intensity by Posthodiplostomum cuticola species in total ichthyo sample

No:	Species	Sampled	Infected	Prevalence %	Infection intensity
1.	*Abramis brama*	35	5	14,28	2-4
2.	*Ballerus sapa*	17	1	5,88	2
3.	*Barbus barbus*	37	3	8,10	1-3
4.	*Blicca bjoerkna*	25	2	8	1-4
5.	*Carassius gibelio*	86	7	8,13	1-3

By analysing the infection prevalence, statistically even distribution of infection in all infected species was determined (x2=4,52; p>0,05). By analysing the infection according to season periods in Carassius gibelio species, there was no statistical significance (H=1,80; p>0,05) although it can be noted that infection in this species occurs on higher temperature, between 10,3°C and 27,1°C.



Picture 7. Seasonal dynamic of Posthodiplostomum cuticola infection in Carassius gibelio species

Highest number of infected specimens was determined during the summer season. Ichthyoparasitological research of Modrac hydroaccumulation have shown that Posthodiplostomum cuticola is represented in the same percentage (11.42%) in researched fish during summer and spring (Skenderović and affiliates, 2012).

By analysing the infection intensity and temperature as a ecological factor, very low negative correlation was determined which was not close to statistical significance (R=-0,148; p>0,05), but as it was mentioned earlier, infection was determined on higher water temperatures where it is notable that given parasite prefers higher temperatures in wider ecological valence. Highest prevalence was determined in Abramis brama species, more than 15%. Some researches have shown that infection prevalence values can be over 60% in some species in hydro accumulations (Skenderović, 2015). Earlier researches have shown that infection by this parasite is noted with different prevalence oriented on Cyprinidae species (Zrnčić and affiliates, 2009). According to data obtained by Skenderović and affiliates (2011,) Posthodiplostomum cuticola is represented in 63.3% in researched fish in river Spreča.

4. CONCLUSION

During the ichthyoparasitological research of fish of middle flow of river Sava, presence of parasites from Trematoda group was determined. Four trematode species, from Monogenea class, presence parasites from Dactylogyrus, Gyrodactylus genera and Eudiplozoon nipponicum was determined, while from Digenea class, Posthodiplostomum cuticola was determined. Researches have shown that species from Gyrodactylus and Dactylogyrus genera appear with the highest frequency in studied fish. Eudiplozoon nipponicum was determined in a very low prevalence in total ichtyo sample, 1.75%. By using microscopical analysis, dominant presence of Posthodiplostomum cuticola species was determined on gills of infected specimens. Highest number of infected specimens was determined during the summer for the researched period.

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BIOGRAPHY

Dr. sc. Isat Skenderović, Biology professor

Isat Skenderović was born 14.2.1965 in Trpezi, municipality of Berane (Ivangrad) Montenegro. He completed primary education there. He completed naturalist high school education in Rožaje. He enrolled in Faculty of Science, Biology department in 1985/86 school year in Priština, and finished it in 1990 and obtained the title of Biology professor. In school year 1999/2000, he enrolled in post graduate study, "Ecology and environment protection" course on Biology department of Faculty of Science in Sarajevo, and he successfully obtained master degree with paper called "Fish population of river Spreča" in 2003.

He was promoted to Phd. in 2010 in University in Sarajevo. After finishing the university, he worked as a Biology teacher for some time in his home town. Since 1997 he worked in a High school centre in Kalesija and "Meša Selimović" gymnasium in Tuzla as a Biology teacher. In academic year 2006/2007, he was enlisted to perform practical lessons in Biology department of Science Faculty of Tuzla University. In academic year 2008/2009, he started working in Faculty of Science of Tuzla University. He is a lecturer in multiple subjects on I, II and III cycles of studies on Biology department of Faculty of Science and Agronomy department of Faculty of Technology of Tuzla University. He attended multiple seminars, some of which were through EUVET and Tempus programs. Dr. Skenderović has published many scientific and expert papers, and he has participated in realisation of scientifical research projects.

For his work, he was awarded with many acknowledgements and awards. He is a co-author Biology textbooks for 6, 7 and 8th grade for nine-year primary schools. He also wrote two scientific monographies and he is a co-author of "Zoology" textbook for Agronomy students. He permanently resides in Tuzla, with his wife and three children.

Systematic position and vulnerability of *Sabanejewia balcanica* in the Balkan area

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ABSTRACT

Sabanejewia balcanica is a fish species that belongs to Cobitidae family and it is the endemic of the Balkan Peninsula. It is present in the tributaries of the Danube and Aegean waters. Systematics of this species has experienced certain changes that are related to the systemic instability of the entire Cobitidae family, so there has been a change in the name of the genus of this species. The genus Sabanejewia was separated from the genus Cobitis in the last century, but this name was generally used much later. According to data of the IUCN Red List of Threatened Species, this species is still not endangered, but is assigned a status of least concern (LC). Sabanejewia balcanica is in the Annex II of the Habitats Directive and Annex III of the Bern Convention which basically require the protection of this species and its habitats. In the proposal to create a red list of fauna of the Federation of Bosnia and Herzegovina, has been concluded that there is not enough information on the population characteristics of this species. The aim of this article is to present data on exploration of Sabanejewia balcanica in the Balkan area as well as Bosnia and Herzegovina, thereby contributing to the determination of its status of vulnerability and protection of its natural habitats.

Key words: Sabanejewia, fish, Balkan, balcanica.

1. INTRODUCTION

Sabanejewia balcanica (Karaman, 1922) or Balkan golden loach is a fish species which belongs to family Cobitidae Swainson, 1838 and it inhabits the Balkan area. According to Mrakovčić et al. (2006) this species inhabits eastern and southeastern Europe, from Bosnia and Herzegovina, Croatia and Romania to Poland, Ukraine and Russia. It could be said that this species occurs in the Danube and Aegean waters (Kottelat & Freyhof, 2007). It inhabits medium to upper flows of rivers and streams, lives individually and is active at night. During the day, it is buried in the rocks and gravel.

The systematics of the species suffered the certain changes related to systemic instability of the entire family Cobitidae, which is the reason why there was a change in the name of this species' genus. The genus Sabanejewia Vladykov, 1929 is separated from the genus Cobitis.

According to the data of the IUCN Red List of Endangered Species, this species is still not endangered, but is assigned a status of least concern (LC). *Sabanejewia balcanica* is in the Annex II of the Habitats Directive and Annex III of the Bern Convention which basically require the protection of this species and its habitats. In the proposal to create a red list of fauna for the Federation of Bosnia and Herzegovina, has been concluded that there is not enough information on the population characteristics of this species, while in other Balkan countries, its conservation status has been differently characterized.

2. MATERIALS AND METHODS

The available literature data and the original results of years of research of this species that could be used to complement the knowledge of this species were collected and presented in the paper for the purposes of this study, with special emphasis on the area of Bosnia and Herzegovina.

3. RESULTS AND DISCUSSION

3.1 Systematics of genus Sabanejewia

According to the available data, several species and subspecies belong to the genus *Sabanejewia* which have been described by different authors on the basis of morphometric characteristics (Nalbant, 1957; Karaman, 1963; Vasil'eva & Vasil'ev, 1988; Witkowski, 1994; Economidis & Nalbant, 1996 etc.). Kottelat (1997) considers *Sabanejewia balcanica* (Karaman, 1922), *S. bulgarica* (Drensky, 1928), *S. larvata* (Filippi, 1859) and *S. romanica* (Bācescu, 1943) valid species of this genus in Europe, including the former USSR countries. The use of karyology and genetic methods has contributed to progress in the systematics of this genus (Vasil'eva & Ráb, 1992; Perdices et al., 2003). Based on this analysis, it can be concluded that within the genus *Sabanejewia* there are six evolution lines: *Sabanejewia larvata*, *S. romanica*, *S. aurata/S. caucasia*, *S. kubanica*, *S. baltica* and Danubian-Balcanian complex which branch into six sub-lines.

I- *S. vallachica*/*S. balcanica* from Romania
II- *S. balcanica*/*S. doiranica* from western Greece
III- *S. bulgarica*/*S. balcanica*/*S. montana* from the middle part of Danube basin
IV- *S. radnensis*/*S. balcanica* from the Mureş basin
V- *S. thrakica*/*S. balcanica* from Greece
VI- *S. balcanica* from the Mur basin

The systematics of the genus *Sabanejewia* has experienced certain changes related to the systemic instability of the entire Cobitidae family. The genus *Sabanejewia* was separated from the genus *Cobitis* by Vladykov (1929), but this genus generally started to be used after revalidation by Nalbant (1963). History of the taxonomy of Balkan golden loach dates from 1839 when Eichwald (1839) first described this group of fish as *Cobitis caspia*. Filippi (1859) described the species *Acanthopisis larvata* in northern Italy, and in 1865 *Acanthopisis aurata* in northern Iran, which were later classified in Linnae's genus *Cobitis* as *Cobitis larvata* and *Cobitis aurata*. Another loach from Black Sea basin named *Cobitis aralalensis* was described by Kessler (1877). Then, Berg (1906) described *Cobitis caucasica* from the western Caucasus. Karaman (1922) described European species *Cobitis aurata* as *Cobitis balcanica* (from the Vardar river basin in Macedonia). Vladykov (1925) described *Cobitis montana* (from the river Tisa), and Drensky (1928) described *C. bulgarica* (from the lower Danube). Vladykov (1929) included the species *Cobitis caspia*, *Cobitis caucasica* and *Cobitis larvata* into the new genus *Sabanejewia* which was not accepted as subgenus until 1970. This author considered the species *Cobitis aurata* and *Cobitis balcanica* as separate species, and species *Cobitis montana* only as a synonym of *Cobitis balcanica*. Vladykov

(1931) concluded that species *Cobitis bulgarica* is also synonym of species *Cobitis balcanica*. Berg (1949) considered that species *Cobitis aralensis* is a subspecies of *Cobitis aurata*, and that *Cobitis balcanica* is their synonym. Bācescu (1943) firstly thought that *Cobitis balcanica* is a subspecies of species *Cobitis aurata*, at the same time describing *Cobitis caspia romanica* as a new subspecies, and concluded that *Cobitis bulgarica* is a separate species. Bānārescu (1948) first conducted extensive research of *Cobitis* (*Sabanejewia*) *aurata balcanica* and *Cobitis* (*Sabanejewia*) *bulgarica*, and based on that concluded that *Cobitis bulgarica* is also a subspecies of species *Cobitis aurata*. Oliva, Balon & Frank (1952) discussed the validity of the statement that *Cobitis bulgarica* is a subspecies of *Cobitis* (*Sabanejewia*) *aurata* putting them into subspecion variation *Cobitis* (*Sabanejewia*) *aurata balcanica*. Nalbant (1957) described *Cobitis aurata vallachica* in the streams of southeastern Romania. Bānārescu & Mùller (1960) promote subspecies *Cobitis caspia romanica* to full species status *Cobitis* (*Sabanejewia*) *romanica*. Bānārescu (1953, 1954, 1964) integrated names *Cobitis balcanica* and *Cobitis bulgarica*, but the name *Cobitis bulgarica* was reserved as an adequate name for the subspecies. Furthermore, Bānārescu, Mùller & Nalbant (1960) discussed separate the species *Cobitis radnensis* as a separated subspecies *Cobitis* (*Sabanejewia*) *aurata*. Nalbant (1963) considered *Sabanejewia* as a valid name, which was accepted by the majority of authors. Bānārescu (1964, 1966) does an extensive revision of the genus, according to which all the Romanian population belongs to one type of *Cobitis* (*Sabanejewia*) *aurata* with four subspecies. Karaman (1963) describes the new subspecies *C.* (*S.*) *aurata bosniaca* from the river Vrbas. A comprehensive review for some of the Romanian population (Bānārescu, Nalbant & Chelmu, 1972) led to the same conclusions set forth in the preceding studies that all the analysed populations or subspecies belong to the species *Sabanejewia aurata*.

Vasil'eva & Vasil'ev (1988) described the new species named *Sabanejewia aurata cubanica* of the pool Kuban river in Russia. Furthermore, these authors concluded that *Sabanejewia bulgarica* is a separate species, and that *Sabanejewia balcanica*, *S. vallachica* and S. *radnensis* are subspecies within the species *Sabanejewia aurata*. Vasil'eva & Ráb (1992) concluded that the karyotype of the subspecies *Sabanejewia aurata balcanica* from the Danube basin is different from *Sabanejewia aurata aurata* and *Sabanejewia aurata cubanica* in Russia, which led to Kottelat (1997) formulating a hypothesis that subspecies *Sabanejewia aurata balcanica* and *Sabanejewia aurata aurata* are different species which was confirmed by the molecular analyses (Boron, 2000). Witkowski (1994) described the new subspecies named *Sabanejewia aurata baltica* from Poland, and Kottelat (1997) questioned its validity and classified it as a synonym of *Sabanejewia balcanica*. Economidis & Nalbant (1996) described the two new subspecies from Greece named *Sabanejewia aurata thrakica* and *Sabanejewia aurata doiranica*. Ludwig et al. (2001) presented the relationship of the Romanian subspecies based on the molecular analysis, where the heterogeneous nature of the subspecies *S. balcanica balcanica* was determined. Perdices et al. (2003) present the molecular analysis based on mtDNA of the most European species and the subspecies of Sabanejewia.

3.2 The review of the research of Sabanejewia balcanica in the Balkans

At the beginning of this century, there was intensive research of this species in the Balkans, which resulted in holding three international conferences on a species from the family Cobitidae (Brno 1999; Olsztyn 2002 and Šibenik 2006).

Sabanejewia balcanica was intensively investigated in Croatia. Delić et al. (2003a) presented the morphometric and meristic characteristics of Balkan golden loach from waters of central Croatia. Delić et al. (2003b) investigated to the distribution of this species in Croatia. Zanella et al. (2008) deal with the age structure and growth of this species. Mičetić et al. (2008) investigated their ecological characteristics. The largest contribution to the understanding of the phylogenetic characterization of this species was given by Buj et al. (2008).

Šumer & Povž (2000) analyzed the morphometric and meristic characteristics of the genus *Sabanejewia* from the waters of Slovenia. The same authors deal with the status of this species and their distribution in the waters of Slovenia (Povž & Šumer, 2000).

It is known that *Sabanejewia balcanica* is one of three species from the family Cobitidae which is present in the waters of Slovakia (Koščo et al., 2008). Pekárik et al. (2008) investigated the communities and affinity for the habitats of the species from the family Cobitidae in the area from Slovakia.

The complex considerations of the taxonomic status of Balkan golden loach in Romania and Moldova was conducted by Iftime (2002). Bănărescu (1948, 1953, 1954, 1964, 1966) made a large contribution to the understanding of this species and its a systematic position.

Marešová et al. (2011) investigated the genetic diversity of the species *Sabanejewia balcanica* in the western Balkans. The taxonomy and genetic diversity of this species was also analyzed in the waters of the Czech Republic (Bartoňová et al., 2008). Perdices et al. (2003) conducted the reconstruction of the historical biogeography of genus Sabanejewia, based on mRNA analysis. Bohlen (2000) conducted the analysis of the molecular relationship between a subspecies in Romania.

Economidis & Nalbant (1996) conducted the study on the species from the genus Cobitis and Sabanejewia in Greece where six new species (subspecies) were described, including *Sabanejewia aurata thrakica* and *Sabanejewia aurata doiranica*.

It is known that in the waters of Montenegro within the family Cobitidae there are five species from two genus, but their exact distribution, ecology and biology are not known. Marić & Milošević (2010) were first to scientifically describe species *Sabanejewia balcanica* in this part of the Balkans.

The presence of this species was confirmed in the waters of Lithuania by Audrius (2003) and in the waters of Austria by Ratschan et al. (2011).

The data on the morphology, ecology and biology of *Sabanejewia balcanica* in Bosnia and Herzegovina are quite scarce and discontinuous. Bajrić (2017) deals with the specific research of

this species. For the first time the hematological characteristics of this species (Bajrić et al., 2018b) and its ecological and systematic characteristics were pointed out (Bajrić et al., 2018a). Particularly interesting population of this species is one from the river Suturlija which is described as subspecies by Karaman (1963). The subsequent studies showed that this population does not differ from the others based on the meristic characteristics (Bajrić et al., 2018a).

3.3 Distribution of Sabanejewia balcanica in Bosnia and Herzegovina

The presence of this species in the waters of Bosnia and Herzegovina has been noticed in several rivers and brooks of the Black Sea basin: Gostelja, Oskova, Turija, Brka, Suturlija, Suha, Tinja and the river Trebačka (Bajrić et al., 2018 b). Also, the presence of this species in the river Gostelja was noted by Adrović (2002), in the river Suturlija by Golub et al. (2016), in the river Tinja by Deljić (2006), and in the river Vrbas by Radević (2001).

In addition to the above research studies dealing with the specific issues of this species, *Sabanejewia balcanica* is mentioned in some fish basics (Muhamedagić et al., 2012), where this species is registered within the ichthyopopulations in the following rivers and localities: the river Krivaja (localities Maoča, Krivaja, Skroze), the river Bosna (localities Modrinje, the town Kakanj, Vranduk, Donja Golubinja, Ulišnjak, the town Maglaj), the river Liješnica (localities Brankovići, Liješnica), the river Rujnica (localities Dolac), the river Usora (localities Matuzići, Rastoke).

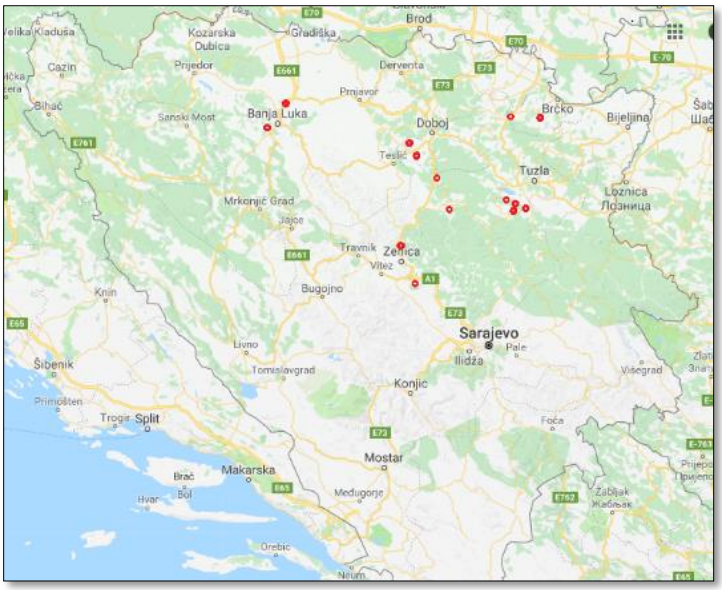

Figure 1. Distribution of *Sabanejewia balcanica* in Bosnia and Herzegovina marked with red circle (Google maps)

3.4 The vulnerability of Sabanejewia balcanica in the Balkans

According to the data of the IUCN Red List of Threatened Species, this species is still not endangered, but is assigned a status of least concern (LC). However it has been variously described in the different countries of the Balkans.

It is cited in the red book of freshwater fish of Croatia (Mrakovčić et al., 2006) that this species is sensitive and is internationally protected by the Berne Convention and the European directive on the protection of its habitats.

Witkowski, Kotusz & Przybylski (2009) indicated the degree of vulnerability of fish in Poland, according to which Sabanejewia balcanica has been listed as endangered since 1999, and since 2009 it has been treated as sensitive and protected.

Mrakovčić et al. (2006) think that this species in Croatia is considered vulnerable (VU), although its global conservation status is at the level of least concern species (LC).

The fishes from family Cobitidae in Slovenia were inadequately explored, thus were classified as data deficient (DD) in the red list for a long time period. There was not enough data on their biology to talk about the extent of their vulnerability (Povž, 1996; Povž & Šumer, 2000). However, in the recent publications Sabanejewia balcanica belongs to a category of endangered fish in Slovenia (Povž, Gregori & Gregori, 2015).

Table 1. Vulnerability of *Sabanejewia balcanica* in the Balkans

Country	**Category of vulnerability**	**Reference**
Croatia	Vulnerable (VU)	Mrakovčić et al. (2006)
Poland	Endangered (EN) Vulnerable (VU)	Witkowski et al. (2009)
Slovenia	Data deficient (DD) Endangered (EN)	Povž & Šumer (2000); Povž, Gregori & Gregori (2015)
Slovakia	Endangered (EN)	Hensel & Mužík (2001)
The Czech Republic	Endangered (EN)	Lusk, Hanel & Lusková (2004)
Bosnia and Herzegovina	Data deficient (DD)	Škrijelj et al. (2013)

Sabanejewia balcanica in Slovakia is protected by national laws (Koščo et al., 2008) and it has the status of the threatened species in the Red List of the country (Hensel & Mužík, 2001). This species has the same status in the waters of the Czech Republic (Lusk, Hanel & Lusková, 2004).

In the proposal for making the Red List of fauna for the Federation of Bosnia and Herzegovina, it was concluded that there is not enough data on the population characteristics of this species (Škrijelj et al., 2013).

4. CONCLUSION

We believe that river partitions, dam construction, water pollution, eutrophication, and impact on the strength and gravelliness of river bottoms have a great impact on the population Sabanejewia balcanica. Certainly, the anthropogenic influence is decisive in this situation, so that a person

directly and indirectly contaminates the upper parts of rivers, streams and reconstructs river flows and in that way affects the water speed, its physical and chemical characteristics, which can certainly threaten the existence of the populations of this species. Given that this species is included in Annex II of the Habitats Directive and Annex III of the Bern Convention which basically require the protection of this species and its habitats, it would require protecting the areas where it has been confirmed as much as possible. The first step would be marking the site, and introducing the local people to this species because many people, due to Sabanejewia balcanica's lifestyle, do not know that these fish live in their environment. Finally, it is necessary to act in accordance with legal regulations that would be carried out directly by fishing associations, cantonal and state institutions.

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Effect of Priming with Silver Fir and Oregano Essential Oils on Seed Germination and Vigour of *Silene sendtneri*

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ABSTRACT

In order to investigate the effects of seed priming with silver fir and oregano essential oils on certain important seedling characteristic and seed vigour of interesting endemic and horticultural species Silene sendtneri, *an experiment was conducted based on randomized completely design with three replications. Traits such as germination rate, water content, dry weight, vigour index and photosynthetic pigments were analysed. Results revealed that the seedlings obtained with priming seeds showed increased growth, water content, vigour and photosynthetic pigment contents but decreased germination rate and dry weight compared with that obtained with non-primed seeds. Analysis of seed priming effects had demonstrated even germination rate is smaller the seedling vigour is slightly higher especially with all oregano oil treatments. Suggesting that oregano oil has a potential as a priming agent for improvement of seedling synchrony, although at lower rate of germination.*

Key words:essential oils, growth parameters, priming, *Silene sendtneri*.

1. INTRODUCTION

Seed needs to be pure, with high vigour, viability and germination rate in order to ensure high yield and productivity for efficient utilization in horticulture. Therefore, it is necessary to use different techniques for improvement of seed germination capacity, vigour and seedling establishment. Seed priming (pre-sowing seed treatments) is one of the most efficient, simple and mostly used method (McDonald, 2000; Ghassemi-Golezani et al., 2013; Hussian et al., 2014).

The success of seed priming is under the influence of different factors and their complex interactions. Direct and indirect benefits of seed priming are: faster seedling emergence, less need for re-sowing, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield (Ghassemi-Golezani et al., 2013). Various pre-sowing seed techniques include osmopriming, hydropriming, halopriming, biopriming, hormonal priming, matrix priming, thermopriming and magnetopriming (Ghassemi-Golezani et al., 2013; Dalil, 2014).

In horticulture, seed priming techniques are widely used for plant protection from different abiotic and biotic stresses and for improvement of seed performances such as to reduce seedling emergence time and to achieve uniform seedling emergence and better allometrics (Ashraf & Foolad, 2005; Conrath et al., 2006).

Silene sendtneri Boiss. (Caryophyllaceae) is an endemic perennial plant of Balkan Peninsula (Jalas & Suominen, 1986) with white, decorative and scented flowers (Šilić, 1984). In Bosnia and Herzegovina, the plant inhabits mountain meadows of the alpine or subalpine vegetation zones (Šilić, 1984; Šoljan et al., 2009). As some other species of *Silene* genus with high decorative values, *S. sendtneri* can be widely used in horticulture.

Most of the seed priming includes field crops; the present study explores the effects of seed priming using silver fir and oregano essential oils on some growth parameters, photosynthetic pigments, and improvement of germination rate and germination synchrony in endemic plant, *Silene sendtneri*.

2. MATERIAL AND METHODS

2.1 . Plant material and seed priming

Seeds of Silene sendtneri were collected during July, 2014. on locality Pjeskovita ravan on Mt. Ozren (43°54'191" N, 18°27'170" E; 1302 m above sea level). All seeds were kept at +4°C in the Laboratory for Plant physiology until use. Seed priming was performed using different concentrations (0, 10, 20 and 30 g/mL) of two essential oils, Abies alba and Origanum vulgare („Liliya“ Halilović d.o.o. Ilijaš, Bosnia and Herzegovina). Priming was performed by submergence of the seeds for 24 hours at +4 °C in appropriate solution, rinsing with sterile distilled water, and followed by seed drying at room temperature for 48 hours. In this way, prepared seeds were further cultivated for evaluation of priming effects on germination and seedling vigour.

2.2 Plant cultivation

Primed 160 seeds were cultivated in pots containing air-dried soil, 10 seeds per pot were cultivated, in 16 pots, for each treatment. Pots with seeds were placed in growth chamber for 15 days under constant temperature (25°C) and humidity (70%) with 16 hours of light provided by neon light tubes. Plants were watered every two days using tap water.

2.3 Germination rate

Germination rate was calculated for each treatment according to the formula:

$$\%G = \frac{GS}{CS} x100$$

Where is: %G - germination percentage; GS - germinated seed; CS - cultivated seed.

2.4 Seedling length

Representative seedlings were selected for each treatment for analysis of seedling length. Seedling length was analysed using ImageJ program (ImageJ, 1.50e, Wayne Rasband National Institute of Health, USA), and using mm paper for calibration of the program. All measurements were done for 10 seedlings per treatment.

2.5 Water content

Analysis of water content was calculated according to fresh and dry mass of seedlings according to used pre-treatment. Plant samples were dried after fresh mass was recorded by placing the material in the oven over night at 60°C. Percentage of water content was calculated according to the formula of Kumari et al. (2007):

$$\%WC = \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}} * 100$$

Where: WC - water content; A - fresh mass of the sample; B - dry mass of the sample.

2.6 Vigour index

Seedling vigour index was calculated according to the formula of Reddy & Khan (2001):

$$SVI = \%GxSL$$

Where: SVI - seedling vigour index; %G - germination percentage; SL - seedling length.

2.7 Photosynthetic pigments content

Photosynthetic pigments were analysed from 80% acetone extracts, using dry plant material, by absorbance reading at 663, 646 and 440 nm according to the Arnon (1949) and quantified

according to Porra et al. (1989) and Holm (1954): Chlorophyll *a* = 12,25*A_{663} – 2,55*A_{646} (g/mL); Chlorophyll *b* = 20,31*A_{646} – 4,91*A_{663} (g/mL); Total Chlorophylls = 17,76*A_{646} – 7,34*A_{663} (g/mL); Carotenoids = 4,69*A_{440} – 0,267*(A_{663}*A_{646}) (g/mL). Final results were expressed as mg of pigment per g of dry weight.

2.8 Statistical analysis

All measurements were repeated in three replicates and values in tables represent mean value (±STDEV). Statistical analysis included analysis of variance using ANOVA and ANOVA post hoc Newman-Keuls test (Statistica 8.0 ©Copyright StatSoft, Inc. 1984-2007) at significance level of $p<0,05$.

3. RESULTS AND DISSCUSION

Effect of pre-treatment with different essential oils on germination rate, growth parameters and vigour of *Silene sendtneri* seedlings are presented in Table 1. As a result of priming, germination rate of *S. sendtneri* was slightly decreased when silver fir essential oil was applied and significantly decreased for oregano oil treatment. Effects of priming on germination have been investigated and showed different results depending upon species, improvements but also inhibition of germination rate have been reported (Basra et al.,2011; Afzal et al.,2012; Imran et al.,2013). This may be related to the type of seeds (plant/species) and/or can be concentration/time depended (Tzortzakis, 2009) or it can be related to reparation of damaged proteins, RNA and DNA (Koehler et al., 1997).

Priming with *O. vulgare* essential oil significantly improved seedling length compared to *A. alba* treated plants and control (Table 1). Seed priming can be effectively used for an improvement of seedling growth, especially when seeds are cultivated under stress conditions (Afzal et al., 2008). Increase of seedling length was according to the rise of the *O. vulgare* essential oil concentration. Similar stimulatory effect of plant extracts was recorded also previously for some other plants (Imran et al., 2014).

Increase in water content was also recorded, especially for seedlings grown from seeds pre-treated with silver fir essential oil (Table 1). These results can implicate that seed priming using of essential oils stimulates root growth and more effective water and nutrient absorption from soil, better plant osmotic adjustment and/or the ability to prevent water waste. Namely, it is known that higher values of relative water content can increase metabolic activity, maintain and retain stomatal conductance, induce higher transpiration rate and photosynthesis in plants (Medrano et al., 2002; Matsushima et al., 2013; Pallaoro et al., 2016; Mohammadi et al., 2017).

Significant decrease of dry weight amount after priming with both essential oils was noted (Table 1) and unexpected. According to some authors, the increase in the stem length tended to be in a positive correlation with the dry weight (Matsushima et al., 2013 and references therein; Pallaoro et al., 2016; Mohammadi et al., 2017 and references therein). Obtained different responses for seedling length and dry mass in this study may suggest that there was a disturbance in the metabolic activity of seedlings caused by some environmental factors.

Significant enhancement of seedling vigour was recorded for seedlings grown from seeds treated with 20 g/mL oregano essential oil (Table 1). According to obtained results, it is possible to presume that oregano oil may be used for better seedling synchrony of *Silene sendtneri*, although at lower rate of germination. Higher values of seedling length have been associated with superior seed vigour (Horii et al., 2007; Afzal et al.,2012; Hussian et al., 2014).

Stimulatory effects of both tested essential oils on photosynthetic pigment content of *Silene sendtneri* is recorded (Table 2), especially for chlorophyll *b*, total chlorophylls and carotenoids. Also, significant increasing of chlorophyll *a* is recorded for all treatments with oregano oil. Photosynthetic rate, biomass production, productivity capacity and plant vigour may be improved by high chlorophyll's concentrations (Sacała et al., 2016; Mohammadi et al., 2017) which are in accordance with observed results. Imbalance in water and photosynthetic pigment contents, from one hand, and dry weight, from other, suggest inadequate pigments ratio, increased stomatal openness and/or hormonal disorder.

4. CONCLUSION

Priming with silver fir and oregano essential oils on *Silene sendtneri* seedlings increased growth, water content, vigour and photosynthetic pigment contents but decreased germination rate and dry weight compared with that obtained with untreated seeds. It seems that applied seed priming demonstrated that seedling vigour is slightly higher even with smaller germination rate, especially with all oregano oil treatments. Therefore, it is possible to assume that oregano oil could be used for better seedling synchrony, although at lower rate of germination.

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Table 1. Effect of pre-treatments with different essential oils (EO) on germination rate, some growth parameters and vigour of *Silene sendtneri* seedlings

Pre-treatment		**G (%)**	**SL (cm)**	**WC (%)**	**DW (mg)**	**SVI**
***Abies alba* EO (□g/mL)**	***Origanum vulgare* EO (□g/mL)**					
0	0	73,00^{a} ±1,42	1,02^{b} ±0,25	69,22^{e} ± 0,19	30,78^{e} ± 0,19	74,39^{e}
10	0	73,00^{a} ± 1,42	1,02^{b} ± 0,25	69,22^{e} ± 0,19	30,77^{e} ± 0,19	74,39^{e}
20	0	72,00^{a} ± 1,81	1,06^{b} ± 0,18	95,89^{a} ± 1,58	4,10^{a} ± 1,58	76,54^{d}
30	0	71,00^{a} ± 1,52	1,11^{b} ± 0,23	91,38^{b} ± 1,66	8,61^{b} ± 1,66	79,15^{c}
0	10	65,00^{a} ±3,03	1,34^{a} ±0,32	87,99^{a,b,c} ± 2,34	12,01^{a,b,c} ± 2,34	87,49^{b}
0	20	65,00^{a} ±3,10	1,44^{a} ±0,26	89,69^{a,b} ± 3,18	10,31^{a,b} ± 3,18	93,6^{a}
0	30	53,00^{a} ±3,83	1,47^{a} ±0,31	88,54^{a,b,c} ± 3,18	11,45^{a,b,c} ± 3,18	77,751^{d}

Data represents average values (±SD); treatments not shearing the same letter within one parameter differ significantly at p≤0.05 level according to Newman-Keuls test. Where: G - germination rate, SL - seedling length, WC - water content, DW - dry weight, SVI – seedling vigour index

Table 2. Effect of pre-treatment with different essential oils (EO) on photosynthetic pigments content of *Silene sendtneri* seedlings

Pre-treatment		**Chlorophyll *a***	**Chlorophyll *b***	**Total chlorophylls**	**Carotenoids**
***Abies alba* EO (□g/mL)**	***Origanum vulgare* EO (□g/mL)**				
0	0	2,76^{d} ±0,26	0,89^{b} ±0,06	3,67^{c} ±0,22	0,78^{d} ±0,09
10	0	4,49^{b} ±1,42	3,46^{a,b} ±0,59	8,0^{a,b} ±2,03	1,16^{b,c,d} ±0,27
20	0	2,47^{d} ±0,34	1,24^{b} ±0,07	3,73^{c} ±0,30	1,42^{a,b,c} ±0,07
30	0	2,96^{d} ±0,23	1,56^{b} ±0,50	4,55^{b,c} ±0,74	1,39^{a,b,c} ±0,17
0	10	6,03^{a,b} ±0,08	3,55^{a} ±0,17	9,55^{a} ±0,24	2,64^{a} ±0,10
0	20	5,92^{b} ±0,08	2,23^{b,c} ±0,08	8,12^{b} ±0,16	1,38^{b} ±0,13
0	30	5,48^{c} ±0,30	2,49^{b,c} ±0,07	7,94^{b} ±0,34	1,64^{a,b} ±0,05

Data represents average values (±SD); treatments not shearing the same letter within one parameter differ significantly at p≤0.05 level according to Newman-Keuls test.

Current Perspectives of DNA Barcoding in Bosnia and Herzegovina Through BOLD Database

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ABSTRACT

DNA barcoding is a method designed to provide rapid and precise species identifications by using one or more of short gene sequences called barcodes. In most plant and fungi studies, the standard barcodes of choice are three plastid (rbcL, matK and trnH-psbA) and one nuclear (ITS) gene regions. The relatively high, but comparatively conserved rate of sequence evolution of mtDNA has made COI the marker of choice in animals. BOLD is a freely available cloud-based data storage and analysis platform developed with the aim to advance biodiversity science through DNA barcoding species identification. To date, over 6 million barcodes have been deposited in BOLD with 196,000 animal species, 68,000 plant species and 22,000 species of fungi and other organism entries. In this database, there are currently 447 entries for organisms from Bosnia and Herzegovina, which makes 0.0067% of the total number of BOLD entries. According to BOLD statistics, only 1.11% of all organism entries from B&H were submitted by B&H institutions.

Despite the fact that Bosnia and Herzegovina has valuable natural resources with a high percentage of endemic and autochthonous species, BOLD statistics elucidated the lack of coordinated and systematic DNA barcoding research so far. It is necessary to establish continuous progress of molecular-genetic characterization of these resources in the future. It is up to B&H institutions to decide if they want to continue the practice of submitting the data sporadically or if they will animate the research community to actively participate in this global project.

Key words: biodiversity databases, BOLD Systems, DNA barcoding

1. INTRODUCTION

In the era of the "taxonomic crisis" when only a small number of taxonomists can reliably identify species by applying morphological methods, the establishment of a fast, reliable and cost-effective tool for species identification becomes a global need. This operational problem was the driving force for the development of a new method - DNA barcoding, designed to enable rapid and precise identification of species using one or more short sequence genes from the entire genome, the so-called barcodes (Hebert et al., 2003a). DNA barcodes (400-800 bp) should be easily generated, informative and applicable for all species on the planet (Kress & Erickson, 2008). In most of the previous studies, three plastid gene regions (*rbcL*, *matK* and *trnH- PsbA*) and one nuclear (*ITS*) were used as standard barcodes for plants and fungi, respectively. The DNA sequence for cytochrome c oxidase subunit I (*COI*) fits DNA barcodes criteria and has been used as the marker of choice in animals (Kress & Erickson, 2012). The DNA barcode concept was described in 2003 by P.D.N. Hebert and associates from the Guelph University of Ontario, who used primers to amplify 648 bp *of COI* gene, described by Folmer et al. (1994). The idea of barcoding began with the creation of a „*COI* profile" for the representatives of different species from 100 families of

eight orders of insect classes. The authors proposed this mitochondrial gene as the basis of the molecular bioidentification system in animals that provides reliable, economical and accessible solutions to current problems in identifying species (Hebert et al., 2003a; Hebert et al., 2003b).

DNA barcoding involves two basic steps: (1) building a reference sequence library of barcodes of already known species, and (2) associating barcodes with sequences of unknown patterns with barcodes from the database. DNA barcoding is useful in cases when species identification by a classic morphological method is hindered, e.g. samples in different developmental stages (Kalamujić Stroil et al., 2018a), damaged samples, specimens from the gut content (Harms-Tuohy et al., 2016), the fecal sample, and others. DNA barcoding is also used to identify potential new or cryptic species, as well as to address fundamental environmental and evolutionary issues (Kress & Erickson, 2012). Therefore, DNA barcodes, as a basic screening tool, could provide an insight into the diversity of species, their ecology, biogeography, and evolution (Costa et al., 2018). Identification of species using DNA barcoding methodology begins with the sampling of individuals from different sources (collected on the field, from collections stored in museums, zoos, botanical gardens, seed banks, etc.). Then, DNA is isolated from a small portion of the sample tissue in the laboratory. Through the process of PCR amplification, products are generated which are subsequently sequenced. The resulting sequence is a barcode of the investigated specimen which is then used to search the databases for the match, i.e. the highest probability that the query sequence belongs to some species.

Biodiversity databases play a key role in storing the information on the state of biodiversity which can be used for revitalization and conservation purposes (Turnhout & Boonman-Berson, 2011). Some reference sequence libraries, such as The Spanish Freshwater Fish Database, German Barcode of Life, Norwegian Barcode of Life, Finnish Barcode of Life, Bibliotheque du vivant, Netherlands Barcode of Life, Swiss Barcode of Life, Barcode of Life, and The International Barcode of Life Project are results of projects of European countries implementing high throughput sequencing and DNA barcoding in attempt to capture the genetic diversity (Kalamujić Stroil et al., 2017). One of the most often used global DNA barcode databases is the Barcode of Life Data Systems (BOLD) database which represents a searchable online repository of barcode records, with accompanying data (iBOL, 2017).

2. BARCODE OF LIFE DATABASE SYSTEMS (BOLD)

Barcode of Life Database Systems (BOLD) is a web-based and free-of-charge IT system, which has a flexible data model that makes it suitable for projects involving more research teams (Ratnasingham & Hebert, 2007; Kalamujić Stroil et al., 2018b). BOLD consists of four main modules: a data portal, an educational portal, a registry of BINs, and a data collection and analysis workbench (BOLD). BOLD evolved from an informatics workbench for a single, high-volume DNA barcode facility into a resource for the DNA barcoding community. Some features of BOLD are available to any visitor, but system registration provides additional privileges. In addition to the basic package (access to data in public projects and using of the Identification System),

registration includes creating private projects and sharing access to password-protected data (Ratnasingham & Hebert, 2007).

2.1.The Structure and Content of BOLD Systems

Four main modules of BOLD are available at http://www.boldsystems.org/. Data portal allows for searching over 1.7 M public records using multiple search criteria. It supports queries based on taxonomy, geography, attribution fields, depositories, specimen and sequence identifiers (BOLD). The educational portal, classroom-focused interface to the BOLD database, provides the analysis and publication of DNA barcode data by students. Students can both, explore the large database of DNA barcode records and add their own data to DNA barcode library, all of that monitored by instructors. The Barcode Index Number (BIN) System classifies sequences using well-known algorithms. This page includes a dendrogram of all member sequences. The workbench is a data storage and analysis platform, supporting the assembly and validation of DNA barcodes and other sequences (BOLD).

2.2.The Statistics Through the Prism of BOLD

To date, over 6,710,000 barcodes have been deposited in BOLD with 196,000 animal species, 68,000 plant species and 22,000 species of fungi and other organism entries (Figure 1).

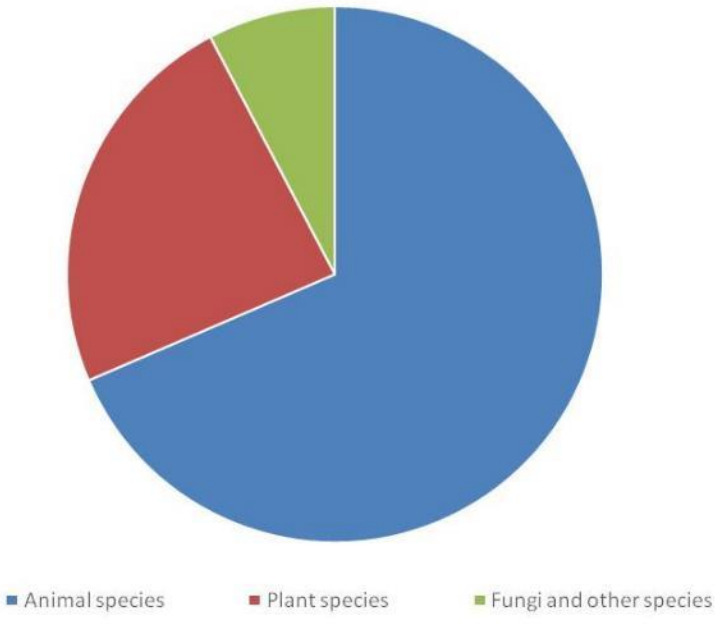

Figure 1. Representation of organisms in the BOLD systems

BOLD's statistics show very significant data. In order to analyze the involvement of different countries in DNA barcode activities, we chose eight countries: four very developed (Germany, Austria, France, and Sweden) and four countries from the Balkan region (Bosnia and Herzegovina, Croatia, Serbia, and Montenegro). Results showed that Germany has the most public records, with species level sequences and BINs. It is followed by France, Austria, and Sweden, respectively

(Figure 2). Observing the countries of the Balkan region, Croatia leads in the number of published sequences and BINs (Figure 3).

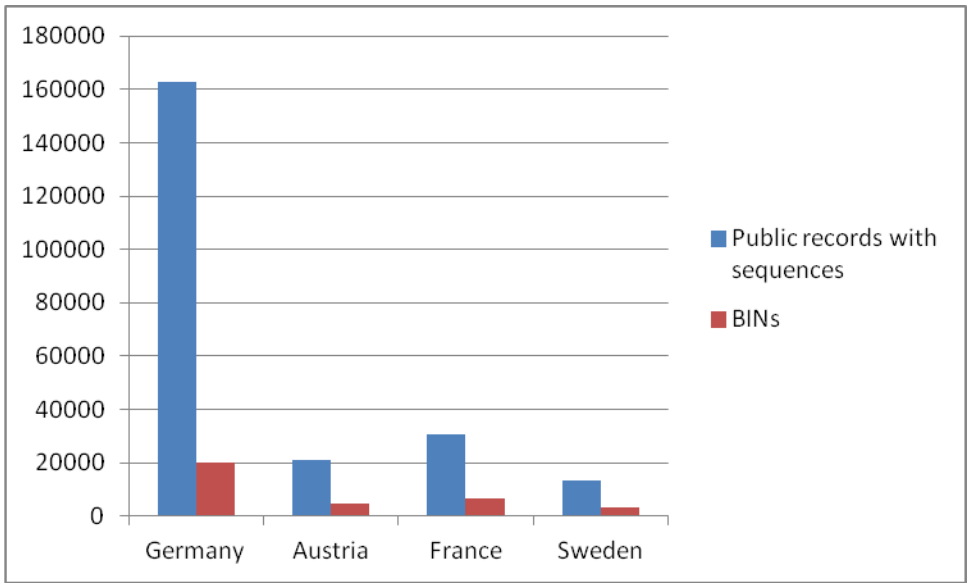

Figure 2. Comparative review of public records with sequences and BINs of four very developed countries

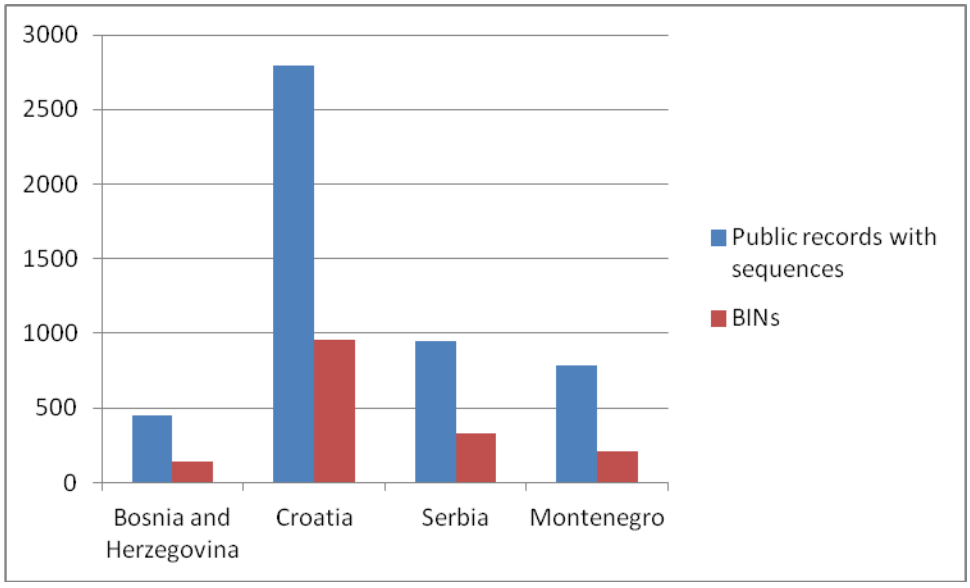

Figure 3. Comparative review of public records with sequences and BINs of the countries of the Balkan region

The top ten orders of sequenced organisms from Bosnia and Herzegovina include Cypriniformes (101), Lepidoptera (80), Entomobryomorpha (49), Decapoda (43), Veneroida (22), Amphipoda (18), Liliales (18), Dipsacales (14), Salmoniformes (12), and Diptera (11). The highest number of entries are for the following species: *Austropotamobius pallipes* (22), *Congeria kusceri* (14), *Lilium bosniacum* (10), *Gammarus balcanicus* (9), *Troglocaris anophthalmus* (8), *Congeria mulaomerovici* (8), *Rutilus basak* (7), *Chondrostoma phoxinus* (7), and *Telestes dabar* (7).

In this database, there are currently 452 entries for organisms from Bosnia and Herzegovina, which makes 0.0067% of the total number of BOLD entries. According to BOLD statistics, only 1.106% of all organism entries from B&H were submitted by B&H institutions. In comparison to neighboring countries, Serbia and Croatia have deposited 950 (5.26% entries submitted by Serbian institutions) and 2,799 entries (12.08% entries submitted by Croatian institutions), respectively (Figure 4). However, neither of 781 entries for organisms from Montenegro is submitted by Montenegro institutions. For instance, Germany has 162,925 BOLD entries and all of them were submitted by German institutions.

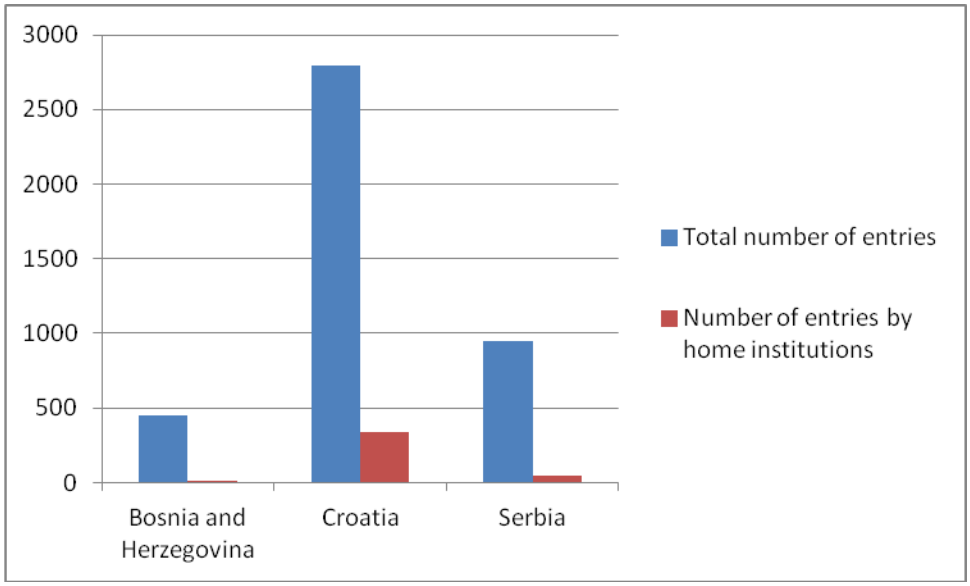

Figure 4. Comparative review of total number of entries and number of entries by home institutions

3. *FUTURE OF DNA BARCODING IN BOSNIA AND HERZEGOVINA*

Despite the fact that Bosnia and Herzegovina has valuable natural resources with a high percentage of endemic and autochthonous species, BOLD statistics elucidated the lack of coordinated and systematic DNA barcoding research so far. It is necessary to establish continuous progress of molecular-genetic characterization of these resources in the future. It is up to B&H institutions to decide if they want to continue the practice of submitting the data sporadically or if they will animate the research community to actively participate in this global project.

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