NATURA SLOVENIAE

Revija za terensko biologijo • Journal of Field Biology

Letnik • Volume 27 2025 Številka • Number 3

NERETVA SCIENCE WEEK 2023

Posebna izdaja • Special Edition • Specijalno izdanje

Manfred Hermsen Stiftung für Natur und Umwelt

save the blue heart of europe

NIB NACIONALNI INŠTITUT ZA BIOLOGIJO NATIONAL INSTITUTE OF BIOLOGY

UNIVERZA V LJUBLJANI BF Biotehniška fakulteta

NATURA SLOVENIAE
Revija za terensko biologijo • Journal of Field Biology
Letnik/Volume 27 • Številka/Issue 3 • 2025
»Neretva Science Week 2023«
https://journals.uni-lj.si/NaturaSloveniae

Založila • Published by: Založba Univerze v Ljubljani/University of Ljubljana Press
Za založbo/For the Publisher: Gregor Majdič, rektor Univerze v Ljubljani/the Rector of the University of Ljubljana

Izdajata • Issued jointly by:
Biotehniška fakulteta, Univerza v Ljubljani
Jamnikarjeva 101, SI-1000 Ljubljana
Tel.: (0)1 320 30 00; Telefax: (0)1 256 57 82
https://www.bf.uni-lj.si
Za izdajatelja/For the Issuer: Marina Pintar, dekanja Biotehniške fakultete UL
the Dean of the Biotehnical Faculty UL

Nacionalni inštitut za biologijo
Večna pot 121, SI-1000 Ljubljana
Tel.: (0)59 232 700; Telefax: (0)1 2412 980
https://www.nib.si
Za izdajatelja/For the Issuer: Maja Ravnikar, direktorica/director

Odgovorna urednica • Editor in Chief: Maja Zagmajster

Gostujoča urednika • Guest Editors: Gabriel Singer (University of Innsbruck, Austria),
Špela Di Batista Borko (Riverwatch & University of Graz, Austria)

Tehnični urednik • Technical Editor: Jernej Polajnar

Uredniški odbor • Editorial Board: Matjaž Bedjanič (Slovenia), Nicola Bressi (Italy), Maarten de Groot (Slovenia), Marijan Govedič (Slovenia), Nejc Jogan (Slovenia), Rok Kostanjšek (Slovenia), Borut Mavrič (Slovenia), Nataša Mori (Slovenia), Toni Nikolić (Croatia), Nina Šajna (Slovenia), Chris Van Swaay (Netherlands), Peter Trontelj (Slovenia), Rudi Verovnik (Slovenia), Damjan Vinko (Slovenia)

Lektorja • Language Editors: Miloš Bartol (za angleščino in slovenščino/for English and Slovene),
Branislava Dukić (za bosanščino/for Bosnian)

Oblikovanje • Layout: o3 oglaševanje (vsebinske strani/content pages)

Oblikovanje naslovnice • Cover layout: Daša Simčič akad. slikarka, Atelje T
Joshua D. Lim (photos by: Vladimir Tadić, Joshua D. Lim, Brais Palmás, Ester Premate)

Naslov uredništva • Address of the Editorial Office: NATURA SLOVENIAE, Večna pot 111, SI-1111 Ljubljana, Slovenija

Izvlečki prispevkov so zavedeni v zbirkah **ASFA, AGRIS, Biological Abstracts, Biosis Previews, COBISS** in **Zoological Records**

Sofinancira • Cofinanced by: Riverwatch & Javna agencija za znanstvenoraziskovalno in inovacijsko dejavnost RS/Slovenian Research and Innovation Agency

CC BY

KAZALO VSEBINE • TABLE OF CONTENTS

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 4–12
»Neretva Science Week 2023«
DOI: 10.14720/ns.25688
Objavljeno na spletu / Published online: 31. 12. 2025
Prejeto / Received: 24. 12. 2025
Sprejeto / Accepted: 29. 12. 2025

UVODNIK /
EDITORIAL

»Neretva Science Week« revisited – maintaining momentum on a conservation mission from river to catchment in the Upper Neretva River valley, Bosnia and Herzegovina

Gabriel SINGER[1*], *Špela DI BATISTA BORKO*[2], *Manuela HABE*[3], *Maja ZAGMAJSTER*[4], *Mirza ČELEBIČIĆ*[5], *Vladimir TOPIĆ*[6], *Jelena IVANIĆ*[6], *Ulrich EICHELMANN*[7]

ABSTRACT

The Blue Heart of Europe campaign keeps publishing updates about the development of hydropower projects on the Balkan peninsula. It is one thing to see a map of thousands of threats to hundreds of rivers, but it is another thing to actually witness when one river gets lost before your eyes. In an act of stubbornness and unbroken optimism, despite ongoing construction of hydropower infrastructure for Ulog and Upper Horizon projects, the Blue Heart of Europe´s Scientists for Balkan Rivers Network once more organised a Science Week at the Neretva River. Between 30 May and 7 June 2023 almost 70 scientists and students from 17 countries and a once more diversified array of scientific disciplines joined forces to expand our knowledge on the biodiversity of the Neretva River catchment. Our mission was to document the biodiversity of the river, its hidden tributaries, underground rivers, mountain springs and the terrestrial valley sides. The 11 contributions published in this second special issue of Natura Sloveniae dedicated to the Neretva demonstrate once again the extraordinary biodiversity residing in this remote part of Europe. The many documented species encourage us to keep fighting for this exceptional natural heritage in spite of all difficulties.

IZVLEČEK

Ponovno »Znanstveni teden Neretve« – ohranjanje zagona za varstveno misijo od reke do porečja v zgornji dolini reke Neretve, Bosna in Hercegovina

Kampanja »Blue Heart of Europe« še vedno objavlja novice o načrtovanih hidroenergetskih projektih na Balkanskem polotoku. Toda eno je videti zemljevid tisočerih groženj za stotine rek, drugo pa je dejansko spremljati izginotje reke z lastnimi očmi. Znanstveniki mreže Balkan Rivers Network so kot vztrajni in neomajni optimisti ponovno organizirali Znanstveni teden na reki Neretvi, ne glede na nadaljevanje gradnje hidroenergetske infrastrukture za projekte Ulog in Gornji Horizonti. V času od 30. 5. do 7. 6. 2023 se je skoraj 70 znanstvenikov in študentov iz 17 držav, in še enkrat toliko različnih disciplin, združilo, da bi izboljšali poznavanje biotske raznovrstnosti porečja reke Neretve. Naša naloga je bila dokumentirati biotsko raznovrstnost reke, njenih skritih pritokov, podzemnih rek, gorskih izvirov in kopenskih pobočij doline. Enajst prispevkov, objavljenih v pričujoči drugi posebni izdaji revije Natura Sloveniae, posvečeni reki Neretvi, ponovno osvetljuje izjemen zaklad biotske raznovrstnosti, ki se nahaja v tem oddaljenem delu Evrope. Številne dokumentirane vrste nas opominjajo, da moramo kljub vsem težavam nadaljevati boj za to edinstveno naravno dediščino.

[1] Department of Ecology, Innsbruck University, Technikerstrasse 25, 6020 Innsbruck, Austria; E-mail: gabriel.singer@uibk.ac.at

[2] Institute of Biology, University of Graz, Universitätsplatz 2, A-8010 Graz, Austria; E-mail: borko.spela@gmail.com

[3] Independent researcher, Vienna, Austria; E-mail: habemanu@gmail.com

[4] University of Ljubljana, Biotechnical Faculty, Department of Biology, SubBioLab, Jamnikarjeva 101, 1000 Ljubljana, Slovenia; E-mail: maja.zagmajster@bf.uni-lj.si

[5] Department of Biology, Faculty of Science and Mathematics, University of Tuzla, Univerzitetska 4, Tuzla, Bosnia and Herzegovina; E-mail: mirzacelebicic24@gmail.com

[6] Center for Environment, Miše Stupara 5, 78 000 Banja Luka, Bosnia and Herzegovina; E-mails: vladimir.topic@czzs.org, jelena.ivanic@czzs.org

[7] Riverwatch, Society for the Protection of Rivers, Neustiftgasse 36, 1070 Vienna, Austria; E-mail: ulrich.eichelmann@riverwatch.eu

* Korespondenčni avtor / Corresponding author

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

KEY WORDS:
Blue Heart of Europe, Scientists for Balkan Rivers, public outreach, hydropower, environmental protection, biodiversity conservation, scientific advocacy

KLJUČNE BESEDE:
Blue Heart of Europe, znanstveniki za balkanske reke, ozaveščanje javnosti, hidroenergija, varstvo okolja, ohranjanje biotske raznovrstnosti, znanstveno zagovarjanje

KLJUČNE RIJEČI:
Plavo srce Evrope, Naučnici za balkanske rijeke, javno informisanje, hidroenergija, zaštita životne sredine, očuvanje biodiverziteta, naučno zagovaranje

APSTRAKT

Ponovljena »Sedmica nauke na Neretvi« – održavanje zamaha za misiju zaštite prirode od rijeke do sliva u gornjem toku rijeke Neretve, Bosna i Hercegovina

Kampanja »Plavo srce Evrope« nastavlja objavljivati novosti o razvoju hidroenergetskih projekata na Balkanskom poluostrvu. Jedno je videti mapu sa hiljadama pretnji stotinama rijeka, ali je nešto sasvim drugo biti svjedok trenutka kada jedna rijeka nestaje pred vašim očima. U činu tvrdoglavosti i nepokolebljivog optimizma, uprkos izgradnji hidroenergetske infrastrukture za projekte »Ulog« i »Gornji horizonti«, mreža »Plavo srce Evrope-Naučnici za balkanske rijeke« ponovo je organizovala Sedmicu nauke na rijeci Neretvi. Od 30. 5. do 7. 6. 2023. godine, gotovo 70 naučnika i studenata iz 17 zemalja, uz još raznovrsniji spektar naučnih disciplina, udružilo je snage kako bi proširili istraživanje biodiverziteta sliva rijeke Neretve. Njihova misija bila je da dokumentuju biodiverzitet rijeke, njenih skrivenih pritoka, podzemnih tokova, planinskih izvora i obala. Jedanaest radova je objavljeno u ovom drugom specijalnom izdanju časopisa Natura Sloveniae, posvećenom Neretvi, te još jednom pokazuju kakvo izuzetno blago biodiverziteta postoji u ovom udaljenom evropskom području. Mnoge dokumentovane vrste podsjećaju nas da nastavimo borbu za ovo prirodno nasljeđe, uprkos svim teškoćama.

WHAT IS THE »BLUE HEART OF EUROPE CAMPAIGN«, WHO ARE THE »SCIENTISTS FOR BALKAN RIVERS« AND WHAT IS A »SCIENCE WEEK«?

The Save the Blue Heart of Europe campaign was launched in 2012 by the NGOs EuroNatur and Riverwatch in cooperation with local partners across the Balkans to save the many ecologically outstanding Balkan rivers, the 'Blue Heart of Europe', from – at that time – more than 3,500 planned hydropower plants (https://balkanrivers.net). The vision of the campaign is to prevent further destruction of rivers by dam constructions or water abstractions. To this aim, a network of NGOs, activists, lawyers, artists and scientists was created – at local, regional and international scales. So far, this diverse network has helped to stop hundreds of dam projects (Riverwatch, unpublished list).

A very important part of the campaign network is the initiative Scientists for Balkan Rivers (SBR, https://balkanrivers.net/en/scientists) – a growing network of scholars and experts from various European countries. They assess the biodiversity and ecological processes in Balkan rivers through a range of activities including collaborative field campaigns and projects, targeted assessments of individual hydropower projects, and small individual projects by young researchers pursuing master or PhD theses. The SBR builds on the remarkable success of the 'Scientists for Vjosa', a group of scientists who contributed critically to the protection of the Vjosa River (Schiemer et al. 2018, 2020) and to the establishment of the Wild River National Park in 2023 (https://www.vjosanationalpark.al). The SBR network includes scientists active in many research fields ranging from hydrology to socio-ecology, at all career stages from students to senior professors, as well as experts working outside academic institutions. What brings them together is the shared idea of acting as engaged scientists, i.e. to advocate for the protection of rivers as mandated by scientific evidence, and the realization that a network of like-minded people is more efficient than any individual as collaborative action fosters motivation and creates and maintains critical momentum.

Key events of the SBR network are 'Science Weeks' (Figs. 1, 2), which have been organised since 2017 on various Balkan Rivers starting with the Vjosa in 2017. Meanwhile, several Science Weeks were held in the Vjosa River Network: at the tributary Shushica (Schiemer & Miho 2021), in the Vjosa Delta (https://balkanrivers.net/en/pages/2024-vjosa-delta-science-week), and at the tributary Sarantaporos (https://balkanrivers.net/en/pages/the-sarantaporos). The Neretva River has seen a first Science Week in 2022 (Singer et al. 2023) and this special issue of Natura Sloveniae summarizes the scientific findings of the second Neretva Science Week held in 2023. If doing solid science collaboratively with others in a network in order to successfully advocate is epitomized in the 'engaged scientist', then a Science Week should enable these three pillars (Fig. 1a): (i) solid science securing evidence through publication and thereby fostering the reputation of involved scientists, (ii) networking with like-minded scholars to build momentum and capacity, (iii) engagement and advocacy by providing opportunities to interact with media and decision makers.

During a Science Week, scientists get an opportunity to do what they can do best – they (voluntarily) gather data. Close and immediate interaction with media and journalists, who are often embedded in field activities, allows skilled storytellers to make the most out of scientific expertise and daily discoveries. Perhaps most importantly, a Science Week provides a unique

chance for networking among dedicated scientists from various nations, institutions and career stages. For senior scholars, a Science Week is a unique opportunity to offer hands-on learning to students; one may view it as fulfilling outreach duties, but, in fact, it may also be seen as assuming societal responsibility by pinpointing destructive impact and promoting conservation, while fostering careers of young, engaged colleagues. Involvement of less experienced colleagues builds additional capacity, while networking empowers scientists to build and maintain momentum in advocacy for nature protection. Lastly, a Science Week is physically present at a given place and the interaction with the local community makes them aware of their homeland as valuable natural heritage and promotes the emergence of alternative visions for their future beyond hydropower development.

From an organisational point of view, a Science Week presents several challenges associated with the various needs of the people involved and the multi-purpose nature of the activity. A typical organisational cycle (Fig. 1b) consists of (i) a prolonged planning phase including a scouting trip to identify a suitable location, ideally a pan-Balkan biodiversity hotspot, and a scientific mission, (ii) the actual event typically lasting only for a few days, (iii) the preparation of a preliminary report accessible and attractive to a general audience, and (iv) the presentation of scientific findings through disciplinary scientific publication. Choice of location is paramount as it defines attractiveness to scientists as well as the media. Luckily, many Balkan rivers present themselves as outstanding places in terms of ecology and landscape, hosting a high degree of endemic biodiversity (Griffiths et al. 2004). A scientific mission, for instance a landscape-scale gradient, may seem superfluous and even futile given the diversity of involved disciplines, yet it unites participants even if formulated in a simplified manner and makes them feel being a part of something bigger, which promotes networking.

During the short actual event it is 'all hands on deck': data collection must be highly efficient, often following 'minimum means' approaches with regard to time, money and instrumentation. Making field work possible in remote locations involves considerable logistics as the requirements of water beetle experts differ from those of mushroom specialists. Some diplomacy may be needed to convince participants to spend effort on networking across disciplinary and cultural borders. Perhaps most importantly, stories must be told on a daily basis through social media and to embedded journalists, who must not be forgotten in the field camp by all-too-eager scientists venturing into the field to collect data at 5 AM. Overall, the field setting provides unique opportunities for a once-in-a-lifetime assembly of people active in science, media, NGOs, locals and the occasional random supporter that shows up to cook for a crowd of 70.

The preparation of reports requires motivational energy in two phases: First, a preliminary report is created by media specialists and NGO representatives based on preliminary scientific findings. The preliminary report (Knook et al. 2022; Borko et al. 2023) has an attractive layout and mainly serves to attract public attention. It is ideally published within a few weeks to months after the field work. Second, scientific publications are prepared by the scientists themselves, ideally (but not exclusively) as a series of papers in a special issue of a disciplinary journal. Being the last step of many, energy may run low at that stage, yet scientific publication is critical: it secures evidence (e.g. about threatened species) in published form, but it also feeds the needs of scientific CVs and thereby maintains scientific engagement and advocacy in the long run. Perhaps not all steps are achieved in all Science Weeks, but this special issue of Natura Sloveniae represents the successful conclusion of one completed Science Week cycle.

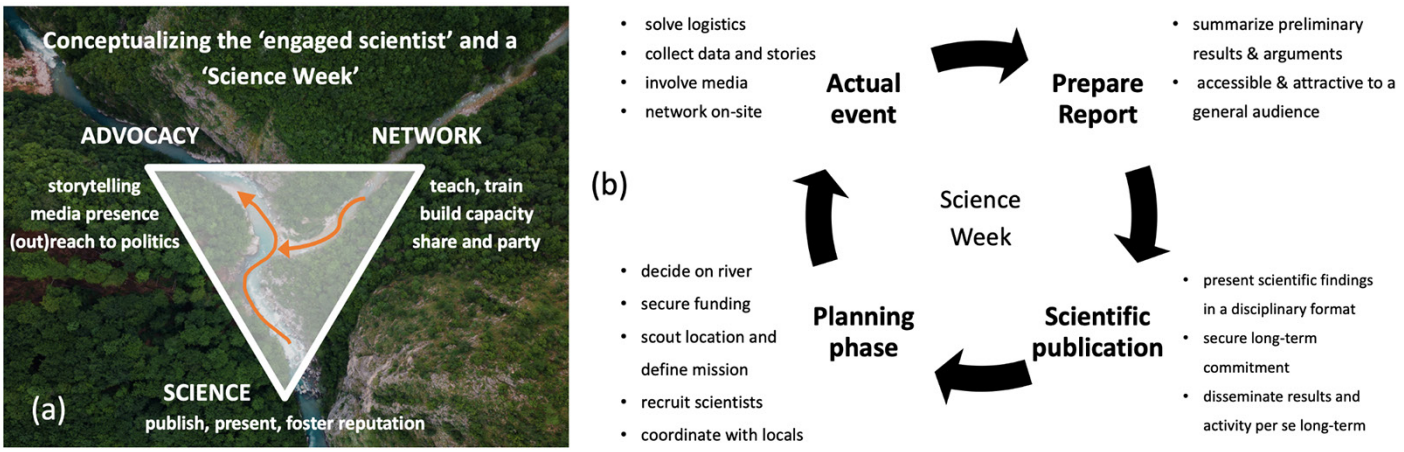

Figure 1. A Science Week is about bringing together engaged scientists ready to advocate for the protection of nature with professional storytellers in an outstanding ecosystem like the Neretva River. (a) Three pillars define an engaged scientist as well as a Science Week, the backdrop picture is an aerial image from the confluence of the Ljuta with the Neretva River (photo: Josh D. Lim). (b) A Science Week organisational cycle.

Slika 1. Teden znanosti združuje zavzete znanstvenike, ki so pripravljeni zagovarjati varstvo narave, s profesionalnimi pripovedovalci zgodb v izjemnem ekosistemu, kot je reka Neretva. (a) Trije stebri opredeljujejo zavzetega znanstvenika in Teden znanosti, slika v ozadju je letalski posnetek sotočja rek Ljuta in Neretva (foto: Josh D. Lim). (b) Prikaz organizacijskega kroga Tedna znanosti.

Slika 1. Sedmica nauke imala je zadatak da okupi naučnike spremne da zagovaraju zaštitu prirode, zajedno sa profesionalnim novinarima u izuzetnom ekosistemu poput rijeke Neretve.(a) Tri stuba definišu angažovane naučnike, kao i Sedmicu nauke; pozadinska fotografija je snimak iz vazduha ušća rijeke Ljute u Neretvu (foto: Josh D. Lim). (b) Organizacijski ciklus Sedmice nauke.

Figure 2. Science Week action epitomized by Ulrich Eichelmann (Riverwatch) being interviewed by CNN in the canyon of the Neretva River downstream of Ulog, while Kurt Pinter prepares for electro-fishing and eDNA-sampling targeting the threatened softmouth trout (photo: Vladimir Tadić).

Slika 2. Dogajanje v okviru Tedna znanosti, kjer je viden Ulrich Eichelmann (Riverwatch) med intervjujem za CNN v kanjonu reke Neretve pod Ulogom, medtem ko se Kurt Pinter pripravlja na električni ribolov in vzorčenje eDNA ogrožene mehkoustne postrvi (foto: Vladimir Tadić).

Slika 2. Snimanje u okviru Sedmice nauke predstavljena kroz Ulricha Eichelmanna (Riverwatch) tokom intervjua za CNN u kanjonu rijeke Neretve nizvodno od Uloga, dok se Kurt Pinter priprema za elektroribolov i eDNA uzorkovanje usmjereno na ugroženu mekousnu pastrmku (foto: Vladimir Tadić).

WAS THERE A MISSION FOR NERETVA SCIENCE WEEK 2023? IF SO, WHAT WAS IT?

Neretva River originates in the remote and sparsely populated mountainous landscape of Bosnia and Herzegovina, from where it flows into Croatia and finally into the Adriatic Sea. While large parts of this 230 km long river are already heavily modified, the Neretva and its tributaries upstream from Konjic are – meanwhile unfortunately with a few exceptions – still mostly free-flowing. Despite the efforts of local and international activists, the construction of HPP Ulog was finished in 2024, its reservoir was filled in 2025, and its operation has already proven to be lethal with a major fish-kill incidence occurring in September 2025 (Singer et al., submitted). Gornja Neretva, the first thirty kilometres of the river from its source to Ulog village, the valley, and part of Mount Crvanj have been lined up for designation as protected area since 2021, yet the river is still under threat by seven planned dams in this area. Downstream of Ulog, the establishment of national parks is planned: on the left side of the Neretva River, Mount Prenj (the process is ongoing for part of the planned area), and on the right side, the mountains Treskavica, Visočica, and Bjelašnica – notably the river itself is included in neither. Two more large hydropower plants, namely HPP Bjelimići and HPP Glavatičevo, are planned downstream of HPP Ulog, and several small HPPs are planned on tributaries such as the Ljuta (15 HPPs) and Jezernica (4 HPPs) rivers. Thus, the area is far from being safe and continuous pressure is needed to emphasise the need for its protection.

The results of the Neretva Science Week 2022 were impressive: over 1000 species living in or along the investigated upper section of the Neretva were identified, of which 24 were new for Bosnia and Herzegovina, and eight species were new to science (Singer et al. 2023). It was clear that we barely scratched the surface with regard to the region´s biodiversity. Also, while there is ongoing construction of hydropower and continued threat to rivers and forests, the Neretva River and its valley still remain natural and outstandingly biodiverse ecosystems in a unique landscape worthy of protection. But – in times of social media and ever-shortening attention spans – do these facts promise success for a second Neretva Science Week just one year later? At least, a new mission was needed to make it attractive enough for scientists as well as the media. In 2022, we focused on aquatic and terrestrial 'river-associated' biodiversity along a length continuum from the river´s source to the city of Konjic, often with an eye on assessing potential direct impacts of hydropower on threatened habitat types and protected species. We achieved local assessments of flora, fauna and habitat along a series of sampling sites following a river growing in size, and, in part, managed to integrate those into an expert-based opinion on biodiversity and ecological integrity of the Neretva at a regional scale. The idea of assessments done at a 'regional scale' also drove our mission development for the Neretva Science Week 2023. A river is more than its wet channel and may be thought of as vertically extending towards groundwater (Saccò et al. 2024) and laterally transcending both its riparian zone as well as its floodplain (Gurnell et al. 2016); ultimately it must be thought together with its catchment, that feeds the river with water and resources and *vice versa*.

For 2023, our mission statement formulated three objectives (Fig. 3): (i) an assessment of biodiversity of the Neretva valley along peak-to-peak transects, ii) an exploration of remote and hard-to-access tributaries, and iii) an excursion to the Zalomka River, itself a hidden tributary to the Neretva. As the unique value of the Upper Neretva is the combination of intact forest and a living river network, our first objective was to explore biodiversity along several altitudinal transects along the slopes of the valley and the karst plateaus above: Zelengora in the north and Morine in the south. These transects were identified during scouting in April 2023; scientists were then following the transects and systematically studied the beech and oak forests on the slopes of the valley and the grasslands of the plateaus, including two lakes, Crvanj (Bosnian: Crvanjsko jezero) and Kladopolje (Bosnian: Kladopoljsko jezero). Our second objective was to explore the diversity of remote tributaries, like the canyon of Međeđak and the Ljuta River. Each of those represented a unique challenge: the first demanded canyoning skills, while the latter was surrounded by areas heavily contaminated with landmines and therefore only accessible at a few points. Finally, we organised a one-day sampling trip to a hidden tributary of the Neretva River: the intermittent Zalomka River, which flows through Nevesinjsko Polje, sinks completely into a cave called Biograd Ponor and reappears again as Bregava, Buna and Bunica springs, three tributaries of the Lower Neretva River downstream of Mostar. The ongoing 'Upper Horizons' hydropower project plans to divert water away from the sinkhole, with devastating impacts on the downstream section of Neretva River.

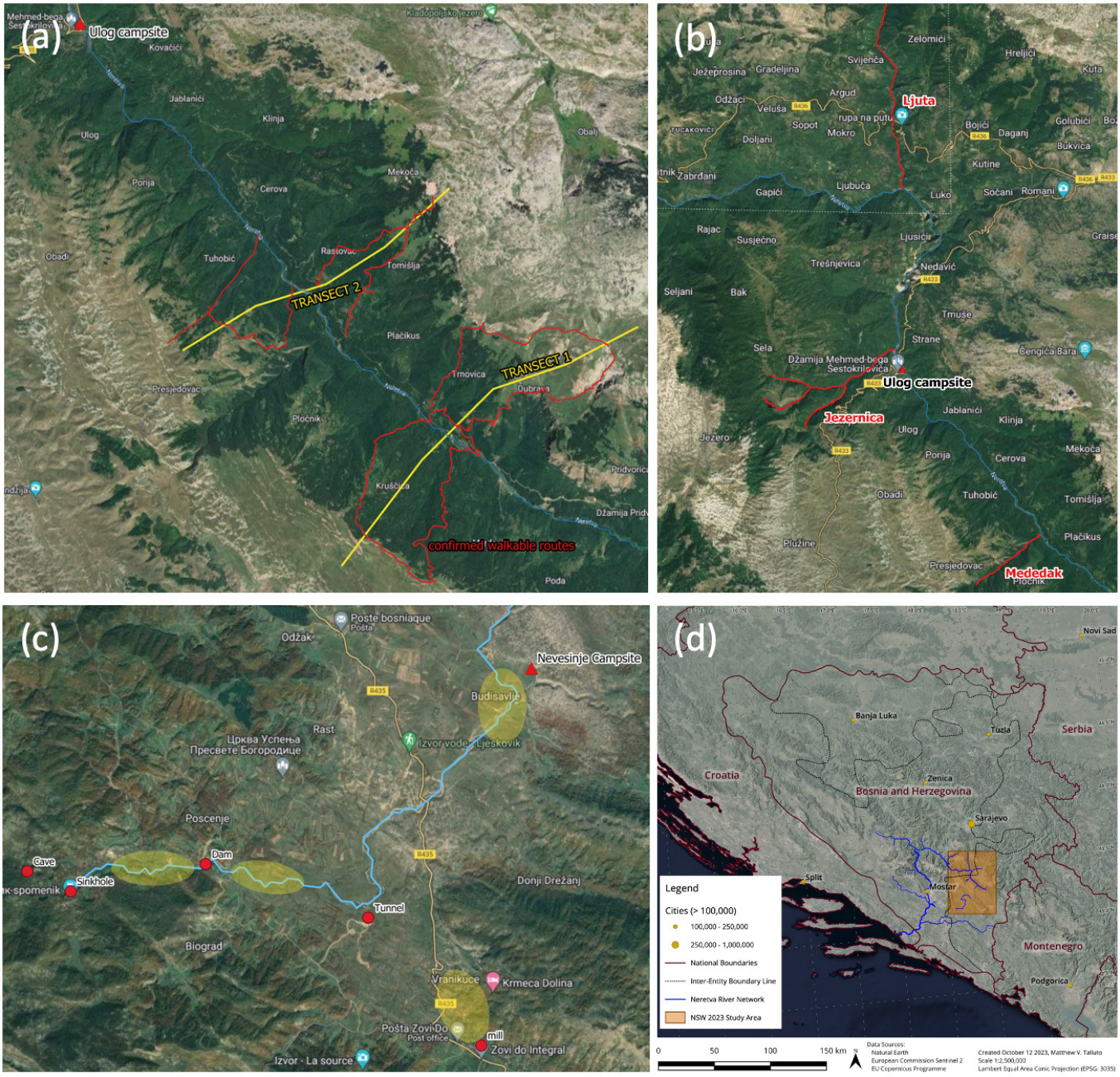

Figure 3. Study locations during the Neretva Science Week 2023. (a) Neretva River upstream of Ulog with predefined peak-to-peak transects; (b) the canyon tributaries Ljuta, Jezernica and Međeđak; (c) the Zalomka River in the Nevesinjsko Polje; (d) overview and location of the River Neretva and its upper section in Bosnia and Herzegovina.

Slika 3. Raziskovane lokacije med Tednom znanosti Neretva 2023. (a) Reka Neretva nad Ulogom z vnaprej določenimi transektnimi potmi; (b) kanjonski pritoki Ljuta, Jezernica in Međeđak; (c) reka Zalomka v Nevesinjskem polju; (d) pregled in položaj reke Neretve in njenega zgornjega dela v Bosni in Hercegovini.

Slika 3. Istraživani lokaliteti tokom Sedmice nauke na Neretvi 2023. (a) Rijeka Neretva uzvodno od Uloga sa unaprijed definisanim transek-tima-od vrha do vrha; (b) kanjonske pritoke: Ljuta, Jezernica i Međeđak; (c) Rijeka Zalomka u Nevesinjskom polju; (d) prikaz i položaj rijeke Neretve i njenog gornjeg toka u Bosni i Hercegovini.

OUTCOMES OF THE NERETVA SCIENCE WEEK 2023 – IN THE PRESENT SPECIAL ISSUE AND BEYOND

Immediately after fieldwork, participants might have summarized the Science Week with »It was cold and rainy, bugs were hiding, data collection remained limited, yet it seems worthwhile to protect the area.« After the publication of a preliminary report, various international presentations, and the present special issue at hand, we can acknowledge its great success despite all challenges. In a week from 30 May to 6 June 2023, almost 70 scientists from 17 countries participated in concert with 30 journalists, artists, photographers, lawyers and activists. Scientists were covering such different fields of biodiversity as forests, flora, fungi, fish, birds, amphibians and reptiles, large carnivores, bats, grasshoppers and crickets, butterflies and moths, spiders, subterranean fauna, soil fauna, aquatic beetles, stoneflies and caddisflies and other aquatic macroinvertebrates. The extension of studied taxonomic groups and research areas resulted in at least another 1000 species identified, thus doubling the taxonomic diversity discovered during the first Neretva Science Week. For the first time, scientists studied the age and structure of near-pristine forests of the Gornja Neretva. Several endangered, endemic, or protected species were newly observed. Various species potentially new to science were found in groups not studied before, like fungi, grasshoppers, and spiders. A total of 11 contributions are collected in this special issue of Natura Sloveniae and a few more publications based on the results of the second Neretva Science Week in 2023 may still be released in the near future.

Notably, in 2023, two socio-cultural aspects were studied for the first time: On the one hand, scientists themselves were made study subjects, as their experiences were probed to understand elements steering engagement and readiness for scientific advocacy. For the first time we thereby learned more about the personal challenges associated with creating real-world impact in the scientific life, i.e. what it takes to be an engaged scientist. Published results (Stritih et al. 2025) may help to improve future Science Weeks. On the other hand, the socio-ecological research team explored the relationships and connections of locals living in the Neretva valley with the river, the landscape and hydropower development through interviews. While results still await to be published, this research enabled us to realize an important consequence of the two Neretva Science Weeks organised at the same location: the so far underestimated effect that the events had had on the local population. Recognition of their homeland as a globally important natural heritage by foreign scientists changed their own perception of the natural value of their surroundings. Once a year, an almost abandoned settlement had come to life under the spotlight of international media. Local guides shared their knowledge with the visitors and discussed their future. One may hope that this leads locals to assume a proactive approach in shaping the future of the area – if so, this should be seen as an important contribution of the Neretva Science Weeks to the protection of this exceptional area. However, the team also documented locals stating a sense of being left unheard between different fronts and ideas of development, while simultaneously suffering a range of never resolved constraints of everyday life, e.g. bad accessibility due to poor road maintenance. This point suggests that future campaigns may wisely invest into a more conscious involvement of the local population into a Science Week or particular river protection project to help generate development visions that will benefit people and nature.

Once again, an important factor for the success of the Neretva Science Week was the effort made to bring journalists along during the fieldwork, allowing them to experience the Neretva landscape while in direct exchange with the scientists. This enabled understandable in-depth storytelling in various media, as journalists could blend personal experience with on-site explanations that made ecological phenomena tangible. A total of 28 and 49 international and national media contributions were produced (without counting social media activities, NGO press releases and public appearances). Notable stories were published, for instance, by CNN (Lewis 2023), Re:wild (Moreno 2023) and Aljazeera (Zukić 2023). A video summarizing the week´s activities remains available on the internet (https://www.youtube.com/watch?v=YchaHwH5eWs).

Two Science Weeks taking place in the village of Ulog over two consecutive years and the developing network of people within and around the Scientists for Balkan Rivers generated a range of activities in the wake of the Neretva Science Weeks. In 2024, the River Collective (https://rivercollective.org) organised a Students for Rivers Camp, i.e. a 6-day interdisciplinary summer school training students in various aspects of river protection. In collaboration with the local NGO Zeleni Neretva, the River Collective also launched the initiative 'Countermapping Neretva', a participatory mapping exercise aiming to portray the Upper Neretva River as experienced by members of the local community, including families, activists, fishermen and conservationists. The resulting map offers a counter-narrative to the extractivist view that appreciates the river solely for resource exploitation, by celebrating its cultural, ecological, and personal significance. And, finally, when Ulog HPP's operation started, causing a major fish-kill incidence in September 2025, the network that had formed during two Neretva Science Weeks jumped into action within days.

CURRENT STATE AND OUTLOOK

At the moment of publication of this special issue, the situation in the Upper Neretva valley is already distinctly different from what could be encountered during Science Weeks in 2022 and 2023. Ulog HPP filled its reservoir, drowning a forest and a living river, and started operation in a maximally destructive hydropeaking mode that kills the threatened softmouth trout in the downstream Neretva River section. The following words of water beetle specialist Michaela Brojer on a single species epitomizes both banality and tragedy of biodiversity loss associated with such development:

> »What I want to emphasize is that the locality downstream of Ulog, directly on the Neretva River (near the former Swimming Beach), was the most interesting and worthy of protection from the perspective of aquatic beetles. *Stenelmis puberula* was found there

in exceptionally high abundance. This species requires fast-flowing, stony sediment with large interstitial spaces not 'blocked' by fine sediment. Species of the genus *Stenelmis* are extremely rare in both Central Europe and the Balkans, they are endangered or extinct/missing in Germany, critically endangered in Austria and the Czech Republic. The reason for their endangerment is presumably primarily the damming of upland streams, reduction of flow velocity, and the input of fine sediment – likely precisely the conditions currently occurring upstream of Ulog HPP.«

In September 2025, a major fish-kill occurred just downstream of Ulog HPP (Fig. 4), with hundreds of dead fish observed, including the critically endangered softmouth trout and white-clawed crayfish. The event followed three abrupt spikes in river discharge consistent with sudden reservoir releases ('hydropeaking'), yet authorities denied any link to the HPP. The Scientists for Balkan Rivers Network immediately reacted with an open letter that outlined the potential link to the release of oxygen-deficient water from hypolimnetic reservoir water layers and demanded prompt investigation and adaptation of Ulog HPP´s operation in the ecologically sensitive river network. In the following weeks, a small team assembled from the Scientists of Balkan Rivers delivered a prime example of what a network of engaged scientists is capable of doing: Less than two weeks after the fish-kill, a field mission was dispatched to collect evidence by assessing vertical stratification of the reservoir and measuring profiles of key variables (Fig. 4a) alongside downstream discharge conditions. Combining these field data with publicly available data on discharge and precipitation, remote sensing imagery from EU's Copernicus missions and past data on river morphology collected during the first Neretva Science Week allowed to clearly demonstrate that – in violation of its environmental permit – Ulog HPP operated in a hydropeaking mode, releasing oxygen-depleted deep water that caused widespread suffocation of aquatic life in the Neretva River. A reoxygenation model for the downstream river (Fig. 4b) further suggested that hydropeaking can be expected to create an ecological trap that allows trout to move into an only transiently deoxygenated river reach of several kilometres. This mechanism lets us expect far-reaching damaging effects on trout populations if hydropeaking operations persist.

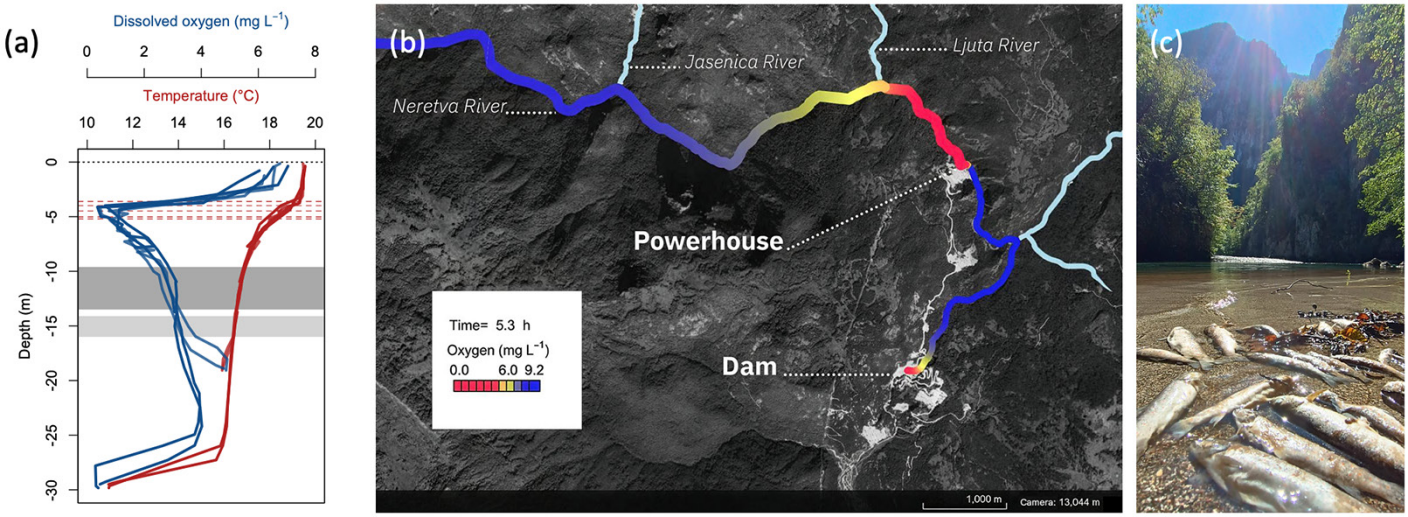

Figure 4. Ulog HPP's hydropeaking operations with oxygen-deficient hypolimnetic reservoir water caused a fish-kill in the Neretva River in September 2025. (a) Vertical profiles of dissolved oxygen and temperature in the reservoir at a distance of 400 m from the dam show strong temperature stratification and oxygen conditions unsuited for trout survival below ~4.5 m. Grey areas show depth windows of water intake to turbines and residual flow section. (b) A reoxygenation model demonstrates extent of 'death zone' (in red) where trout likely cannot survive. As this death zone appears and disappears transiently with hydropeaking, an ecological trap is formed. (c) Dead specimens of various species of Salmo, including softmouth trout (*Salmo obtusirostris*), European bullhead (*Cottus gobio*) and white-clawed crayfish (*Austropotamobius pallipes*) observed in the Neretva River section between Ulog HPP powerhouse and the tributary Jasenica on 13.–15. 9. 2025 (photo: Hrabren Kapić).

Slika 4. Hidroelektrarna Ulog je s svojim delovanjem in spuščanjem hipolimnične vode iz akumulacije, ki je bila osiromašena s kisikom, septembra 2025 povzročila pogin rib v reki Neretvi. (a) Vertikalni profili raztopljenega kisika in temperature v rezervoarju na razdalji 400 m od jezu kažejo močno temperaturno stratifikacijo in stanje kisika, ki niso primerne za preživetje postrvi pod ~4,5 m. Siva območja prikazujejo globinske okvire za dovod vode v turbine in preostali del pretoka. (b) Model ponovnega oksigeniranja prikazuje obseg »smrtne cone« (v rdeči barvi), kjer postrvi verjetno ne morejo preživeti. Ker se ta smrtna cona pojavlja in izginja prehodno s hidroelektrarno, se oblikuje ekološka past. (c) Mrtvi primerki različnih vrst rodu Salmo, vključno z mehkoustno postrvjo (*Salmo obtusirostris*), kapljem (*Cottus gobio*) in primorskim koščakom (*Austropotamobius pallipes*), opazovani v odseku reke Neretve med elektrarno Ulog HPP in pritokom Jasenica med 13. in 15. 9. 2025 (foto: Hrabren Kapić).

Slika 4. Hidroelektrana Ulog je svojim djelovanjem ispuštanja hipolimetrične vode siromašne kiseonikom iz akumulacije izazvala pomor ribe u rijeci Neretvi u septembru 2025. godine. (a) Vertikalni profili rastvorenog kiseonika i temperature u akumulaciji, na udaljenosti od 400 m od brane, pokazuju snažnu temperaturnu stratifikaciju i kiseonične uslove nepogodne za opstanak pastrmke ispod približno 4,5 m dubine. Sive oblasti označavaju dubinske okvire za zahvat vode za turbine i presjek preostalog protoka. (b) Model reoksigenacije pokazuje obim »zone smrti« (označene crveno) u kojoj pastrmka vjerovatno ne može preživjeti. Kako se ova zona privremeno pojavljuje i nestaje usljed hidropeakinga, formira se ekološka zamka. (c) Uginuli primjerci različitih vrsta roda Salmo, uključujući mekousnu pastrmku (*Salmo obtusirostris*), peša (*Cottus gobio*) i riječnog raka (*Austropotamobius pallipes*), zabilježeni u području rijeke Neretve između mašinske zgrade hidroelektrane Ulog i pritoke Jasenice u periodu 13–15.9.2025. (foto: Hrabren Kapić).

These results were presented in the Bosnian parliament on 28 November 2025, alongside the demand to immediately stop hydropeaking, enforce run-of-river operation, and implement transparent continuous monitoring. The results were also published (Singer et al. 2025) in a national scientific journal, the Acta Geographica Bosniae et Herzegovinae, and will potentially also be published internationally. There will be a chance to see how successful these interventions were in 2026, when Ulog HPP´s environmental permit will be up for renewal.

The Neretva River is challenging and instructive for the Blue Heart of Europe Campaign. For ecologists, a Science Week has so far largely been an activity on the sunny side of things – an invitation to help describe astonishing biodiversity in an outstanding landscape is hard to decline, while the fact that discovering a new or threatened species contributes to conservation of ecosystems morally reassures the excited ecologist. A Science Week attracts attention and puts the river and the scientists themselves into the spotlight, while the gathered data represent support for advocating the protection of an intact ecosystem also in legal terms. However, both Neretva Science Weeks were organised in the face of ongoing destruction, the construction of Ulog HPP was not just a threat looming on the horizon. Today, the pre-programmed defeat is real; Ulog HPP is in operation and challenges us to maintain momentum in our work for conservation despite the ecological loss we have to witness. Indeed, even if steering a boat through dead forest on a newly formed reservoir is only a fraction of the fun that it was to hike along the pristine river before, nailing down Ulog HPP as responsible for a major fish-kill and carrying evidence to the highest political levels may indeed be a worthwhile activity for the Scientists of Balkan Rivers network. After all, it is not time yet to give up on this exceptional river. Ulog HPP is a particularly destructive project, both due to its location as well as its operation – and this may be showcased again and again. The Gornja Neretva upstream of Ulog HPP is still a near-pristine landscape hosting great biodiversity in a landscape of unmatched beauty. The same applies to the canyon of the Ljuta and the Neretva River downstream of Ulog HPP, where protected area plans associated with mountain landscapes on either riverside are being developed and should include the Neretva River itself. Let us imagine a protected Neretva River from source to Konjic, where Ulog HPP may be a scar in the landscape now, optimally managed to harm the river as little as possible in the short term, and simply brought down again in the long term – like all built things, dams need to be removed one day. So, Scientists for Balkan Rivers, maintain the momentum built up through two Science Weeks with one or the other activity!

NO DATA WITHOUT SUPPORT – ACKNOWLEDGEMENTS:

All involvement of scientists in the Neretva Science Week, including on-site participation, preparatory work before the event and analysis thereafter, happened on a completely voluntary basis without any payment. This special issue of Natura Sloveniae is their contribution to saving the Neretva River from further damming – Thank you! Organising the whole Science Week would not have been possible without the support of Manfred-Hermsen-Stiftung (https://www.m-h-s.org/en/), a long-standing partner of the Save the Blue Heart campaign. Individual scientists used their own projects and funds for further analyses of the material they gathered during the NSW23, and these funds are acknowledged in the individual contributions. The engagement of MZ was cofinanced by the Slovenian Agency for Research and Innovation through core programme P1-0184. We would like to thank the team from the Center for Environment for organisational support. The association of sports fishermen in Konjic and the fish association from Kalinovik welcomed us and supported the event. Finally, the support of the local community was crucial for the entire event. They are the first ones directly impacted by the changes in their environment. We specifically thank Boban Škrkar and his friends and family from Ulog, who helped us with logistics, opened up their houses and gardens as places to stay, and provided meals to all participants.

We dedicate this article to Toni Vorauer, a friend, colleague and participant of several Science Weeks, who passed away completely unexpectedly after short illness on 25 November 2025. Toni enriched the Scientists for Balkan Rivers network with unmatched expertise on bats and tireless motivation for their discovery in hidden sheds, tree holes and caves. He was a river conservationist and a key figure within the Blue Heart of Europe campaign thanks to his photographical skills.

REFERENCES

Borko Š, Singer G, Eichelmann U, editors. 2023. Science Week 2023, Neretva River, Bosnia and Herzegovina. Preliminary Report for Riverwatch and EuroNatur Foundation. Save the Blue Heart of Europe; [accessed 24. 12. 2025]. https://balkanrivers.net/en/studies/neretva-science-week-preliminary-report-mjvi

Griffiths HI, Kryštufek B, Reed JM. 2004. Balkan biodiversity, Pattern and process in the European hotspot. Dordrecht: Springer. https://doi.org/10.1007/978-1-4020-2854-0

Gurnell A, Bertoldi W, Tockner K, Wharton G, Zolezzi G. 2016. How large is a river? Conceptualizing river landscape signatures and envelopes in four dimensions. WIREs Water. 3(3): 313-325. https://doi.org/10.1002/wat2.1143

Knook VG, Weiss S, Singer G, editors. 2022. Science Week 2022, Neretva River, Bosnia and Herzegovina. Preliminary Report for River Watch and EuroNatur. Save the Blue Heart of Europe. https://balkanrivers.net/en/studies/neretva-science-week-preliminary-report

Lewis N. 2023. Scientists are fighting to save the 'blue heart' of Europe. CNN; [accessed 24. 12. 2025]. https://edition.cnn.com/2023/08/10/world/neretva-river-save-the-blue-heart-of-europe-c2e-spc-intl

Moreno L. 2023. The mind, the heart, and the megaphone: Neretva Science Week and the Balkan rivers movement. re:wild; [accessed 9. 10. 2024]. https://www.rewild.org/news/the-mind-the-heart-and-the-megaphone-neretva-science-week-and-the-balkan

Schiemer F, Beqiraj S, Drescher A, Graf W, Egger G, Essl F, Frank T, Hauer C, Hohensinner S, Miho A, et al. 2020. The Vjosa River corridor: a model of natural hydro-morphodynamics and a hotspot of highly threatened ecosystems of European significance. Landscape Ecology. 35(4): 953-968. https://doi.org/10.1007/s10980-020-00993-y

Saccò M, Mammola S, Altermatt F, Alther R, Bolpagni R, Brancelj A, Brankovits D, Fišer C, Gerovasileiou V, Griebler C, et al. 2023. Groundwater is a hidden global keystone ecosystem. Global Change Biology. 30: e17066. https://doi.org/10.1111/gcb.17066

Schiemer F, Beqiraj S, Graf W, Miho A, editors. 2018. The Vjosa in Albania - a riverine ecosystem of European significance. Acta ZooBot Austria. 155/1.

Schiemer F, Miho A, editors. 2021. The Shushica River - Interdisciplinary exploration of the unique ecosystem. Save the Blue Heart of Europe. https://balkanrivers.net/uploads/files/3/Shushica%20Report.pdf

Singer G, Čelebičić M, Pinter K, Dalvai Ragnoi M, Spahić M. 2025. Fish kill in the Neretva River in September 2025: Identifying water releases from the Ulog hydropower plant as likely cause - An ecological crime scene investigation report. Acta Geographica Bosnia et Herzegovinae. 12(24): 5-28.

Singer G, Eichelmann U, Knook V, Weiss S, Topić V, Ivanić J, Borko Š, Zagmajster M. 2023. Neretva Science Week 2022 – shedding light on the biodiversity of the upper Neretva River valley, Bosnia and Herzegovina. Natura Sloveniae. 25(3): 5-13. https://doi.org/10.14720/ns.25.3.5-13

Stritih A, Brouillet C, Habe M, Salliou N, Singer G, Scaini A. 2025. Can a Science Week empower scientists for conservation advocacy? Environmental Science and Policy. 170: 104098. https://doi.org/10.1016/j.envsci.2025.104098

Zukić O. 2023. I naučnici u borbi za spas Neretve, jedne od najljepših i najugroženijih rijeka u Evropi. Aljazeera; [accessed 24. 12. 2025]. https://balkans.aljazeera.net/teme/2023/6/13/i-naucnici-u-borbi-za-spas-neretve-jedne-od-najljepsih-i-najugrozenijih-rijeka-u-evropi

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0I nternational License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 13–27
»Neretva Science Week 2023«

ZNANSTVENI ČLANEK /
SCIENTIFIC PAPER

DOI: 10.14720/ns.20053
Objavljeno na spletu / Published online: 22. 12. 2025

Prejeto / Received: 18. 12. 2024
Sprejeto / Accepted: 2. 7. 2025

Contribution to the fungal diversity of the Upper Neretva River valley (Bosnia and Herzegovina)

Linda MAJDANOVÁ[1*], *Adam POLHORSKÝ*[2]

ABSTRACT

A mycological survey on fungal diversity following the planned construction of hydropower plants in the Upper Neretva valley took place from 31. 5. to 4. 6. 2023 near Ulog, Bosnia and Herzegovina. The species diversity of fungi in this area was investigated for the first time. A fruitbody-based approach of fungi visible to the naked eye or using a hand lens was performed at four study sites. In total, 102 fungal species were recorded. Out of these, 10 species (*Cerinomyces aeneus*, *Glyphium elatum*, *Kurtia macedonica*, *Ophiocordyceps stylophora*, *Orbilia lentiformis*, *Patinella punctiformis* f. *quercina*, *Perenniporia narymica*, *Proliferodiscus tricolor*, *Triblidium caliciiforme*, *Xerombrophila crystallifera*) are new to the country to our knowledge. Other interesting records include *Porotheleum fimbriatum*, *Crustomyces subabruptus*, *Guepiniopsis buccina*, *Elaiopezia polaripapulata* or *Perrotia flammea*. The presence of dead wood supported a high number of wood-inhabiting species. The number of new and rare species recorded during the survey indicates a considerable research and conservation potential of the Upper Neretva valley.

IZVLEČEK

Prispevek k raznolikosti gliv zgornje doline reke Neretve (Bosna in Hercegovina)

Mikološka raziskava o raznovrstnosti gliv zaradi načrtovane gradnje hidroelektrarn v zgornji dolini Neretve je potekala od 31. 5. 2023 do 4. 6. 2023 v bližini Uloga v Bosni in Hercegovini. Vrstna pestrost gliv na tem območju je bila raziskana prvič. Na štirih raziskovalnih lokacijah je bil izveden pristop na podlagi plodnih teles gliv, vidnih s prostim očesom ali z ročno lečo. Skupno sta bili zabeleženi 102 vrsti gliv. Od teh je 10 vrst (*Cerinomyces aeneus*, *Glyphium elatum*, *Kurtia macedonica*, *Ophiocordyceps stylophora*, *Orbilia lentiformis*, *Patinella punctiformis* f. *quercina*, *Perenniporia narymica*, *Proliferodiscus tricolor*, *Triblidium caliciiforme*, *Xerombrophila crystallifera*) novih za državo. Med drugimi zanimivimi najdbami so *Porotheleum fimbriatum*, *Crustomyces subabruptus*, *Guepiniopsis buccina*, *Elaiopezia polaripapulata* in *Perrotia flammea*. Prisotnost odmrlega lesa podpira veliko število lesnih vrst. Število novih in redkih vrst, zabeleženih med raziskavo, kaže na velik raziskovalni in ohranitveni potencial zgornje doline Neretve.

[1] Czech University of Life Sciences Prague, Faculty of Forestry and Wood Sciences, Kamýcká 129, Praha 6 - Suchdol, 165 00, Czech Republic;
E-mail: linda.majdanova@gmail.com

[2] Plant Science and Biodiversity Centre, Institute of Botany, Slovak Academy of Sciences, Dúbravská Cesta 9, 845 23 Bratislava, Slovakia;
E-mail: adam.polhorsky@savba.sk

* Korespondenčna avtorica / Corresponding author

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

KEY WORDS:
Ascomycota, Balkan Peninsula, Basidiomycota, *Fagus sylvatica*, fruiting body, old-growth forest, red-listed species, riparian forest

KLJUČNE BESEDE:
Ascomycota, Balkanski polotok, Basidiomycota, *Fagus sylvatica*, plodišče, starorastni gozd, rdečelistne vrste, obvodni gozd

KLJUČNE RIJEČI:
Ascomycota, Balkansko poluostrvo, Basidiomycota, *Fagus sylvatica*, plodonosno tijelo, prašuma, crvenolisne vrste, priobalna šuma

APSTRAKT

Doprinos raznolikosti gljiva gornje doline rijeke Neretve (Bosna i Hercegovina)

Mikološko istraživanje diverziteta gljiva nakon planirane izgradnje hidroelektrana u dolini Gornje Neretve sprovedeno je od 31. 5. 2023. do 4. 6. 2023. godine u blizini Uloga, u Bosni i Hercegovini. Diverzitet vrsta gljiva na ovom području ispitana je po prvi put. Pristup je zasnovan na posmatranju plodnih tjela gljiva vidljivih golim okom ili pomoću ručnog sočiva i sproveden je na četiri lokacije. Ukupno je zabeleženo 102 vrste gljiva. Od njih, 10 vrsta (*Cerinomyces aeneus*, *Glyphium elatum*, *Kurtia macedonica*, *Ophiocordyceps stylophora*, *Orbilia lentiformis*, *Patinella punctiformis* f. *quercina*, *Perenniporia narymica*, *Proliferodiscus tricolor*, *Triblidium caliciiforme*, *Xerombrophila crystallifera*) su, po našim saznanjima, nove vrste za BiH. Ostali zanimljivi nalazi uključuju vrste: *Porotheleum fimbriatum*, *Crustomyces subabruptus*, *Guepiniopsis buccina*, *Elaiopezia polaripapulata* ili *Perrotia flammea*. Prisustvo mrtvog drveta omogućilo je uslove velikom broju vrsta koje naseljavaju drveće. Broj novih i rijetkih vrsta zabilježenih tokom istraživanja ukazuje na veliki istraživački i zaštitni potencijal gornje doline Neretve.

INTRODUCTION

Research on the funga of Bosnia and Herzegovina has lagged behind for a long time. The available data from the past are fragmented and there is currently no official checklist of fungi or a more comprehensive publication available. The first version of the red list of fungi of Bosnia and Herzegovina contained 86 taxa (Đug 2013). In recent years, mycological research throughout the country has intensified and results can be found in several publications improving our knowledge of the local funga (e.g. Jukić et al. 2020a, 2020b; Treštić et al. 2021; Jukić et al. 2022). Comprehensive field research focused on Pezizales, Ascomycota, resulted in a publication including the proposed IUCN red list categories (Jukić & Omerović 2017) and evaluated areas with conservation potential based on the indicator value of fungi (Jukić et al. 2019). However, the overall funga of Bosnia and Herzegovina is still relatively poorly known and requires further long-term research. The Mycological Society MycoBH from Sarajevo started research on the Neretva river in July 2023, within the project focused on identifying top priority freshwater sites in Bosnia and Herzegovina, downstream of the sites investigated during Neretva Science Week 2023 (NSW23).

The aim of our study was to survey the fungal diversity of Upper Neretva valley, currently threatened by the planned construction of hydropower plants, and to contribute to the knowledge of the mycobiota of this area and of Bosnia and Herzegovina.

MATERIAL AND METHODS

STUDY AREA

The study was conducted during NSW23, organized by the Scientists for Balkan Rivers project, within the Save the Blue Heart of Europe campaign, from 31. 5. to 4. 6. 2023 in the Upper Neretva valley near Ulog, Bosnia and Herzegovina (Fig. 1). Neretva (230 km), the largest karst river in the Dinaric Alps with a catchment area of over 10,000 km^2, flows through Bosnia and Herzegovina and Croatia and finally drains into the Adriatic Sea (Skoulikidis et al. 2022). The upper course of the river flows through an area with subalpine Mediterranean climate with snow potential at higher altitudes (FHMZBiH 2025), the dominant lithology is limestone and dolomite with karst formations (Operta & Pamuk 2015). The habitats in the study area comprise a diverse mosaic dominated by forests and extensively managed grasslands.

STUDY SITES

Research was carried out at four study sites (Fig. 1, Tab. 1). Attention was paid mainly to forest stands and marginally to pastures in the vicinity of settlements. Grassland habitats at higher altitudes were not examined due to time limitations. Research at the Neretva (Fig. 4) and Dubrava sites roughly followed transects starting at the river bank and progressing uphill. This was partly limited by bad accessibility of some areas and weather with daily thunderstorms during the science week. The other two study sites covered a smaller area around Lake Crvanj and the bottom of the Mededak Canyon. All study sites were investigated for a single day, except for the Neretva site, which was studied for two days. The daily field research time was four to six hours long, depending on the accessibility of study sites. Additionally, our results include one record of *Mycena* from Golubnjača cave collected by Maja Zagmajster.

The habitats consisted largely of forests, often with old-growth character, ranging from mesophilous forests dominated by the European beech (*Fagus sylvatica*) on the cooler north-facing slopes (Neretva, Mededak canyon) to thermophilous oak (*Quercus petraea* and *Q. cerris*) forests on the southern slopes (Dubrava) and *Alnus rohlenae* dominated riparian forests around the riverbank. Evidence of past grazing and other forms of management was noticeable across study sites. The beech forests around the Crvanj lake exhibited signs of recent fire disturbance.

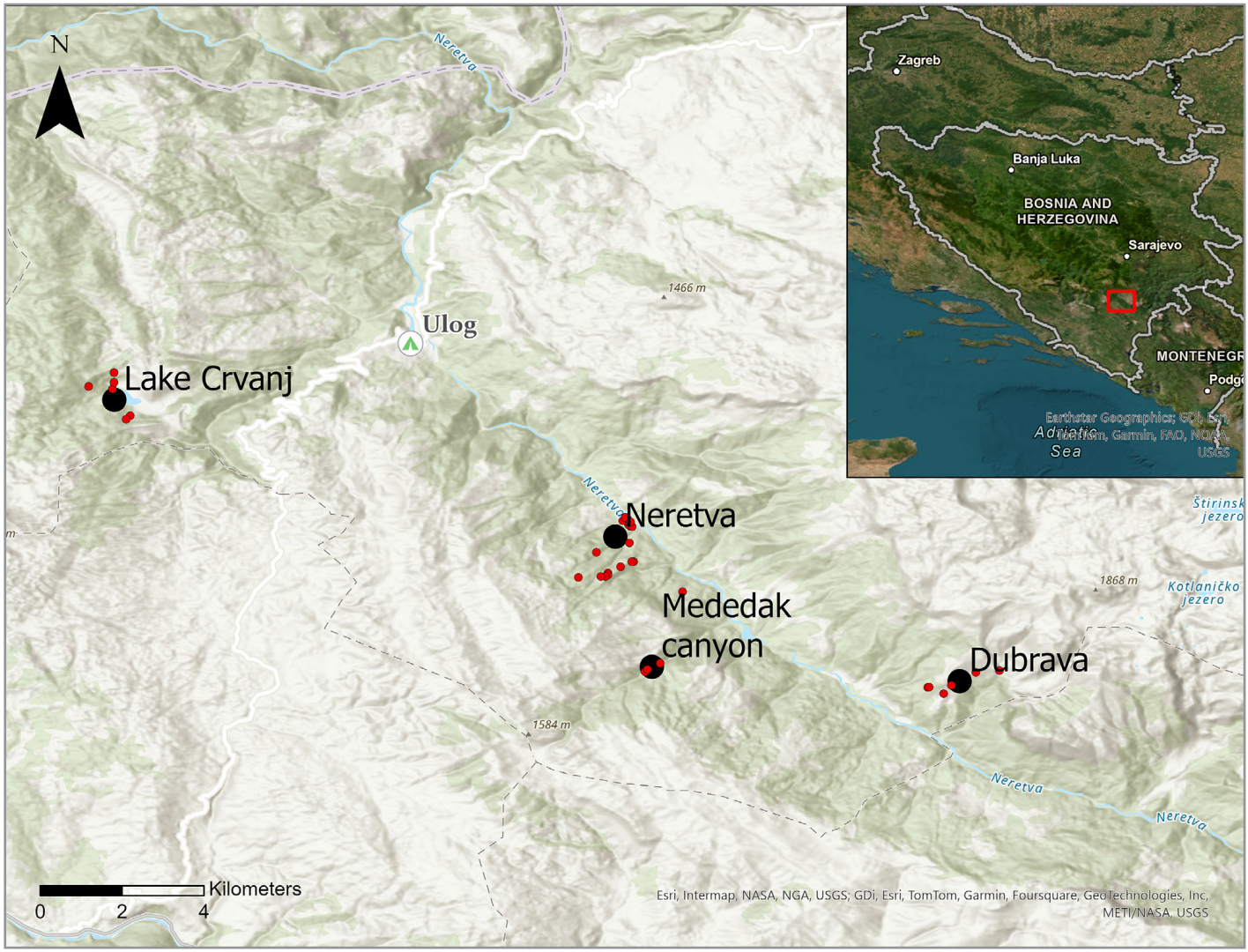

Figure 1. Study sites (black) with sampling microlocalities (red) along the Upper Neretva valley and the location of the study area within Bosnia and Herzegovina.

Slika 1. Preučevane lokacije (črne točke) z mikrolokacijami (rdeče točke) vzdolž zgornje doline Neretve in položaj območja raziskave znotraj Bosne in Hercegovine.

Slika 1. Lokacije istraživanja (crne tačke) sa svim mikrolokacijama uzorkovanja (crvene tačke) duž gornje doline rijeke Neretve i lokacija područja istraživanja unutar Bosne i Hercegovine.

Table 1. Study sites, coordinates, altitude range and date(s) of sampling.

Tabela 1. Lokacije študije, koordinate, višinski razpon in datum(i) vzorčenja.

Tabela 1. Lokacije istraživanja, koordinate, raspon nadmorskih visina i datum(i) uzorkovanja.

Study site	N	E	Elevation [m]	Date
Dubrava	43.34181	18.42993	1046–1248	2. 6.2023
Neretva	43.37353	18.35433	695–1128	31. 5.–1. 6. 2023
Mededak	43.34494	18.36236	983–1042	4. 6. 2023
Crvanj	43.40354	18.24437	1061–1245	3. 6. 2023

FUNGI SURVEY

The overall species diversity of fungi visible to the naked eye or with the help of a hand lens was assessed with regard to rare and threatened species (Đug 2013; Jukić & Omerović 2017; Treštić et al. 2021) using a fruitbody-based approach. The research was carried out by examining the wider vicinity of the four study sites (Tab. 1), without establishing specific research plots. Ascomycetes and Basidiomycetes of all groups (e.g. Agaricales s.l., Corticiaceae s.l., Polyporales s.l., Discomycetes, Pyrenomycetes) were investigated, intended to record as many fungal species as possible. Fungi were identified directly in the field, or, when this was not possible, fungi samples were collected and dried for further microscopic examination. Collected samples were determined under a light microscope by the authors. Specimens are currently stored in the authors' private collections, but are planned to be deposited at the Natural History Museum (Slovak National Museum) in Bratislava, Slovakia. The literature used for determination included more

comprehensive works (e.g. Bernicchia & Gorjón 2010; Hansen & Knudsen 2018; Bernicchia & Gorjón 2020; Rivoire 2020; Larsson & Ryvarden 2021) and other publications focused on individual genera and species.

RESULTS AND DISCUSSION

During the five-day survey in the Upper Neretva valley, 102 fungal species were recorded (35 Ascomycota and 67 Basidiomycota; Tab. 2), with the prevalence of wood-inhabiting fungi, including rare species and species new for the country. The number of recorded species per study site ranged between 23 and 55 (Tab. 2), with Neretva site having the highest number of species. This site was, however, investigated for two days, while other locations were only visited for a single day. In addition, we included one record of *Mycena capillaris* (Schumach.) P. Kumm. collected in Golubnjača cave by Maja Zagmajster.

To our knowledge, at least ten species including *Cerinomyces aeneus* A. Savchenko, Miettinen & J.C. Zamora, *Glyphium elatum* (Grev.) H. Zogg, *Kurtia macedonica* (Litsch.) Karasiński, *Ophiocordyceps stylophora* (Berk. & Broome) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora, *Orbilia lentiformis* Baral & G. Marson, *Patinella punctiformis* f. *quercina* Feltgen, *Perenniporia narymica* (Pilát) Pouzar, *Proliferodiscus tricolor* (Sowerby) Baral, *Triblidium caliciiforme* Rebent. and *Xerombrophila crystallifera* Baral, G. Marson & Unter. have not yet been known from Bosnia and Herzegovina. They are discussed further along with other rare species.

Perenniporia narymica (Fig. 2B) is a rare resupinate polypore with a wide habitat range, recorded from lowlands to montane forests with different degree of naturalness, preferring old-growth stands and expanding according to recent data (Rivoire 2020; Kunca et al. 2022). The species is known from dead wood of numerous tree species, both deciduous and conifer (Rivoire 2020; Kunca et al. 2022). It was

Figure 2. A: *Elaiopezia polaripapulata* (J. Moravec) Van Vooren, B: *Perenniporia narymica* (Pilát) Pouzar, C: *Crustomyces subabruptus* (Bourdot & Galzin) Jülich, D: *Guepiniopsis buccina* (Pers.) L.L. Kenn. (photo A-D: L. Majdanová).

Slika 2. A: *Elaiopezia polaripapulata* (J. Moravec) Van Vooren, B: *Perenniporia narymica* (Pilát) Pouzar, C: *Crustomyces subabruptus* (Bourdot & Galzin) Jülich, D: *Guepiniopsis buccina* (Pers.) L.L. Kenn. (foto A-D: L. Majdanová).

Slika 2. A: *Elaiopezia polaripapulata* (J. Moravec) Van Vooren, B: *Perenniporia narymica* (Pilát) Pouzar, C: *Crustomyces subabruptus* (Bourdot & Galzin) Jülich, D: *Guepiniopsis buccina* (Pers.) L.L. Kenn. (foto A-D: L. Majdanová).

originally described from the Siberian part of Russia as *Trametes narymica* Pilát (Pilát 1936). In Europe, it was first recorded in Poland and is currently known from several European countries (Rivoire 2020; Bernicchia & Gorjón 2022; Kunca et al. 2022; GBIF 2025). In Balkan Peninsula it is known from Serbia and North Macedonia (David & Tortić 1986). In the Upper Neretva valley it was recorded from a large dead *Fagus sylvatica*, growing as typical – over a large surface of the trunk. Apparently, it was recorded for the first time in Bosnia and Herzegovina.

Kurtia macedonica has resupinate corticioid basidiomata similar to *Kurtia argillacea* (Bres.) Karasiński, from which it differs in the size of cystidia and basidiospores. It is saprotrophic, growing on dead wood of deciduous and coniferous trees. It is known from several European countries including the Czech Republic, Slovakia, Germany, Switzerland, Turkey, France, Poland, Croatia, North Macedonia, Slovenia, Serbia, Belgium, United Kingdom, Belarus, Sweden, Italy and Spain (Bernicchia & Gorjón 2010; Hagara 2015). The present collection from the remnants of deciduous wood in Mededak canyon represents the first record in Bosnia and Herzegovina.

Crustomyces subabruptus (Bourdot & Galzin) Jülich (Fig. 2C) is a corticioid species with thick odontoid hymenophore known from both coniferous and deciduous wood. It is distributed across southeastern Europe and is widespread in North America (Larsson & Ryvarden 2021). It has been recorded from lowlands to montane zone (Hagara 2015) and is often associated with old-growth forest stands (Zíbarová & Pouska 2020). In Balkan Peninsula this species is known from Bosnia and Herzegovina, North Macedonia, Croatia, Bulgaria, Slovenia and Serbia (Bernicchia & Gorjón 2010). We recorded it in a riparian forest in Neretva valley (*Alnus* sp. log) and beech-dominated forest near Crvanj Lake (*Fagus sylvatica* log).

Porotheleum fimbriatum (Pers.) Fr. is an interesting species with an intermediate fruiting body type between a resupinate polypore and a cyphelloid fungus, characterized by its unique pore development and conspicuous rhizomorphs. It grows on dead deciduous trunks and branches, rarely on conifers. It is mostly associated with near-natural forests (Dvořák & Běťák 2017). It is widespread with worldwide distribution and known from many European countries (references summarised in Martini 2024) but only rarely recorded. As such, it has a proposed Data Deficient (DD) IUCN category in Bosnia and Herzegovina (Treštić et al. 2021).

Ophiocordyceps stylophora (Fig. 3B) is a widespread but rarely encountered entomopathogenic fungus parasitizing on beetle larvae. Originally described from North America, this species is also known from China, Japan, New Zealand and Mexico. In Europe it is reported from Sweden, Norway, Latvia, Poland, Slovakia and Portugal. This fungus most frequently grows on Elateridae larvae embedded in rotting trunks of angiosperm and gymnosperm trees. Most previously known collections in Europe originate from protected localities of old-growth forests with an abundance of dead wood. The present collection was found in a riparian forest in Neretva valley on a fallen rotting trunk of *Alnus* sp. This is the first record of this species in Bosnia and Herzegovina (Chachuła et al. 2011; Chachuła et al. 2019).

Xerombrophila crystallifera, a genus and species which has been described only in 2013, occurs on attached corticated branches of *Salix* spp. and is characterized by strongly gelatinous tissues, abundant presence of octahedral crystals and its desiccation tolerance. It can survive in a dry state for several weeks. It is a widespread but rarely collected species known from several European countries (Germany, Belgium, Estonia, France, Luxembourg, Switzerland, Austria and Slovakia). The riparian forest in Neretva valley represents the southernmost known locality of this species (Baral et al. 2013; Krisai-Greilhuber & Friebes 2021).

Another widespread but seldomly collected species is *Orbilia lentiformis*, a minute, strongly xerotolerant discomycete, growing on attached dead branches of various angiosperm plants, in this case *Clematis vitalba*. This species is typified from Australia and is further known from North America, Morocco, Romania, France, Russia, Austria and Mongolia (Baral et al. 2020; Krisai-Greilhuber & Friebes 2021). It is characterized by 8-spored asci, cylindric-clavate ascospores with a lens-shaped spore body. It is differentiated from the very similar *O. ocellata* Baral, G. Marson & E. Weber by slightly wider asci and larger ascospores. Our collection represents the first record of this species in Bosnia and Herzegovina (Baral et al. 2020).

Patinella punctiformis f. *quercina* (Fig. 3D) is an almost unknown taxon described in 1903, up to now only known from its type collection from Luxembourg. From our investigation it is apparent that this taxon does not belong to the genus *Patinella* Sacc. s. str., but shares a lot of similarity with the genus *Pseudotryblidium* Rehm. Further phylogenetic study of this species may confirm this presumed relationship. This species seems to be confined to the living bark of *Quercus* trunks, which is further confirmed by an unpublished collection from Slovakia (Feltgen 1903). Alongside this taxon, other typical but rarely encountered xerotolerant inhabitants of oak bark, *Proliferodiscus tricolor* and *Triblidium caliciiforme*, were also found for the first time in Bosnia and Herzegovina.

Cerinomyces aeneus (Fig. 3A) was described in 2021 from Ukraine and is further known from the Czech Republic, Finland, Norway and Sweden. It is characterized by gelatinous, resupinate, coalescing, bronze-coloured basidiomata growing on angiosperm, decorticated wood (Savchenko at al. 2021). Our collections on *Carpinus* and *Fagus sylvatica* rotting trunks represent the first findings of this species in Bosnia and Herzegovina.

Glyphium elatum (Fig. 3C) is a widespread, cosmopolitan species with characteristic morphology. It forms distinctive, erect, hatched-shaped, carbonaceous ascomata that dehisce along a longitudinal split. The ascomata grow on undecayed wood or bark of various angiosperms. The species is further characterized by very long (up to 650 µm), filiform, multiseptate, non-disarticulating ascospores. Despite its striking appearance, it is rarely reported. Our finding appears to be the first record of this species in Bosnia and Herzegovina (Boehm et al. 2015).

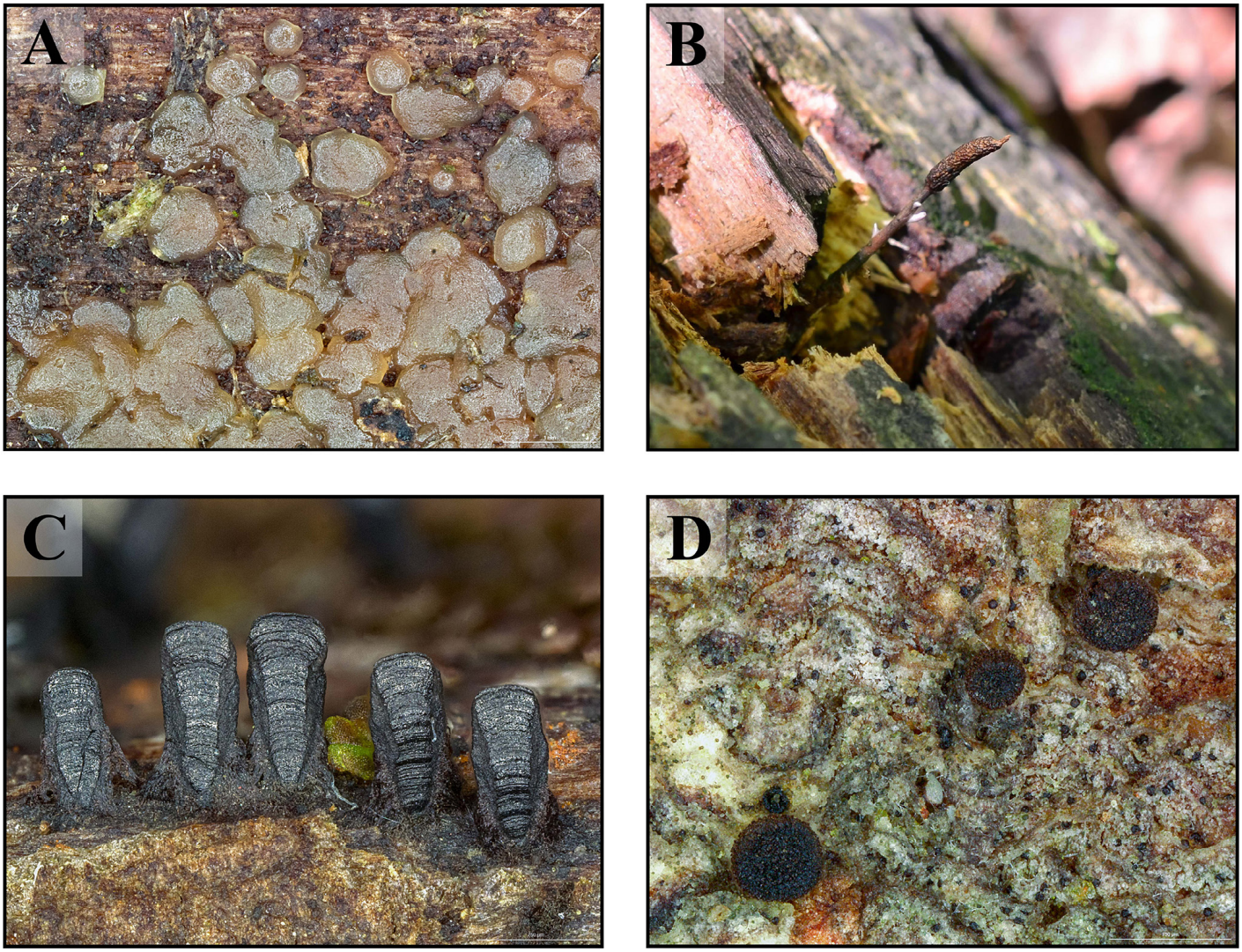

Figure 3. A: *Cerinomyces aeneus* A. Savchenko, Miettinen & J.C. Zamora (photo: A. Polhorský), B: *Ophiocordyceps stylophora* (Berk. & Broome) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora (photo: L. Majdanová), C: *Glyphium elatum* (Grev.) H. Zogg (photo: A. Polhorský), D: *Patinella punctiformis* f. *quercina* Feltgen on *Quercus cerris* bark.

Slika 3. A: *Cerinomyces aeneus* A. Savchenko, Miettinen & J.C. Zamora (foto: A. Polhorský), B: *Ophiocordyceps stylophora* (Berk. & Broome) G.H. Sung, J. M. Sung, Hywel-Jones & Spatafora (foto: L. Majdanová), C: *Glyphium elatum* (Grev.) H. Zogg (foto: A. Polhorský), D: *Patinella punctiformis* f. *quercina* Feltgen na lubju *Quercus cerris*.

Slika 3. A: *Cerinomyces aeneus* A. Savchenko, Miettinen & J.C. Zamora (foto: A. Polhorský), B: *Ophiocordyceps stylophora* (Berk. & Broome) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora (foto: L. Majdanová), C: *Glyphium elatum* (Grev.) H. Zogg (foto: A. Polhorský), D: *Patinella punctiformis* f. *quercina* Feltgen na kori *Quercus cerris*.

Other noteworthy findings discovered during NSW23 known only from a few other localities within Bosnia and Herzegovina (Jukić in litt.) include *Guepiniopsis buccina* (Pers.) L.L. Kenn. (Fig. 2D), a rare dacrymycetalean fungus growing on dead deciduous wood, which is proposed as a Near Threatened (NT) species in Bosnia and Herzegovina (Treštić et al. 2021); *Elaiopezia polaripapulata* (J. Moravec) Van Vooren (Fig. 2A), a very rare discomycete belonging to the group with apiculate spore ornamentation, saprotrophic on deciduous wood; *Perrotia flammea* (Alb. & Schwein.) Boud., an infrequently reported colourful discomycete from deciduous wood. Our records of all three species mentioned above represent the southernmost records in the country.

During the survey, five species listed in the Red list of fungi of the Federation of Bosnia and Herzegovina (Đug 2013) were recorded, four of which are listed in the DD category (*Cyathus striatus* Willd., *Mutinus caninus* (Schaeff.) Fr., *Mycena haematopus* (Pers.) P. Kumm., *Mycena renati* Quél.) and one species, *Polyporus tuberaster* (Jacq. ex Pers.) Fr. in Critically Endangered (CR) category. From the list of Pezizales species with IUCN categories proposed by Jukić & Omerović (2017), we recorded four species, all in the Least Concern (LC) category (*Helvella acetabulum* (L.) Quél., *Peziza arvernensis* Roze & Boud., *Paragalactinia michelii* (Boud.) Van Vooren and *Tarzetta cupularis* (L.) Lambotte). Other species with proposed IUCN categories within Bosnia and Herzegovina (Treštić et al. 2021) include *Porotheleum fimbriatum* (DD) and *Guepiniopsis buccina* (NT). Three species appear on the lists of protected species of the nearby countries. *Aleurodiscus disciformis* (DC.) Pat. is a species protected in Montenegro, *Mutinus caninus* is protected

in Montenegro and Serbia and *Boletus reticulatus* Schaeff. is protected in Serbia (Kasom & Miličković 2006; Ivančević et al. 2012). Some of the species (*Aleurodiscus disciformis*, *Kurtia macedonica*, *Guepiniopsis buccina*, *Mutinus caninus*, *Pycnoporus cinnabarinus* (Jacq.) P. Karst., *Artomyces pyxidatus* (Pers.) Jülich, *Mycena capillaris* (Schumach.) P. Kumm.) also appear in official or provisory red lists of the neighbouring countries (HMD 2005; Perić & Perić 2005; ECCF 2024).

The heterogeneity of the environment in the Upper Neretva valley creates various habitats for many fungal species. The presence of older stands of old-growth character with a large amount and heterogeneity of dead wood supported a high diversity of wood-inhabiting fungal species. Despite many interesting finds, it is quite challenging to investigate the diversity of fungi in a short period of time over just a few days, as the fructification season of most species was just beginning. The seasonality of species, together with the ephemerality of fruiting bodies of certain species, require long-term periodic research throughout the year or even better over several years. Based on our results, namely the number of newly recorded species for the country and many finds of rare and threatened species, it seems that the area of the Upper Neretva valley has considerable research and conservational potential.

Figure 4. The structure of forests on the northern slopes of the study site »Neretva« with dead wood of large diameters, colonized by common wood-inhabiting species *Laetiporus sulphureus* (Bull.) Murrill.

Slika 4. Struktura gozdov na severnih pobočjih raziskovalnega območja »Neretva« z odmrlim lesom velikih premerov, ki ga zaseda pogosta vrsta *Laetiporus sulphureus* (Bull.) Murrill.

Slika 4. Struktura šume na sjevernim padinama istraživačkog područja »Neretva« sa mrtvim drvetom velikog promjera koje naseljava uobičajena vrsta *Laetiporus sulphureus* (Bull.) Murrill.

Table 2. List of recorded species with information on the number of records at study sites, habitat type and substrate on which the species was found. Records marked with an asterisk have voucher specimens available.

Tabela 2. Seznam zabeleženih vrst s podatki o številu zapisov na raziskovalnih lokacijah, tipu habitata in substratu, na katerem je bila vrsta najdena. Zapisi, označeni z zvezdico, imajo na voljo primerke z vavčerji.

Tabela 2. Spisak zabilježenih vrsta sa informacijama o broju zapisa sa istraživačkih lokacija, tipu staništa i supstratu na kojem je vrsta pronađena. Zapisi označeni zvjezdicom imaju dostupne primjerke vaučera.

Taxon	Study site/Number of records				Habitat	Substrate
	Dubrava	Neretva	Mededak	Crvanj		
ASCOMYCOTA						
Arachnopeziza delicatula Fuckel	1				oak forest	*Quercus*
Ascobolus saccharifer Brumm.	1				oak forest	*Cervus* dung
Biscogniauxia nummularia (Bull.) Kuntze		1	1	1	beech-dominated forest, forest road	*Fagus*
Capitotricha bicolor (Bull.) Baral			1		beech-dominated forest	*Crataegus*
Cryptodiscus foveolaris (Rehm) Rehm				1	pasture	*Corylus*
Elaiopezia polaripapulata (J. Moravec) Van Vooren		1*			riparian forest	*Carpinus*
Glyphium elatum (Grev.) H. Zogg		1*	1		riparian forest	*Carpinus*
Helminthosphaeria stuppea (Ellis & Everh.) A.N. Mill., Huhndorf & J. Fourn.		1			riparian forest	*Alnus*
Helvella acetabulum (L.) Quél.	1*				oak forest	soil
Hypoxylon fragiforme (Pers.) J. Kickx f.		2	1		beech-dominated forest	*Fagus*

Taxon	Study site/Number of records				Habitat	Substrate
	Dubrava	Neretva	Mededak	Crvanj		
Hypoxylon fuscum (Pers.) Fr.	1*	1			pasture, riparian forest	*Corylus*, *Alnus*
Kretzschmaria deusta (Hoffm.) P. M. D. Martin			2	1	beech-dominated forest	*Fagus*
Lachnum crystallinum (Fuckel) Rehm	1				oak forest	*Quercus*
Lasiobelonium variegatum (Fuckel) Raitv.	1				oak forest	*Quercus*
Lasiosphaeria ovina (Pers.) Ces. & De Not.				1	beech-dominated forest	*Fagus*
Lophiostoma cf. *erumpens* Andreasen, Jaklitsch & Voglmayr	1*				pasture	*Thymus*
Melaspilea emergens (Fr.) Rehm	1*				pasture	*Thymus*
Ophiocordyceps stylophora (Berk. & Broome) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora		1*			riparian forest	*Elateridae* larva
Orbilia lentiformis Baral & G. Marson	1*				oak forest	*Clematis vitalba*
Ostropa barbara (Fr.) Nannf.				1*	pasture	*Acer*
Paragalactinia michelii (Boud.) Van Vooren		1			beech-dominated forest	soil
Paraxylaria xylostei (Pers.) M.C. Samar. & K.D. Hyde*Amphisphaerella xylostei*				1*	pasture	*Lonicera xylosteum*
Patinella punctiformis f. *quercina* Feltgen		1*			beech-dominated forest	*Quercus cerris* bark
Perrotia flammea (Alb. & Schwein.) Boud.	1*		1*		oak forest, beech-dominated forest	*Crataegus*
Pezicula ocellata (Pers.) Seaver			1		beech-dominated forest	*Salix*
Peziza arvernensis Roze & Boud.		1*		1*	disturbed (fire, wind) beech-dominated forest, beech-dominated forest	soil
Platystomum compressum (Pers.) Trevis.				1*	pasture	*Crataegus*
Proliferodiscus tricolor (Sowerby) Baral	1				oak forest	*Quercus cerris* bark
Scutellinia crinita (Bull.) Lambotte			1		beech-dominated forest	*Fagus* leaves, soil
Schizoxylon alboatrum Rehm				1*	pasture	*Acer*
Tarzetta cf. *cupularis* (L.) Lambotte		1*			riparian forest	soil
Triblidium caliciiforme Rebent.		1*			beech-dominated forest	*Quercus cerris* bark

Taxon	Study site/Number of records				Habitat	Substrate
	Dubrava	Neretva	Mededak	Crvanj		
Trichopeziza viridula Grelet				1*	pasture	*Acer*
Unguicularіopsis lettaui (Grummann) Coppins		1			beech-dominated forest	*Evernia prunastri*
Xerombrophila crystallifera Baral, G. Marson & Unter.		1*			riparian forest	*Salix*
BASIDIOMYCOTA						
Agrocybe praecox (Pers.) Fayod	2*	2*	1		riparian forest, oak forest, beech-dominated forest and pasture	*Carpinus*, soil
Aleurodiscus disciformis (DC.) Pat.	1*				oak forest	*Quercus*
Artomyces pyxidatus (Pers.) Jülich		1			beech-dominated forest	*Quercus*
Astraeus hygrometricus (Pers.) Morgan	1				oak forest	soil
Athelia neuhoffii (Bres.) Donk		1*			riparian forest	*Sambucus*
Bjerkandera adusta (Willd.) P. Karst.			1		beech-dominated forest	*Fagus*
Boletus reticulatus Schaeff.		1			beech-dominated forest	soil
Calocera cornea (Batsch) Fr.		1			beech-dominated forest	*Fagus*
Candolleomyces candolleanus (Fr.) D. Wächt. & A. Melzer				1*	disturbed (fire, wind) beech-dominated forest	deciduous wood
Cantharellus pallens Pilát	1				oak forest	soil
Cerinomyces aeneus A. Savchenko, Miettinen & J.C. Zamora		1*		1*	beech-dominated forest	*Carpinus, Fagus* wood
Cerioporus varius (Pers.) Zmitr. & Kovalenko	1				oak forest	*Quercus*
Crepidotus applanatus (Pers.) P. Kumm.		1*			beech-dominated forest	deciduous wood
Crucibulum laeve (Huds.) Kambly	1*				pasture	deciduous wood
Crustomyces subabruptus (Bourdot & Galzin) Jülich		1		1	riparian forest, beech-dominated forest	*Alnus*, *Fagus*
Cyathus striatus Willd.		1			riparian forest	deciduous wood
Exidiopsis effusa (Bref. ex Sacc.) Möller			1*		beech-dominated forest	*Fagus*

Taxon	Study site/Number of records				Habitat	Substrate
	Dubrava	Neretva	Mededak	Crvanj		
Fomes fomentarius (L.) Fr.		1	1	2	disturbed (fire, wind) beech-dominated forest, beech-dominated forest, forest road	*Fagus*
Fomitopsis pinicola (Sw.) P. Karst.		1		1	beech-dominated forest	*Fagus*
Galerina marginata (Batsch) Kühner		1			beech-dominated forest	deciduous wood
Ganoderma applanatum (Pers.) Pat.		1	1		riparian forest, beech-dominated forest	*Alnus*, *Fagus*
Guepiniopsis buccina (Pers.) L.L. Kenn.		2*			riparian forest	*Carpinus*, deciduous wood
Gymnopus aquosus (Bull.) Antonín & Noordel.		1*			riparian forest	litter
Gymnopus dryophilus (Bull.) Murrill	1	1	1	1	disturbed (fire, wind) beech-dominated forest, oak forest, beech-dominated forest	soil
Gymnopus foetidus (Sowerby) P.M. Kirk		1			riparian forest	detritus
Helicogloea compressa (Ellis & Everh.) Malysheva & K. Põldmaa		1			beech-dominated forest	*Fagus*
Hymenochaete rubiginosa (Dicks.) Lév.	2*				oak forest	*Quercus*
Hypholoma lateritium (Schaeff.) P. Kumm.		1			beech-dominated forest	*Fagus*
Kurtia macedonica (Litsch.) Karasiński			1*		beech-dominated forest	deciduous wood
Laetiporus sulphureus (Bull.) Murrill		1			beech-dominated forest	*Quercus*
Marasmius rotula (Scop.) Fr.		1			riparian forest	deciduous wood
Megacollybia platyphylla (Pers.) Kotl. & Pouzar	1	2			riparian forest, oak forest	*Quercus*, deciduous wood
Mutinus caninus (Schaeff.) Fr.		1			beech-dominated forest	soil
Mycena acicula (Schaeff.) P. Kumm.		1			riparian forest	*Alnus*
Mycena capillaris (Schumach.) P. Kumm. (leg. Maja Zagmajster, Golubnjača cave)	-	-	-	-	cave	angiosperm wood
Mycena galericulata (Scop.) Gray	2				oak forest, pasture	*Quercus*

Taxon	Study site/Number of records				Habitat	Substrate
	Dubrava	Neretva	Mededak	Crvanj		
Mycena haematopus (Pers.) P. Kumm.				1	disturbed (fire, wind) beech-dominated forest	*Fagus*
Mycena maculata P. Karst.		1			riparian forest	*Alnus*
Mycena renati Quél.		3	1	2	riparian forest, disturbed (fire, wind) beech-dominated forest, beech-dominated forest	*Alnus*, *Fagus*, deciduous wood
Mycetinis alliaceus (Jacq.) Earle ex A.W. Wilson & Desjardin		1			beech-dominated forest	detritus
Pachykytospora tuberculosa (Fr.) Kotl. & Pouzar	1				oak forest	*Quercus*
Parasola lactea (A.H. Sm.) Redhead, Vilgalys & Hopple			1*		beech-dominated forest	soil
Peniophorella pubera (Fr.) P. Karst.				1*	disturbed (fire, wind) beech-dominated forest	*Fagus*
Perenniporia narymica (Pilát) Pouzar		1*			beech-dominated forest	*Fagus*
Phaeomarasmius erinaceus (Fr.) Scherff. ex Romagn.			1		beech-dominated forest	*Salix*
Phanerochaete sordida s.l. (P. Karst.) J. Erikss. & Ryvarden			1*		beech-dominated forest	deciduous wood
Pleurotus ostreatus (Jacq.) P. Kumm.		1			beech-dominated forest	*Fagus*
Pluteus cervinus (Schaeff.) P. Kumm.				1	disturbed (fire, wind) beech-dominated forest	*Fagus*
Pluteus romellii (Britzelm.) Lapl.		1			riparian forest	deciduous wood
Pluteus semibulbosus agg. (Lasch) Quél.	1*	1*			riparian forest, oak forest	*Carpinus*, *Quercus*
Podofomes mollis (Sommerf.) Gorjón				1	disturbed (fire, wind) beech-dominated forest	*Fagus*
Polyporus tuberaster (Jacq. ex Pers.) Fr.		1*			beech-dominated forest	deciduous wood
Porotheleum fimbriatum (Pers.) Fr.			1*	1*	beech-dominated forest	*Fagus*, deciduous wood
Pycnoporus cinnabarinus (Jacq.) P. Karst.	1				pasture	*Rosaceae*
Russula lepida Fr.		1			beech-dominated forest	soil

Taxon	Study site/Number of records				Habitat	Substrate
	Dubrava	Neretva	Mededak	Crvanj		
Schizophyllum commune Fr.		1		1	riparian forest, disturbed (fire, wind) beech-dominated forest	*Fagus*, deciduous wood
Steccherinum fimbriatum (Pers.) J. Erikss.			1*		beech-dominated forest	*Fagus*
Stereum hirsutum (Willd.) Pers.	1		1	1	disturbed (fire, wind) beech-dominated forest, beech-dominated forest, oak forest	*Quercus*, deciduous wood
Stereum insignitum Quél.		1*			beech-dominated forest	*Fagus*
Stereum subtomentosum Pouzar		1			riparian forest	deciduous wood
Thelephora wakefieldiae Zmitr., Shchepin, Volobuev & Myasnikov		1*			riparian forest	deciduous wood
Trametes hirsuta (Wulfen) Lloyd	1			2	pasture, forest road, beech-dominated forest	*Fagus*, *Rosaceae*
Trametes versicolor (L.) Lloyd		1	1	3	riparian forest, disturbed (fire, wind) beech-dominated forest, beech-dominated forest	*Fagus*, deciduous wood
Tremella mesenterica (Schaeff.) Pers.				1	beech-dominated forest	*Fagus*
Trichaptum biforme (Fr.) Ryvarden	1	1*			oak forest, beech-dominated forest	*Fagus*, *Quercus*
Xerula radicata (Relhan) Dörfelt		1			beech-dominated forest	deciduous wood
Xylobolus frustulatus (Pers.) P. Karst.	1	1			riparian forest, oak forest	*Quercus*
Sum of species	**28**	**55**	**23**	**27**		

POVZETEK

Podatki o raznolikosti in razširjenosti gliv v Bosni in Hercegovini so razdrobljeni in trenutno ni na voljo nobenega uradnega kontrolnega seznama gliv. Rezultate mikoloških raziskav iz zadnjih let, v katere so v veliki meri vključeni člani Mikološkega društva MycoBH iz Sarajeva, je mogoče najti v več publikacijah (npr. Jukić et al. 2020a, 2020b; Treštić et al. 2021; Jukić et al. 2022). Poleg prvotnega rdečega seznama gliv (Đug 2013) so bile v zadnjih letih kot rezultat sistematičnih raziskav predlagane tudi kategorije IUCN za druge vrste (npr. Jukić & Omerović 2017; Treštić et al. 2021).

Cilj naše študije je bil raziskati glivno raznolikost zgornje doline Neretve, ki jo trenutno ogroža načrtovana gradnja hidroelektrarn, in prispevati k poznavanju mikobiote tega območja in regije Bosne in Hercegovine. Študija je bila izvedena med Tednom znanosti Neretve 2023, od 31. 5. 2023 do 4. 6. 2023 na štirih raziskovalnih lokacijah v zgornji dolini Neretve blizu Uloga v Bosni in Hercegovini (Sl. 1, Tab. 1). Habitati na preiskovanih lokacijah so bili predvsem ekstenzivno upravljani travniki in gozdovi, pogosto s starodavnim značajem, v katerih so prevladovali *Fagus sylvatica* na hladnejših severnih pobočjih, *Quercus petraea* in *Q. cerris* na južnih pobočjih ter *Alnus rohlenae* okoli rečnega brega. Celotna vrstna raznolikost gliv, vidnih s prostim očesom ali s pomočjo ročne leče, je bila ocenjena glede na redke in ogrožene vrste z uporabo pristopa, ki temelji na plodnih telesih.

Med raziskavo je bilo zabeleženih 102 vrst gliv (35 Ascomycota in 67 Basidiomycota), s prevlado gliv, ki naseljujejo les, vključno z redkimi vrstami in vrstami, novimi za državo. Seznam vseh zabeleženih vrst s podatki o številu zapisov na posameznih lokacijah, vrsti habitata in substratu, na katerem je bila vrsta zabeležena, je podan v Tab. 2. Po našem vedenju je za Bosno in Hercegovino novih vsaj deset vrst (*Cerinomyces aeneus* (Sl. 3A), *Glyphium elatum* (Sl. 3C), *Kurtia macedonica*, *Ophiocordyceps stylophora* (Sl. 3B), *Orbilia lentiformis*, *Patinella punctiformis* f. *quercina* (Sl. 3D), *Perenniporia narymica* (Sl. 2B), *Proliferodiscus tricolor*, *Triblidium caliciiforme*, *Xerombrophila crystallifera*). Druge zanimive najdbe vključujejo *Guepiniopsis buccina* (Sl. 2D), ki je predlagana kot skoraj ogrožena vrsta v Bosni in Hercegovini (Treštić et al. 2021), *Porotheleum fimbriatum* s predlagano kategorijo pomanjkanja podatkov (DD) (Treštić et al. 2021), *Crustomyces subabruptus* (Sl. 2C), *Elaiopezia polaripapulata* (Sl. 2A) in *Perrotia flammea*. Pet zabeleženih vrst je uvrščenih na Rdeči seznam gliv Federacije Bosne in Hercegovine (Đug 2013), od tega so štiri vrste navedene kot DD (*Cyathus striatus*, *Mutinus caninus*, *Mycena haematopus*, *Mycena renati*), ena vrsta, *Polyporus tuberaster* (Jacq. ex Pers.) Fr., pa kot kritično ogrožena. Nekatere vrste so v sosednjih državah zaščitene ali uvrščene na rdeči seznam (npr. HMD 2005; Perić & Perić 2005; Kasom & Miličković 2006; Ivančević et al. 2012; ECCF 2024). Na podlagi naših rezultatov, števila na novo zabeleženih in številnih redkih ter ogroženih vrst se zdi, da ima območje zgornje doline Neretve velik raziskovalni in ohranitveni potencial.

SAŽETAK

Podaci o raznolikosti i rasprostranjenosti gljiva u Bosni i Hercegovini su nepotpuni i trenutno ne postoji zvanična lista vrsta gljiva. Rezultati mikoloških istraživanja iz poslednjih godina, u kojima su u velikoj meri uključeni članovi Mikološkog društva MycoBH iz Sarajeva, mogu se naći u nekoliko publikacija (npr. Jukić et al. 2020a, 2020b; Treštić et al. 2021; Jukić et al. 2022). Pored originalne Crvene liste gljiva (Đug 2013), predložene su i IUCN kategorije za druge vrste kao rezultat sistematskog istraživanja poslednjih godina (npr. Jukić & Omerović 2017; Treštić et al. 2021).

Cilj naše studije bio je da istražimo diverzitet gljiva doline Gornje Neretve, koja je trenutno ugrožena planiranom izgradnjom hidroelektrana i da doprinesemo poznavanju mikobiota ovog područja i regiona Bosne i Hercegovine. Studija je sprovedena tokom Sedmice nauke Nertva 2023, od 31. 5. 2023. do 4. 6. 2023. na četiri istraživačke lokacije u dolini Gornje Neretve kod Uloga u Bosni i Hercegovini (Sl. 1, Tab. 1). Staništa na istraživanim lokacijama predstavljali su uglavnom ekstenzivno upravljanim travnjacima i šumama, često starog karaktera, u kojima dominiraju *Fagus sylvatica* na hladnijim severnim padinama, *Quercus petraea* i *Q. cerris* na južnim padinama i *Alnus rohlenae* oko obale rijeke. Ukupna raznolikosti vrsta gljiva vidljivih golim okom ili uz pomoć ručnog sočiva procenjena je u odnosu na rijetke i ugrožene vrste korišćenjem pristupa zasnovanog na plodnim telima.

Tokom istraživanja zabilježene su 102 vrste gljiva (35 Ascomycota i 67 Basidiomycota), sa prevalencijom gljiva koje nastanjuju drvo, uključujući rijetke vrste i vrste nove za zemlju. Spisak svih zabilježenih vrsta sa informacijama o broju zapisa na pojedinačnim lokacijama, vrsti staništa i supstratu na kojem je vrsta zabilježena dat je u Tab. 2. Koliko znamo, najmanje deset vrsta (*Cerinomyces aeneus* (Sl. 3A), *Glyphium elatum* (Sl. 3C), *Kurtia macedonica*, *Ophiocordyceps stylophora* (Sl. 3B), *Orbilia lentiformis*, *Patinella punctiformis* f. *quercina* (Sl. 3D), *Perenniporia narymica* (Sl. 2B), *Proliferodiscus tricolor*, *Triblidium caliciiforme*, *Xerombrophila crystallifera*) su nove za Bosnu i Hercegovinu. Drugi zanimljivi nalazi uključuju *Guepiniopsis buccina* (Sl. 2D) koja je predložena kao gotovo ugrožena vrsta u Bosni i Hercegovini (Treštić et al. 2021), *Porotheleum fimbriatum* sa predloženom kategorijom deficitarnih podataka (DD) (Treštić et al. 2021), *Crustomyces subabruptus* (Sl. 2C), *Elaiopezia polaripapulata* (Sl. 2A) i *Perrotia flammea*. Pet zabilježenih vrsta navedeno je na Crvenoj listi gljiva Federacije Bosne i Hercegovine (Đug

2013), od kojih su četiri vrste navedene kao DD (*Cyathus striatus*, *Mutinus caninus*, *Mycena haematopus*, *Mycena renati*) i jedna vrsta, *Polyporus tuberaster* (Jacq. ex Pers.) Fr., kao kritično ugrožena. Neke od vrsta su zaštićene ili su na Crvenoj listi u okolnim zemljama (npr. HMD 2005; Perić & Perić 2005; Kasom & Miličković 2006; Ivančević et al. 2012; ECCF 2024). Na osnovu naših rezultata, broja novozabilježenih, rijetkih i ugroženih vrsta, čini se da područje gornje doline Neretve ima veliki istraživački i konzervacijski potencijal.

ACKNOWLEDGEMENTS

We thank Nedim Jukić and Mycological Society MycoBH from Sarajevo for kindly providing their data and useful information on the mycobiota of Bosnia and Herzegovina.

REFERENCES

Baral HO, Marson G, Bogale M, Untereiner WA. 2013. *Xerombrophila crystallifera*, a new genus and species in the Helotiales. Mycological Progress. 12: 475-488. https://doi.org/10.1007/s11557-012-0854-6

Baral HO, Weber E, Marson G. 2020. Monograph of Orbiliomycetes (Ascomycota) based on vital taxonomy. Part I + II. Luxembourg: National Museum of Natural History Luxembourg.

Bernicchia A, Gorjón SP. 2010. Fungi Europaei 12: Corticiaceaes s.l. Salamanca (ES): Edizioni Candusso.

Bernicchia A, Gorjón SP. 2020. Polypores of the Mediterranean region. Segratte (IT): Ed. Romar.

Boehm EWA, Marson G, Mathiassen GH, Gardiennet A, Schoch CL. 2015. An overview of the genus *Glyphium* and its phylogenetic placement in Patellariales. Mycologia. 107(3): 607-618. https://doi.org/10.3852/14-191

Chachuła P, Vončina G, Kozik J. 2011. *Ophiocordyceps stylophora* (Ascomycota, Hypocreales), new species for Poland. Polish Botanical Journal. 56: 321-326.

Chachuła P, Vončina G, Stanczak P. 2019. *Ophiocordyceps stylophora* (Ophiocordycipitaceae) in Poland: new localities and host species. Acta Mycologica. 54(2): 1125. https://doi.org/10.5586/am.1125

[HMD] Croatian Mycological Society. 2005. Crveni popis gljiva Hrvatske; [accessed 30. 8. 2024]. https://mycolsoc.hr/crveni-popis-gljiva-hrvatske/

David A, Tortić M. 1986. Contribution à l'étude de quatre Polypores européens peu connus. Cryptogamie Mycologie. 7(1): 1-13. https://doi.org/10.5962/p.354214

Đug S. 2013. Crvena lista gljiva Federacije Bosne i Hercegovine. Sarajevo: EU »Greenway« Sarajevo; [accessed 30. 8. 2024]. https://spdzdk.ba/sadrzaj/fsc/crvena_lista_gljiva_FBiH.pdfDvořák D, Běťák J. 2017. Interesting collections of polypores in the Czech Republic, particularly in Moravia – I. Acta Musei Moraviae, Scientiae biologicae. 102(1): 49-87.

[ECCF] European Council for the Conservation of Fungi. 2024. The preliminary red list of Albanian macrofungi; [accessed on 30. 8. 2024]. http://www.eccf.eu/Albania.pdf

[FHMZBiH] Federation of Bosnia and Herzegovina Hydrometeorological Institute. 2025. Klima Bosne i Hercegovine; [accessed 5. 6. 2025]. https://www.fhmzbih.gov.ba/latinica/KLIMA/klimaBIH.php

Feltgen J. 1903. Vorstudien zu einer Pilzflora des Grossherzogthums Luxemburg. I. Theil. - Ascomycetes. Nachträge III.

[GBIF] Global Biodiversity Information Facility. 2025. *Perenniporia narymica*; [accessed 5. 6. 2025]. https://www.gbif.org/occurrence/map?taxon_key=7918684

Hagara L. 2015. Ottova encyklopédia húb. Prague: Ottovo nakladatelství.

Hansen L, Knudsen H. 2018. Funga Nordica: Agaricoid, boletoid, clavarioid, cyphelloid and gastroid genera. 2nd ed. Copenhagen (DK): Nordsvamp.

Ivančević BN, Matavulj MN, Vukojević JB, Karaman MA. 2012. Fungi in the Legislation of the Republic of Serbia. Zbornik Matice srpske za prirodne nauke. 123: 51-64. https://doi.org/10.2298/ZMSPN1223051I

Jukić N, Matočec N, Kušan I, Gašić R, Omerović N, Tomić S. 2019. Diversity of ascomycetous fungi in the territories of protected areas and in the areas evaluated for the protection in Bosnia-Herzegovina - establishing Important Fungus Areas (IFA). Sarajevo: Mycological Society MycoBH.

Jukić N, Omerović N, Tomić S. 2020a. Inventarizacija gljiva na teritoriji zaštićenih područja Kantona Sarajevo (SP Vrelo Bosne, ZP Bijambare, SP Skakavac). Smjernice i preporuke za upravljanje specifičnim tipovima staništa na teritoriji zaštićenih područja. Mikološko udruženje MycoBH. Sarajevo.

Jukić N, Omerović N, Tomić S. 2022. Gljive gorskih očiju - svijet koji nestaje. Sarajevo: Mikološko udruženje MycoBH.

Jukić N, Omerović N. 2017. Gljive reda Pezizales u Bosni i Hercegovini: ugroženost, ekologija i biogeografija. Sarajevo: Amatersko mikološko udruženje.

Jukić N, Tomić S, Gašić R. 2020b. Contribution to the knowledge on the mycobiota of southeast Herzegovina – Diversity of the ascomycetous fungi in the territory of the »Orjen« Nature Park. Glasnik Šumarskog fakulteta Univerziteta u Banjoj Luci 30: 115-133. https://doi.org/10.7251/GSF2030001J

Kasom G, Miličković N. 2006. Protected species of macromycetes in the Republic of Montenegro. Podgorica: Institute for the Protection of Nature.

Krisai-Greilhuber I, Friebes G, editors. 2021. Mycological Database. Austrian Mycological Society; [accessed 22. 5. 2025]. https://pilzdaten-austria.eu

Kunca V, Peiger M, Tomka P, Vampola P. 2022. Old-growth forest fungi – new localities and habitat and host preferences in Slovakia (I). Czech Mycology. 74(1): 33-55. https://doi.org/10.33585/cmy.74103

Larsson KH, Ryvarden L. 2021. Corticioid fungi of Europe: volume 1 – *Acanthobasidium* – *Gyrodontium*. Oslo: Fungiflora. (Synopsis Fungorum; vol. 43)

Martini E. 2024. *Porotheleum fimbriatum*. Crusts & Jells; [accessed 30. 8. 2024]. https://www.aphyllo.net

Operta M, Pamuk S. 2015. Geološke karakteristike in tektonska građa slivnog područja gornje Neretve. Acta geographica Bosniae et Herzegovinae. 4: 69-81.

Perić B, Perić O. 2005. The provisory red list of endangered macromycetes of Montenegro. Mycologia Montenegrina. 7: 7-33.

Pilát A. 1936. Additamenta ad floram Sibiriae Asiaeque orientalis mycologicam. Pars III. Bulletin de la Société mycologique de France. 51: 351-426.

Rivoire B. 2020. Polypores de France et d´Europe. Orliénas: Mycopolydev.

Savchenko A, Zamora JC, Shirouzu T, Spirin V, Malysheva V, Koljalg U, Miettinen O. 2021. Revision of *Cerinomyces* (Dacrymycetes, Basidiomycota) with notes on morphologically and historically related taxa. Studies in Mycology. 99: 1-72. https://doi.org/10.1016/j.simyco.2021.100117

Skoulikidis NT, Zogaris S, Karaouzas I. 2022. Rivers of the Balkans. In: Tockner K, Zarfl C, Robinson CT, editors. Rivers of Europe. Amsterdam: Elsevier. p. 593-653.

Treštić T, Jukić N, Omerović N. 2021. Diverzitet gljiva Zaštićenog pejzaža »Konjuh« - Inventarizacija, zaštita i promocija. Banovići, Sarajevo: Javna ustanova Zaštićeni pejzaž »Konjuh«, Mikološko udruženje MycoBH.

Zíbarová L, Pouska V. 2020. New records of corticioid fungi in the Bohemian Forest (Czech Republic). Czech Mycology. 72(2): 109-150. https://doi.org/10.33585/cmy.72201

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 28–65
»Neretva Science Week 2023«

ZNANSTVENI ČLANEK /
SCIENTIFIC ARTICLE

DOI: 10.14720/ns.19952
Objavljeno na spletu / Published online: 9. 10. 2025

Prejeto / Received: 9. 10. 2024
Sprejeto / Accepted: 2. 2. 2025

A contribution to the vascular and bryophyte flora of the Upper Neretva and Zalomka River valleys (Bosnia and Herzegovina)

Đorđije MILANOVIĆ[1*], *Simona STRGULC KRAJŠEK*[2*], *Jugoslav BRUJIĆ*[1], *Ivan JURAJ ČEHULIĆ*[3], *Valentin HEIMER*[4], *Dragan KOLJANIN*[1], *Marija KRAVANJA*[5], *Ivana REŠETNIK*[6], *Vladimir STUPAR*[1], *Peter SCHÖNSWETTER*[4], *Božo FRAJMAN*[4*]

[1] University of Banja Luka, Faculty of Forestry, Petra Bojovića 1A, Banja Luka, Bosnia and Herzegovina

[2] University of Ljubljana, Biotechnical Faculty, Department of Biology, Večna pot 111, SI-1000 Ljubljana, Slovenia

[3] University of Zagreb, Faculty of Forestry and Wood Technology, Svetošimunska cesta 23, 10000 Zagreb, Croatia

[4] University of Innsbruck, Department of Botany, Sternwartestraße 15, Innsbruck, Austria

[5] Slovenian Forestry Institute, Večna pot 2, SI-1000 Ljubljana, Slovenia

[6] University of Zagreb, Faculty of Science, Department of Biology, Ravnice 48, Zagreb, Croatia

* Korespondenčni avtorji / Corresponding authors; E-mails: djordjije.milanovic@sf.unibl.org (vascular flora), simona.strgulc@bf.uni-lj.si (bryoflora); bozo.frajman@uibk.ac.at

ABSTRACT

Between 1st and 6th June 2023, we conducted floristic research on several sites in the upper Neretva River valley and along Zalomka River at Nevesinjsko Polje. We recorded 933 taxa in total; 897 plant taxa including 125 bryophytes were found at 51 localities in the upper Neretva River valley, and 200 plant taxa, including 32 bryophytes, were found at 11 sites in the Zalomka River valley. Among the registered taxa, 39 taxa are endemic to the Balkan Peninsula, 56 are listed in the List of endangered and rare taxa of Bosnia and Herzegovina, 27 are on the Red List of the Federation of Bosnia and Herzegovina, and 95 taxa are protected in the Republic of Srpska. We also registered several species new to the flora of Bosnia and Herzegovina. Among Angiosperms these were *Barbarea intermedia*, *Lamium hybridum*, *Myosotis sicula* and *Poa ursina*, and among bryophytes *Fissidens gracilifolius*, *Grimmia dissimulata*, *Plagiomnium ellipticum*, *Schistidium robustum*, *Sphenolobus minutus*, *Tortella fasciculata* and *T. pseudofragilis*. Our study reveals the high nature conservation value of the upper Neretva and Zalomka River valleys that should be protected for future generations. In addition, further systematic research of the flora of Bosnia and Herzegovina is needed.

IZVLEČEK

Prispevek k poznavanju vaskularne flore in mahov zgornje doline Neretve in Zalomke (Bosna in Hercegovina)

Med 1. in 6. junijem 2023 smo opravili floristične raziskave na več lokacijah v zgornjem toku reke Neretve in v manjšem obsegu v dolini Zalomke in na Nevesinjskem polju. Skupaj smo zabeležili 933 taksonov; 897 vrst, od tega 125 mahov, smo našli na 51 nahajališčih v dolini zgornje Neretve, 200 vrst, od tega 32 mahov, pa na 11 lokacijah v dolini reke Zalomke. Med registriranimi taksoni jih je 39 endemičnih na Balkanskem polotoku, 56 taksonov je uvrščenih na seznam ogroženih in redkih taksonov Bosne in Hercegovine, 27 na rdeči seznam Federacije Bosne in Hercegovine, 95 taksonov pa je zavarovanih v Republiki Srbski. Poleg tega smo zabeležili tudi nekaj novih vrst za floro Bosne in Hercegovine. Med kritosemenkami so to *Barbarea intermedia*, *Lamium hybridum*, *Myosotis sicula* in *Poa ursina*, med mahovi pa *Fissidens gracilifolius*, *Grimmia dissimulata*, *Plagiomnium ellipticum*, *Schistidium robustum*, *Sphenolobus minutus*, *Tortella fasciculata* in *T. pseudofragilis*. Naša študija razkriva visoko naravovarstveno vrednost dolin zgornje Neretve in Zalomke, ki jih je treba zavarovati za prihodnje generacije. Poleg tega so potrebne nadaljnje sistematične raziskave flore Bosne in Hercegovine.

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

KEY WORDS:
angiosperms, mosses, nature conservation, Neretva River, rare species, vegetation

KLJUČNE BESEDE:
kritosemenke, mahovi, naravovarstvo, Neretva, redke vrste, vegetacija

KLJUČNE RIJEČI:
mahovine, rijeka Neretva, rijetke vrste, skrivenosjemenice, vegetacija, zaštita prirode

APSTRAKT

Prilog poznavanju vaskularne flore i brioflore dolina gornje Neretve i Zalomke (Bosna i Hercegovina)

Između 1. i 6. juna 2023. godine proveli smo floristička istraživanja na nekoliko lokaliteta u dolini gornjeg toka rijeke Neretve, te u dolini rijeke Zalomke u Nevesinjskom polju. Zabilježili smo ukupno 993 taksona; 897 biljnih taksona, uključujući 125 briofita, koje su pronađene na 51 lokalitetu u dolini gornjeg toka rijeke Neretve, dok je 200 taksona, uključujući 32 briofite, pronađeno na 11 lokaliteta u dolini rijeke Zalomke. Među zabilježenim taksonima 39 su endemi za Balkansko poluostrvo, 56 se nalazi na Listi ugroženih i rijetkih biljaka Bosne i Hercegovine, 27 je na Crvenoj listi Federacije Bosne i Hercegovine, dok 95 uživa status zaštite u Republici Srpskoj. Također, zabilježili smo i nekoliko novih vrsta za floru Bosne i Hercegovine. Među skrivenosjemenicama to su: *Barbarea intermedia*, *Lamium hybridum*, *Myosotis sicula* i *Poa ursina*, a među mahovinama: *Fissidens gracilifolius*, *Grimmia dissimulata*, *Plagiomnium ellipticum*, *Schistidium robustum*, *Sphenolobus minutus*, *Tortella fasciculata* i *T. pseudofragilis*. Ovo istraživanje pokazuje da područja gornjeg toka rijeke Neretve i okoline rijeke Zalomke imaju visoku prirodnu vrijednost i trebaju biti predmet zaštite zbog budućih generacija. Dodali bismo da su dalja sistematska istraživanja flore Bosne i Hercegovine neophodna.

INTRODUCTION

Between 1. and 6. 6. 2023, several non-government organizations organized a research camp in the village of Ulog (Gornja Neretva, Republic of Srpska, Bosnia and Herzegovina) to study the biodiversity of the upper course of the Neretva River and the course of the Zalomka River at Nevesinjsko Polje. The aim was to collect scientific data before the planned construction of several hydroelectric power plants, which would disrupt the free flow of these rivers and affect the surrounding riparian vegetation, flora and fauna.

The lithology of the study area is mainly sandstone and calcarenite, which are the predominant substrates throughout the Neretva River valley (Fig. 1; Mojićević & Tomić 1981). These slopes are mainly covered with oak forests on the southerly and beech forests on the northerly exposed slopes. The forests are interspersed with numerous hamlets of the sprawling village of Borač, which are currently mostly abandoned. At the edges of the valley, the sandstones are replaced by limestones, which are the predominant substrate in the surrounding mountain massifs (Zelengora, Crvanj and Površ) marked by elements of glacial reliefs, moraines and depressions with glacial lakes. These areas were traditionally used as pastures, which are skeletal and covered by xerophilous vegetation. By now, they are largely deserted, as seasonal livestock farming has been completely abandoned after the civil war (1992–1995). Wetland communities are developed only in glacial depressions, ranging from aquatic communities in lakes to swamps, mires and wet grasslands, which were traditionally used as hay meadows. In addition, alluvial deposits are characteristic for the Neretva riverbed. Depending on the nature of the terrain, they are wide or narrow, and various alluvial forests including Rohlena alder (*Alnus rohlenae*) and white willow (*Salix alba*), grey willow thickets (*Salix eleagnos*), open communities on gravel bars and tall herbs on mud deposits have developed on them.

The Zalomka River flows through various regions with specific geological and geomorphological features. In its upper basin, it flows through a gorge of Jurassic and Triassic limestones

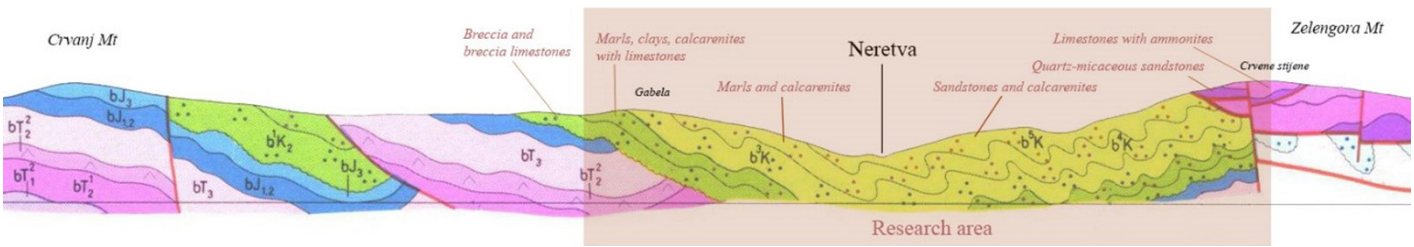

Figure 1. Geological transect across the Neretva River valley in Bosnia and Herzegovina (after Mojićević & Tomić 1981) with indicated research area where we investigated vascular plants and bryophytes in June 2023.

Slika 1. Geološki transekt čez dolino reke Neretve v Bosni in Hercegovini (po Mojićević & Tomić 1981) z označenim območjem, kjer smo junija 2023 raziskovali višje rastline in mahove.

Slika 1. Geološki transekt preko doline rijeke Neretve u Bosni i Hercegovini (prema Mojićević & Tomić, 1981) sa označenim područjem istraživanja vaskularnih biljkaka i mahovina u junu 2023. godine.

overgrown with thermophilic oak forests in various stages of degradation. Closer to the river bed, mostly bushy formations of low willows are developed. Downstream from the village of Kifino selo, Zalomka flows into Nevesinjsko polje, which lies on the alluvial deposits with a slightly undulating topography that has been cleared of forest and converted into mowed meadows in ancient times, with remnants of *Quercus cerris* forests on the hills and slopes. In the lower part the Zalomka flows through an extensive floodplain over conglomerates, while the substrate surrounding the river chasm is limestone overgrown with beech forests (*Fagus sylvatica*) having developed on the northern slopes above the river. The central part of the area consists of lake sediments where various wetland and peatland communities are developed.

Previous research of the flora of the Neretva basin from the source to Ulog did not have a systematic character and was limited to individual records of plant species (Blau 1877; Adamović 1889; Formanek 1890; Vandas 1909; Malý 1928, 1933; Milanović 2014). Only the surroundings of the Crvanjsko jezero and the slopes facing towards the Neretva and the summit of Crvanj were the subject of phytocenological investigations (Redžić et al. 1996; Redžić & Barudanović 2010; Redžić et al. 2013). On the other hand, the flora of Nevesinjsko polje has been studied in much more detail and floristic records were published in several contributions (Sagorski 1901; Sagorski 1912a, 1912b, 1914a, 1914b; Ritter-Studnička 1952, 1953, 1954, 1955, 1956; Lakušić et al. 1982; Perić et al. 2018). Previous research was focused on the flora of intermittently flooded meadows and peatlands, whereas forest ecosystems and the flora of riparian willow thickets along the Zalomka River were largely neglected. Finally, the bryoflora of these areas has not yet been studied with the exception of a few species of moss recorded in Nevesinjsko polje, on the mires around Srednja voda, Dušila and Čitluk (Ritter-Studnička 1954, 1956).

The goal of our study is to supplement the knowledge of the flora in both study areas, paying special attention to those ecosystems that are characterized by the greatest species richness, as well as to those that have not yet been investigated. In addition to the list of floristic records, we assess the nature conservation relevance of selected records.

MATERIAL AND METHODS

The field research was conducted in the period from 1. to 6. 6. 2023. The research area comprised two separate sites: part of the upper Neretva valley and the wider valley of the Zalomka River (Fig. 1). The first area covers the wider valley of the Neretva River, from the river body between the site where the hydropower dam is being built (lowest point at 620 m) and the village of Tomišlja (710 m), including the surrounding slopes of Zelengora on the right bank (highest point is Crvene stijene – 1783 m) to Kladopoljsko jezero (1385 m) and the slopes of the Morine plateau on the left bank to Mlakva above the village of Presjedovac (1239 m). The research area in the Zalomka River is mainly associated with the river body and riparian forest ecosystems between the village of Kunjak (931 m) in the east and the gorge near the village of Ponor (805 m), with sporadic studies of the surrounding forests and wetland ecosystems (Fig. 2).

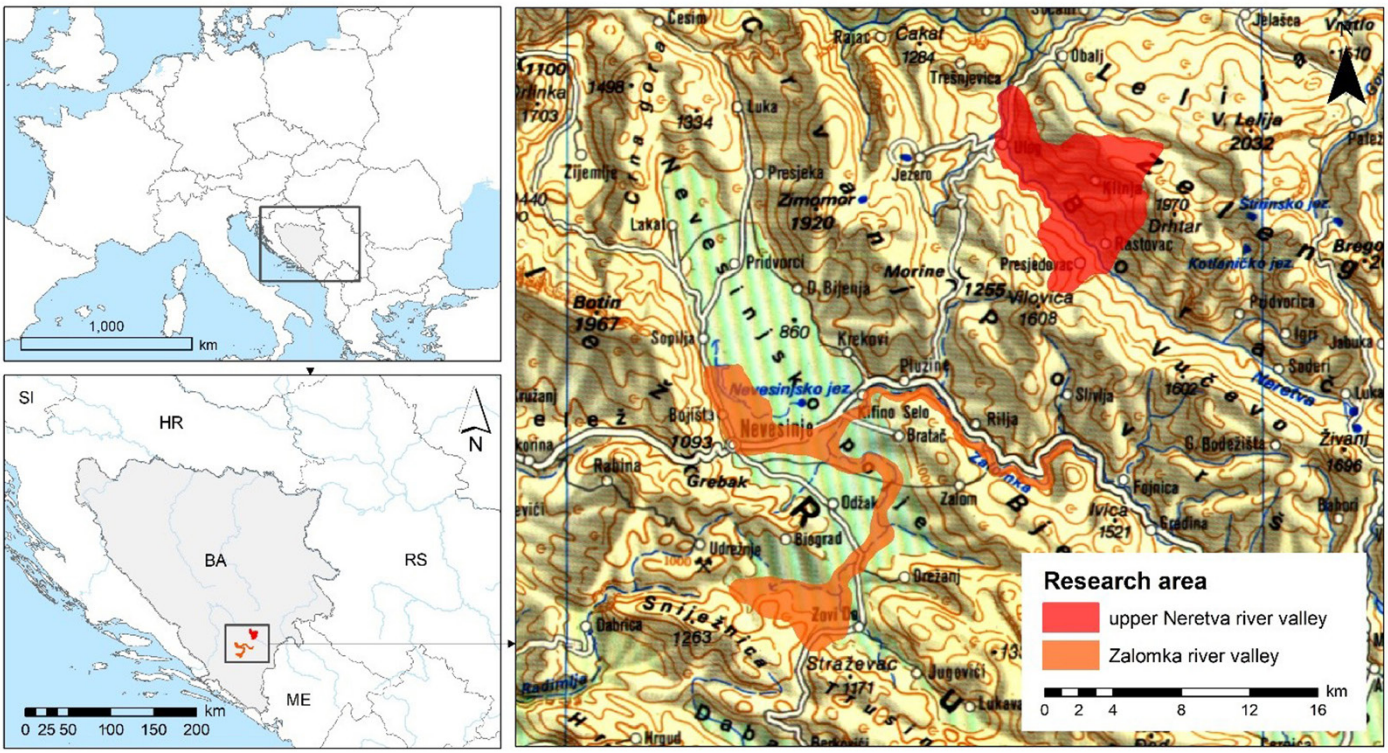

Figure 2. Locations of the research areas in the upper Neretva River valley and the Zalomka River valley in Bosnia and Herzegovina, where we studied vascular plants and bryophytes in June 2023.

Slika 2. Lokaciji območij v dolinah zgornje Neretve in Zalomke v Bosni in Hercegovini, kjer smo junija 2023 raziskovali višje rastline in mahove.

Slika 2. Položaji područja istraživanja u dolini gornjeg toka rijeke Neretve i Zalomke u Bosni i Hercegovini, gdje smo u junu 2023. godine istraživali vaskularne biljke i mahovine.

Due to the short study period covering only a fragment of the vegetation season, our floristic records are incomplete. We only provide the data recorded in the field during the camp and refrain from analysing the literature data. We studied the flora in 62 different localities: 51 in upper Neretva and 11 along Zalomka River and its surroundings (Tab. S1). We present the records separately for these two areas and provide the localities for each taxon (Tab. S2). When possible, we identified the taxa to subspecies level, but mostly we list species or, in cases of critical groups, »aggregates«. In cases of uncertain identifications, we add a question mark (»?«) after the taxon name.

We recorded the flora of the riparian ecosystems in both study areas by taking phytocenological relevés (Braun-Blanquet 1964), from which we only present the species lists here. We also recorded the flora and bryoflora of the upper Neretva valley along two vertical transects from the river body to the edges of the valley on mountain ridges and glacial lakes. We produced floristic lists for different ecosystems along the transects. We only collected and herbarized the plant material if we could not identify the taxon in the field; the identification was performed later using available identification keys (e.g. Tutin et al. 2001; Fischer et al. 2018; Nikolić 2019). Bryophytes were collected and identified in the laboratory using the microscope and stereomicroscope. For identification, we used Frey et al. (2006), Casas et al. (2006, 2009), Paton (1999), Schumacker & Váňa (2005), Lüth (2019), Atherton et al. (2010). Bryophytes were also collected by members of other research teams, M. Zagmajster, E. Premate and G. Singer. Herbarium specimens are stored in the herbaria IB, BALU, LJU, and in private collections. The nomenclature of bryophytes follows Hodgetts et al. (2020), while that of vascular plants is in accordance with Plants of the World Online (POWO 2024). The name *Sesleria interrupta*, not accepted by POWO, is in accordance with Kuzmanović et al. (2017).

RESULTS AND DISCUSSION

We recorded 896 plant taxa, including 125 bryophytes, at 52 surveyed localities in the upper Neretva River valley. In addition, we recorded 200 plant taxa, including 32 bryophytes, at 11 sites in the Zalomka River valley (Tab. S2). In total, 933 taxa were recorded in both areas. The total number of taxa in both areas is certainly higher, but not all taxa could be registered in the short study period.

Among the registered taxa, 39 or 4.16 % are endemic to the Balkan Peninsula. They mainly inhabit open grasslands, limestone screes and cliffs, but a certain number are also associated with riparian and forest ecosystems (*Alnus rohlenae*, *Cephalaria pastricensis*, *Cicerbita pancicii*, *Eryngium palmatum*, *Rhizomatophora aegopodioides*).

Fifty-six of the registered taxa are listed in the List of endangered and rare taxa of Bosnia and Herzegovina (Šilić 1996): one is critically endangered (*Paeonia officinalis*), 36 are rare, 19 are vulnerable and one is insufficiently known (*Dactylis glomerata* subsp. *lobata*). According to the Red list of the Federation of Bosnia and Herzegovina (Đug et al. 2013), 27 taxa are considered endangered: 3 are critically endangered (CR) (*Malcolmia orsiniana* subsp. *angulifolia*, *Ranunculus auricomus* and *Paeonia officinalis*), 11 are endangered (EN), 13 are vulnerable (VU) and 8 taxa have the data deficient (DD) status. In the Republic of Srpska, 95 taxa found are under protection, 21 of which enjoy strict protection (Uredba o strogo zaštićenim i zaštićenim divljim vrstama 2020).

Although most of the registered taxa have been identified at the species or subspecies level, this does not apply to the entire list. Some problematic apomictic taxa of the genus *Taraxacum* were retained at the section level (sect. *Erythrosperma* and sect. *Taraxacum*), while some species were represented at the aggregate level: *Arenaria serpyllifolia*, *Hieracium murorum* and *Ranunculus auricomus*. For example, all specimens of *Arenaria serpyllifolia* agg. showed transitional characteristics between *A. leptoclados* and *A. serpyllifolia*, suggesting that these taxa should rather be treated as subspecies. In the western Balkan Peninsula, plants better corresponding to *A. leptoclados* occur at lower elevations, whereas *A. serpyllifolia* thrives in the mountains at higher elevation. The specimens assigned to other aggregates and sections were generally not sufficiently developed or their taxonomic status is unresolved. Finally, the plants belonging to the genus *Eleocharis* could not be assigned to any species with certainty due to the lack of mature fruits and were therefore labelled with »?« in Tab. S2.

The comprehensive study of available literature data revealed that some recorded taxa are new for the flora of Bosnia and Herzegovina. Among the Angiosperms these were *Barbarea intermedia*, *Lamium hybridum*, *Myosotis sicula* and *Poa ursina*, and among bryophytes *Fissidens gracilifolius*, *Grimmia dissimulata*, *Plagiomnium ellipticum*, *Schistidium robustum*, *Sphenolobus minutus*, *Tortella fasciculata* and *Tortella pseudofragilis.*

Barbarea intermedia was mentioned in the first overview of the flora of Bosnia and Herzegovina (Ascherson & Kanitz 1877) for Hercegovina, but without any locality provided. Beck-Mannagetta (1916) states without hesitation that this record refers to Pantocsek's material from Mt. Jastrebica, which (according to Grisebach) belongs to a form of the species *Barbarea bracteosa*. This record seems unfounded, as there is a complete lack of suitable habitats for this species on Jastrebica. *Barbarea intermedia* is clearly distinguished from other similar species by thick glabrous siliquae (cca. 2 mm in diameter), short style in fruit (less than 1.5 mm), and stout pedicels not more than ¼ of the length of the siliqua. We recorded it on the edge of a wet meadow with *Sesleria uliginosa* near a temporary pond named Čengića bara, traditionally used as a cattle watering place. Therefore, this is the first confirmed record of this species in the territory of Bosnia and Herzegovina.

Lamium hybridum (Fig. 3) is morphologically similar to *Lamium purpureum* and is sometimes considered to be only a variety of this species (e.g. Chytrý et al. 2024), which is most likely why it has been overlooked in previous research on the flora of Bosnia and Herzegovina. Irregular and deeply incised leaves and bracts as well as upper bracts, which are decurrent along the petiole, separate it from this species. In the study area, it occurs

in intensively grazed and fertilised grasslands on Lisičjak above Kovačić and disturbed nitrified parts of thermophilic forests above Jasen. It is expected that the species occurs also in other semi-ruderal and ruderal places in Bosnia and Herzegovina.

Figure 3. *Lamium hybridum* that we recorded in two localities at M. Zelengora is a new species of the flora of Bosnia and Herzegovina (Photo: Đ. Milanović).

Slika 3. Deljenolistna mrtva kopriva (*Lamium hybridum*), ki smo jo zabeležili na dveh nahajališčih na Zelengori, je nova vrsta za floro Bosne in Hercegovine (foto: Đ. Milanović).

Slika 3. *Lamium hybridum* koju smo registrovali na dvije lokacije na Zelengori i predstavlja novu vrstu za floru Bosne i Hercegovine (foto: Đ. Milanović).

Myosotis sicula is an annual to biennial species of wet habitats without stolons, with a calyx with equal and even, straight, compressed, upward-pointing hairs, without hooked hairs. The calyx is persistent in the fruit; nutlets are brown and ovoid to ellipsoid (Grau & Merxmüller 1972). We found it in damp places around Kladopoljsko jezero. The species' distribution area is South and West Europe, with records also from the area of former Yugoslavia (Grau & Merxmüller 1972; WFO 2024). This is the first confirmed record of this species in Bosnia and Herzegovina.

Poa ursina (=*P. media* Schur) was only found in a single site, on limestone outcrops in Lisičjak above Kovačić in a community with some other rare species, such as *Gagea villosa*, *Ornithogalum dalmaticum* and *Juniperus sabina*. It differs from similar species of *Poa* sect. *Bolbophorum* Asch. & Kan. by a lemma glabrous between the veins, taller stems and elongated ellipsoidal panicles. The specimens we collected are 20–30 cm high, with a panicle 50–70 mm long, clearly glabrous among the ciliate ridges of the lemma. It is likely that this species is more widespread in Bosnia and Herzegovina and that the section needs a comprehensive taxonomic revision in Bosnia and Herzegovina.

In addition to these new records, some other recorded species are known only from a small number of localities in Bosnia and Herzegovina, e.g. *Myosotis stricta*, *Astragalus hypoglottis*, *Gagea villosa*, *Medicago truncatula*, *Ornithogalum dalmaticum* and *Taraxacum janchenii*.

The annual species *Myosotis stricta* was first recorded in fields in the vicinity of Mostar (Struschka 1880), but could not be confirmed in more recent studies on the urban flora of this city (Maslo 2014) and its surroundings (Maslo & Abadžić 2015; Maslo & Boškailo 2018). Subsequently, the species was found in Varda Mt near Rudo (Fukarek in Beck-Mannagetta et al. 1967) as a rare species in the area, but was also not confirmed in systematic studies of serpentine areas by Ritter-Studnička (1970). Our record is thus the third observation of this species for Bosnia and Herzegovina. We recorded it together with the closely related *Myosotis ramosissima* in short semi-open montane grasslands on the slopes of Kuništa above Kovačić. *M. stricta* can be recognised by calyces that are almost without pedicels and by the presence of hooked hairs on the adaxial side of main leaf nerve and on stem (Grau & Merxmüller 1972).

Astragalus hypoglottis has so far only been recorded as *Astragalus purpureus* subsp. *gremlii* at two different localities in the Čvrsnica and Dinara mountain ranges. The first record was confirmed in Dugo polje between Vran and Čvrsnica (Abadžić 1989), while the second was refuted by Beck-Mannagetta (1927). Since our specimens were not fully developed during field research, it remains questionable to which species they belong. Especially their relationships with typical *A. hypoglottis* subsp. *hypoglottis* and closely related *A. danicus* should be the subject of further studies of this genus that needs to be systematically revised in Bosnia and Herzegovina.

The species of the genus *Gagea* are not sufficiently known in the flora of Bosnia and Herzegovina, mainly because of their early flowering time. Only a few species with a small number of localities have been recorded so far, and even some widespread species of this genus in northern Bosnia and Herzegovina have only recently been recorded for the first time (Milanović et al. 2013; Koljanin et al. 2021). Therefore, plant material with preserved bulbs and entire plants with well-developed flowers needs to be systematically collected throughout the country and a taxonomic revision undertaken. It is noteworthy that *Gagea villosa* (Fig. 4A) was recently recorded in Herzegovina (Maslo 2014; Maslo & Abadžić 2015; Maslo & Boškailo 2018) in the localities in which we found only *Gagea pusilla*, which is not mentioned in any of the listed papers. This species was also recorded as *G. arvensis* (syn. *G. villosa* in Beck-Mannagetta 1904) according to Pichler (1890) in ruderal sites of Mostar, Hensch in Vandas (1889) in Bileća and Pantocsek (1874) around Trebinje and Drača, but these data should be considered dubious for the same reason as the previous ones. In spring 2024, we only found a single adult individual of this species along the path from Kovačići to Lisičjak, on the edge of rocky outcrops.

Medicago truncatula has so far only been unequivocally recognised in the city of Mostar (Struschka, 1880) as *M. tribuloides*?. Beck-Mannagetta (1927) did not doubt this evidence and stated that Maly also found it in Mostar. However, this species has not been confirmed in more recent articles on the urban flora of the city (Maslo 2014). We found it in ruderalised meadows above the village of Tomišlja, where it appears to be rare.

The latest taxonomic revision of *Ornithogalum* sect. *Heliocharmos* in the Balkan Peninsula (Rat 2019) partly clarified the situation of this genus for Bosnia and Herzegovina. However, further research on the chorology and ecology of the

included species as well as the taxonomy of other sections of the genus is still needed. Among the species requiring more attention is also *Ornithogalum dalmaticum*, which was considered stenoendemic to Croatia (Speta 1990; Rat 2019) where it occurs in the narrow Mediterranean coastal zone and in the Adriatic islands. So far, the species has only been indirectly recorded in Neum (Rat 2019) in a dissertation as part of the list of collected plant material, with the distribution map of the studied species missing only for this taxon. We found this species on the limestone slopes above Kovačići to Lisičjak. The specimens with their long bracts, large flowers and large, almost spherical bulbs fully fit the original diagnosis and show that this species likely occurs deeper inland and is possibly distributed throughout the mediterranean and submediterranean part of Hercegovina.

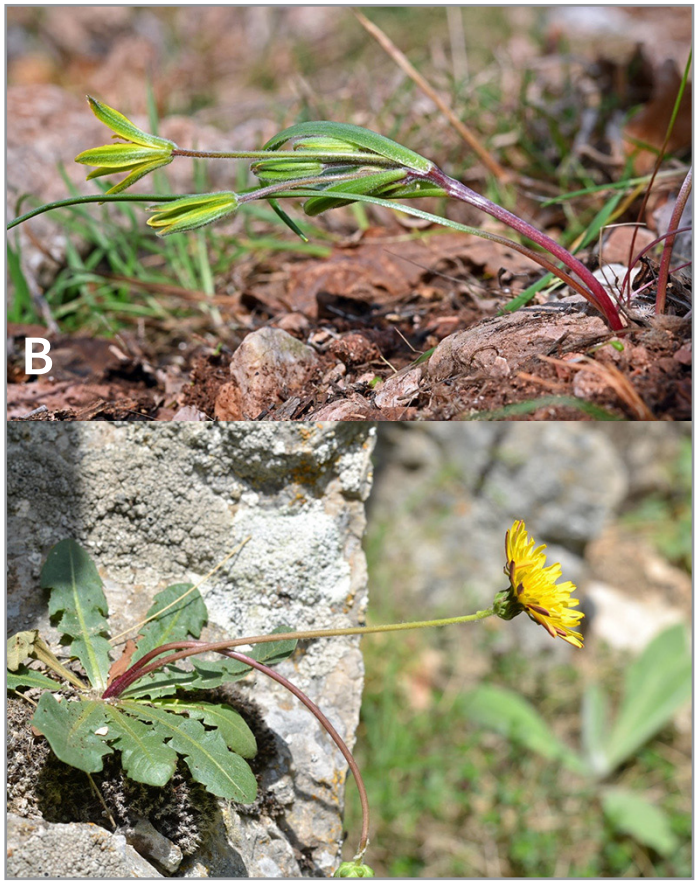

Figure 4. *Gagea villosa* (upper photo) and *Taraxacum janchenii* (lower photo) are rare and insufficiently known species in the flora of Bosnia and Herzegovina. We recorded them below Lisičjak at Mt. Zelengora (Photos: Đ. Milanović).

Slika 4. Dlakava pasja čebulica (*Gagea villosa*) (zgoraj) in Janchenov regrat (*Taraxacum janchenii*) (spodaj) sta redki in nezadovoljivo poznani vrsti v flori Bosne in Hercegovine. Zabeležili smo ju pod Lisičjakom na planini Zelengora (Foto: Đ. Milanović).

Slika 4. Lukovica dlakavog psa (*Gagea villosa*) (gore) i Janchenov maslačak (*Taraxacum janchenii*) (dole) rijetke su i slabo istražene vrste u flori Bosne i Hercegovine. Registrovali smo ih ispod lokaliteta Lisičjak na planini Zelengori (Foto: Đ. Milanović).

The genus *Taraxacum* is one of the most taxonomically complex genera in the world. Very narrowly defined apomictic species are only known to a few specialized botanists, while these taxa are only represented at section level in numerous floras, including Flora Europaea (e.g. Tutin et al. 2001). It is therefore not surprising that the species of this genus occurring in Bosnia and Herzegovina are still completely unknown and that further research is necessary. For example, *Taraxacum janchenii* (Fig. 4B) was not mentioned for Bosnia and Herzegovina since the species was described by Kirschner and Štěpánek (1985), who provided also a large number of localities for the territory of this country. Our record fits into the already known distribution area of the species, which inhabits limestone cliffs in the central Dinaric Mountains.

In addition to several interesting vascular plant species mentioned above, we also recorded some new species and distribution data for bryophytes. For example, on the shady vertical rocks at the entrance to the Vranjača Cave, we collected several interesting taxa. Among them was *Fissidens gracilifolius*, which is new for the bryoflora of Bosnia and Herzegovina (Hodgetts & Lockhart 2020). This is a small representative of the genus with bordered leaves. Its typical habitat are humid calcareous rocks (Frey et al. 2006), which were also the habitat of the collected specimens. At the same site, in a rock crevice filled with organic material, we found the tiny liverwort *Sphenolobus minutus* (synonym *Anastrophyllum minutum* (Schreb.) R. M. Schust.), also new for Bosnia and Herzegovina. It has transversely inserted leaves and almost equally thickened cell walls. Gemmae are angular and two-celled. The species has a circumboreal and tropical-alpine distribution (Frey et al. 2006). We also recorded *Seligera trifaria*, which is listed as data deficient in the European Red List (Hodgetts et al. 2019).

On the thermophilic sites above the Neretva River, we found several species that grow on exposed carbonate rocks. Among them was the acrocarpous moss *Grimmia dissimulata*, which is the first record for Bosnia and Herzegovina. While the genus *Grimmia* is easy to recognise by dense growth in roundish pillows and hyaline hairs at the end of leaves, the species are often difficult to identify. *Grimmia dissimulata* grows in carbonate rocks and occurs in most of the countries of the Balkan Peninsula (Hodgetts & Lockhart 2020). *Schistidium robustum* is also an acrocaropus moss growing on carbonate rocks. This species is similar to the more common *S. crasipilum*, however it has longer capsules and hair points that have several sharp teeth. Our identification relies on Nyholm (1998) and Lüth (2019), as well as on comparison with the herbarium material from Herbarium LJU.

Several papers have been published about the genus *Tortella* in the last years. One of them was dealing with *Tortella bambergeri* s. lat. (Köckinger & Hedenäs 2017), with a new identification key, which we used to identify the material we collected. We found two new species from this group, *T. fasciculata* and *T. pseudofragilis*. *Tortella fasciculata* is a thermophilous species growing on exposed rocks. We collected it at two thermophilous sites on the slopes above Neretva River (Grčko groblje). *Tortella pseudofragilis* was collected on the rocks along the Međeđak stream. Köckinger & Hedenäs (2017) stated that the ecology of this species does not differ much from that of T. *fasciculata*. Still, at lower altitudes in Central Europe, it also grows on shaded boulders in woods, gorges, or even in the flood zone of rivers. For the morphological differ-

ences among the species, see Köckinger & Hedenäs (2017) and Ottley & Blockeel (2019). The second revision within the same genus was made for *T. tortuosa* s. lat., which has been split into eight species (Köckinger & Hedenäs 2023). The material we collected from this group still needs to be revised, so we consider it as *T. tortuosa* s. lat. for now.

In the *Salix fragilis* riparian forest, we collected *Plagiomnium ellipticum*, a species that has not yet been recorded in Bosnia and Herzegovina. Representatives of the genus *Plagiomnium* are easily recognisable by thin leaf lamina bordered with elongated cells and denticulate to dentate. They grow in moist, shaded habitats, often in forests or along streams. *Plagiomnium ellipticum* is known from all countries of the Balkan Peninsula (Hodgetts & Lockhart 2020; Alegro & Šegota 2024). The main identification characters are: leaf base is not decurrent, laminal cells are porose and longer than wide and teeth are often small and missing at the basal part of the leaf (Frey et al. 2006).

Pulvigera lyelii is an epiphytic moss species, which is common in forests along the Neretva River. It is bigger than the *Orthotrichum* species and easily recognised by lanceolate leaves with numerous brown filamentous gemmae (Frey et al. 2006; Fig. 5). In Bosnia and Herzegovina, the species was already found in 2018 by Đ. Milanović in *Picea omorika* (Pančić) Prukyne stands on Radomišlja planina by Foča (Milanović 2022). We believe that it was neglected and will be found elsewhere in Bosnia and Herzegovina as it is not a rare species, especially in mountain forests.

Based on our results we conclude that the areas of the upper Neretva and Zalomka River valleys with Nevesinjsko polje are characterized by exceptionally well-preserved natural features harbouring a high number of rare and protected species of great importance for biodiversity and nature conservation. Despite our efforts, the study area remains insufficiently explored and further systematic research in the area as well as in whole Bosnia and Herzegovina is needed.

Figure 5. *Pulvigera lyelii* is an epiphytic moss species, which is common in forests along the Neretva River, where we registered it at several localities (Photo: Đ. Milanović).

Slika 5. *Pulvigera lyelii* je epifitska vrsta mahu, ki je pogosta v gozdovih ob reki Neretvi, kjer smo jo zabeležili na več lokacijah (Foto: Đ. Milanović).

Slika 5. *Pulvigera lyelii* je epifitska vrsta mahovine česta u šumama uz rijeku Neretvu, gdje smo je zabilježili na više lokacija (Foto: Đ. Milanović).

POVZETEK

Med 1. in 6. 6. 2023 smo opravili floristične raziskave na več lokacijah v zgornjem toku reke Neretve in v manjšem obsegu v dolini Zalomke in na Nevesinjskem polju. Raziskovano območje sestavljajo predvsem peščenjaki in kalkareniti, ki so prevladujoča podlaga v celotni dolini reke Neretve. Le na robovih doline peščenjake zamenjajo apnenci, ki so prevladujoča podlaga okoliških gorskih masivov. Pobočja doline reke Neretve so večinoma porasla s hrastovimi gozdovi na južnih in bukovimi gozdovi na severno usmerjenih pobočjih. Gozdovi so deloma preoblikovani v večinoma opuščene zaselke in pašnike. Mokrotne združbe so razvite le v ledeniških depresijah. Poleg tega so za strugo Neretve značilni aluvialni nanosi, kjer so razviti različni aluvialni gozdovi, grmišča sive vrbe, odprte združbe na prodnatih brežinah in visoka zelišča na muljastih nanosih. Po drugi strani pa reka Zalomka teče skozi različna območja s posebnimi geološkimi značilnostmi, od apnencev v zgornjem porečju do naplavin na Nevesinjskem polju. Na južno usmerjenih pobočjih so razviti predvsem toploljubni hrastovi gozdovi in različne stopnje njihove degradacije, na severno usmerjenih pobočjih pa bukovi gozdovi. Za osrednje območje Nevesinjskega polja z jezerskimi sedimenti so značilne različne mokriščne in šotne združbe. Dosedanje raziskave flore porečja Neretve od Uloga do izvira reke niso bile sistematične in so bile omejene na zapise posameznih rastlinskih vrst. Po drugi strani pa je bila flora Nevesinjskega polja veliko bolje raziskana, s poudarkom na flori začasno poplavljenih travnikov in šotišč. Cilj naše študije je bil torej dopolniti poznavanje flore na obeh preučevanih območjih, pri čemer smo posebno pozornost namenili tistim ekosistemom, za katere je značilno največje vrstno bogastvo, pa tudi tistim, ki doslej še niso bili raziskani. Raziskovali smo floro na 62 različnih lokacijah: na 51 lokacijah v zgornji Neretvi ter na 11 lokacijah ob reki Zalomki in njeni okolici (Tab. S1). Skupaj smo zabeležili 933 taksonov; 897, od tega 125 mahov, smo našli na 51 nahajališčih v dolini zgornje Neretve, in 200, od tega 32 mahov, pa na 11 lokacijah v dolini reke Zalomke. Med registriranimi taksoni jih je 39 endemičnih na Balkanskem polotoku, 56 taksonov je uvrščenih na seznam ogroženih in redkih taksonov Bosne in Hercegovine, na rdeči seznam Federacije Bosne in Hercegovine, 95 taksonov pa je zavarovanih v Republiki Srbski. Poleg tega smo zabeležili tudi nekaj novih vrst za floro Bosne in Hercegovine. Med kritosemenkami so to *Barbarea intermedia*, *Lamium hybridum*, *Myosotis sicula* in *Poa ursina*, med mahovi pa *Fissidens gracilifolius*, *Grimmia dissimulata*, *Plagiomnium ellipticum*, *Schistidium robustum*, *Sphenolobus minutus*, *Tortella fasciculata* in *T. pseudofragilis*. Naša študija razkriva visoko naravovarstveno vrednost dolin zgornje Neretve in Zalomke, ki jih je treba zavarovati za prihodnje generacije. Poleg tega so potrebne nadaljnje sistematične raziskave flore Bosne in Hercegovine.

SAŽETAK

Između 1. i 6. juna 2023. godine proveli smo floristička istraživanja na više lokaliteta u dolini gornjeg toka rijeke Neretve, te, u manjem obimu, u dolini rijeke Zalomke u Nevesinjskom polju. Područje istraživanja građeno je uglavnom od pješčara i kalkarenita, što predstavlja dominantni supstrat na području doline gornjeg toka rijeke Neretve. Samo na rubnim dijelovima doline pješčare zamjenjuju krečnjaci, od kojih su uglavnom izgrađene okolne planine. Padine doline Neretve su pokrivene šumom hrastova na južnim i bukovim šumama na sjevernim ekspozicijama, djelimično isprekidanim uglavnom napuštenim zaseocima i pašnjacima. Vlažni ekosistemi razvijeni su jedino u glacijalnim depresijama. Aluvijalni nanosi zastupljeni su neposredno uz rijeku Neretvu, i na njima se razvijaju različite riparijske šume, šikare sive vrbe, otvorene zajednice na šljunčanim sprudovima i visoke zeleni na muljevitim polojima. Sa druge strane, rijeka Zalomka teče kroz raznovrsna područja sa specifičnim geološkim karakteristikama: od krečnjaka u gornjem toku do aluvijalnih nanosa u Nevesinjskom polju. Na južnim padinama oko rijeke razvijene su uglavnom termofilne hrastove šume u različitim degradacionim stadijumima, dok su na sjevernim padinama prisutne uglavnom bukove šume. Centralni dio Nevesinjskog polja razvijen je na jezerskim sedimentima i karakterišu ga različite močvarne i tresetne zajednice. Dosadašnja istraživanja flore gornjeg toka rijeke Neretve, od Uloga do izvorišta rijeke, nisu imala sistematski karakter i svodila su se na pojedinačna zapažanja biljnih vrsta. Sa druge strane, flora Nevesinjskog polja značajno je bolje istražena, sa akcentom na floru periodično plavljenih livada i tresetišta. Cilj ove studije je da se doprinese boljem poznavanju flore oba ispitivana područja, sa naročitom pažnjom na ekosisteme koji su po vrstama najraznovrsniji, kao i na one ekosisteme koji nisu ranije istraživani. Floru smo istraživali na 62 različita lokaliteta: 51 na području gornjeg toka rijeke Neretve, te 11 uz rijeku Zalomku i njenu bližu okolinu (Tab. S1). Zabilježili smo ukupno 993 taksona; 897 biljnih taksona, uključujući 125 briofita, su pronađeni u dolini gornjeg toka rijeke Neretve, dok je 200 taksona, uključujući 32 briofite, pronađeno u dolini rijeke Zalomke. Među zabilježenim taksonima 39 su endemi za Balkansko poluostrvo, 56 se nalazi na Listi ugroženih i rijetkih biljaka u Bosni i Hercegovini, 27 je na Crvenoj listi Federacije Bosne i Hercegovine, dok 95 uživa status zaštite u Republici Srpskoj. Takođe, zabilježeno je nekoliko vrsta koje se po prvi put registrovane za floru Bosne i Hercegovine. Među skrivenosjemenicama to su: *Barbarea intermedia*, *Lamium hybridum*, *Myosotis sicula* i *Poa ursina*, a među briofitama: *Fissidens gracilifolius*, *Grimmia dissimulata*, *Plagiomnium ellipticum*, *Schistidium robustum*, *Sphenolobus minutus*, *Tortella fasciculata* i *T. pseudofragilis*. Ovo istraživanje pokazuje da područje gornjeg toka rijeke Neretve i okoline rijeke Zalomke imaju visoku prirodnu vrijednost i trebaju biti predmet zaštite zbog budućih generacija. Dalja sistematska istraživanja flore Bosne i Hercegovine su neophodna.

ACKNOWLEDGEMENTS

The authors would like to thank the staff of the Centre for Environment and Save the Rivers for logistical support, Jan Kirschner for confirmation of the identification of *Taraxacum janchenii*, and Žan Lobnik Cimerman for identification of the selected liverwort specimens.

REFERENCES

Abadžić S. 1989. *Astragalo-Edraianthetum dalmatici* ass. nova na Vran-planini u Hercegovini. Glasnik Zemaljskog Muzeja Bosne Hercegovine u Sarajevu Prirordne Nauke Nova Serija. 28: 121-127.

Adamović L. 1889. Naknadno k flori južne Bosne i Hercegovine od dr viteza G. Becka. Na osnovu rezultata dvadesetdnevnog putovanja u ljetu 1888. Glasnik Zemaljskog Muzeja u Bosni i Hercegovini. 1(1): 44-50.

Alegro A, Šegota V. 2018. Rasprostranjenost *Plagiomnium ellipticum* (Brid.) T. J. Kop. u Hrvatskoj. In: Nikolić T. editor. Flora Croatica Database, Prirodoslovno - matematički fakultet, Sveučilište u Zagrebu [accessed on 23. 9. 2024]; http://hirc.botanic.hr/fcd/

Ascherson P, Kanitz A. 1877. Catalogus Cormophytorum et Anthophytorum Serbiae, Bosniae, Hercegovinae, Montis Scodri, Albaniae. Berolini et Claudiopoli.

Atherton I, Bosanquet S, Lawley M, editors. 2010. Mosses and Liverworts of Britain and Ireland. A field guide. British Bryological Society, UK. p. 342.

Beck-Mannagetta G. 194. Flora von Bosnien, der Herzegowina und des Sandžaks Noovipazar I. Teil. Wissenschaftliche Mitteilungen aus Bosnien und Hercegovina. 9: 407-518.

Beck-Mannagetta G. 1916. Flora Bosne, Hercegovine i novopazarskog Sandžaka II. (7.) dio Nastavak. Glasnik Zemaljskog Muzeja u Bosni i Hercegovini. 28(1): 41-168.

Beck-Mannagetta G. 1927. Flora Bosnae, Hercegovinae et regionis Novipazar III. Choripetalae (finis). Srpska Kraljevska Akademija Posebno Izdanje 63 Priroda Matice Spske. 15: 1-487.

Beck-Mannagetta G, Malý K, Bjelčić Ž. 1967. Flora Bosnae et Hercegovinae IV Sympetalae Pars 2. Zemaljski Muzej Bosne i Hercegovine u Sarajevu Prirodne Nauke Posebna Izdanja. 2: 5-111.

Bjelčić Ž. 1965. Flora planine Jahorine. Glasnik Zemaljskog Muzeja Bosne Hercegovine u Sarajevu Prirordne Nauke Nova Serija. 3-4: 109-158.

Blau O. 1877. Reisen in Bosnien und der Hertzegowina. Topographische Und Pflanzengeographische Aufzeichnungen. Berlin: Verlag von Dietrich Veimer.

Braun-Blanquet J. 1964. Pflanzensoziologie, Grundzüge der Vegetationskunde. 3rd ed. Wien: Springer Verlag.

Casas C, Brugués M, Cros RM, Sérgio C, Infante M. 2009. Handbook of liverworts and hornworts of the Iberian Peninsula and the Balearic Island: illustrated keys to genera and species. Institut d'Estudis Catalans. Secció de Ciències Biològiques, Barcelona.

Casas C, Brugués M, Cros RM, Sérgio C. 206. Handbook of Mosses of the Iberian Peninsula and the Balearic islands. Illustrated Keys to the Genera and Species. Institut d'Estudis Catalans, Barcelona.

Chytrý M, Řezníčková M, Novotný P, Holubová D, Preislerová Z, Attorre F, Biurrun I, Blažek P, Bonari G, Borovyk D, et al. 2024. FloraVeg.EU – an online database of European vegetation, habitats and flora. Applied Vegetation Science 27: e12798. https://doi.org/10.1111/avsc.12798

Đug S, Muratović E, Drešković N, Boškailo A, Dudević S. 2013. Crvena lista flore Federacije Bosne i Hercegovine. Sarajevo, BA: EU »Greenway«. https://www.fmoit.gov.ba/upload/file/okolis/Crvena%20lista%20Flore%20FBiH.pdf

Fischer MA, Oswald K, Adler W. 2008. Exkursionsflora für Österreich, Liechtenstein und Südtirol. Biologiezentrum der Oberösterreichischen Landesmuseen, Linz.

Formanek E. 1890. Zweiter Beitrag zur Flora von Bosnien und der Hercegovina. Österreische Botanische Zeitung. 40(2): 73-16.

Frey W, Frahm J-P, Fischer E, Lobin W. 206. The Liverworts, Mosses and Ferns of Europe. Harley Books, Essex.

Grau J, Merxmüller H. 1972. 29. *Myosotis* L. In: Tutin TG et al. (eds.) Flora Europaea, Vol. 3, Cambridge University Press. p. 111-117.

Hodgetts N, Lockhart N. 2020. Checklist and country status of European bryophytes – update 2020. Irish Wildlife Manuals 123. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland.

Hodgetts NG, Söderström L, Blockeel TL, Caspari S, Ignatov MS, Konstantinova NA, Lockhart N, Papp B, Schröck C, Sim-Sim M, et al. 2020. An annotated checklist of bryophytes of Europe, Macaronesia and Cyprus. Journal of Bryology. 42(1): 1-116. https://doi.org/10.1080/03736687.2019.1694329

Hodgetts N, Cálix M, Englefield E, Fettes N, García Criado M, Patin L, Nieto A, Bergamini A, Bisang I, Baisheva E, et al. 2019. A miniature world in decline: European Red List of Mosses, Liverworts and Hornworts. IUCN, Brussels.

Kirschner J, Štěpánek J. 1985. »*Taraxacum hoppeanum*« and its allies (Studies in *Taraxacum* 4.). Preslia. 57: 111-134.

Köckinger H, Hedenäs L. 2017. A farewell to *Tortella bambergeri* (Pottiaceae) as understood over the last decades. Journal of Bryology. 39(3): 1-13. https://doi.org/10.1080/03736687.2017.1307313

Köckinger H, Hedenäs L. 2023. The supposedly well-known carbonate indicator *Tortella tortuosa* (Pottiaceae, Bryophyta) split into eight species in Europe. Lindbergia. 2023: e2493.

Koljanin D, Milanović Đ, Stupar V. 2021. New data on the distribution and threat status of three rare spring geophytes from Bosnia and Herzegovina. Phytologia Balcanica. 27(1): 107-114.

Kuzmanović N, Lakušić D, Frajman B, Alegro A, Schönswetter P. 2017. Phylogenetic relationships in Seslerieae (Poaceae) including resurrection of *Psilathera* and *Sesleriella*, two monotypic genera endemic to the Alps. Taxon. 66(6): 1349-1370. https://doi.org/10.12705/666.5

Lakušić R, Muratspahić-Pavlović D, Redžić S. 1982. Vegetacija ekosistema kraških polja Hercegovine. Godišnjak Biološkog Instituta Univerziteta u Sarajevu. 35: 81-92.

Lüth M. 2019. Mosses of Europe. A Photographic Flora, set of 3 volumes. Freiburg, Germany.

Malý K. 1928. Prilozi za floru Bosne i Hercegovine X. Glasnik Zemaljskog Muzeja u Bosni i Hercegovini. 40(1): 107-166.

Malý K. 1933. Materialien zu G. v. Beck's Flora des ehemaligen Bosnien-Hercegovina. Glasnik Zemaljskog Muzeja u Bosni i Hercegovini. 45(1): 71-141.

Maslo S. 2014. The urban flora of the city of Mostar (Bosnia and Herzegovina). Natura Croatica. 23(1): 101-145.

Maslo S, Abadžić S. 2015. Vascular flora of the town of Blagaj (South Bosnia and Herzegovina). Natura Croatica. 24(1): 59-92.

Maslo S, Boškailo A. 2018. Vascular flora of the old town of Počitelj and its surrounding area (South Bosnia and Herzegovina). Glasnik Zemaljskog Muzeja u Sarajevu Prirodne Nauke Nova Serija. 37: 19-45.

Milanović Đ. 2014. Prilog poznavanju rasprostranjenja nekih rijetkih vrsta iz roda *Carex* L. u Bosni i Hercegovini. Glasnik Šumarskog Fakulteta Univerziteta u Banjoj Luci. 21: 5-23.

Milanović Đ. 2022. Biljne zajednice sa Pančićevom omorikom (*Picea omorika* (Pančić) Prukyne) u Bosni i Hercegovini [Master Thessis]. Univerzitet u Banjoj Luci, Šumarski fakultet, Banja Luka.

Milanović Đ, Stupar V, Brujić J. 2013. Novelties for vascular flora of Bosnia and Herzegovina. Botanica Serbica. 37(2): 173-181.

Mojićević M, Tomić B. 1981. Osnovna geološka karta SFRJ, list Kalinovik.

Nikolić T. 2019. Flora Croatica - Vaskularna flora Republike Hrvatske. Zagreb, HR: Alfa d.d.

Nyholm E. 1998. Illustrated Flora of Nordic Mosses, fasc. 4. Nord. Bryol. Soc. Coenhaged and Lund.

Ottley T, Blockeel T. 2019. *Tortella fasciculata* and *T. pseudofragilis* in Britain and Ireland. Field Bryology. 121: 19-22.

Pantocsek J. 1874. Adnotationes ad floram et faunam Hercegovinae, Crnagorae et Dalmatiae. Posonii: C. F. Wigand.

Paton AJ. 1999. The liverwort flora of the British Isles. Harley Books, Colchester.

Perić R, Škondrić S, Knežević J. 2018. First confirmed record of *Carex limosa* L. (Cyperaceae) and community *Caricetum limosae* Br.–Bl. for Nevesinjsko polje (Bosnia & Herzegovina). Ecologica Montenegrina. 19: 152-158. https://doi.org/10.37828/em.2018.19.15

Pichler A. 1890. Slike iz mostarske flore. Mostar: Velika gimnazija Peti godišnji izvještaj Velike gimnazije u Mostaru.

POWO. 2024. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew; [accessed 12. 8. 2024]. https://powo.science.kew.org/

Rat M. 2019. *Ornithogalum* Sect. Heliocharmos Baker (Hyacinthaceae, Ornithogaloideae) na Balkanskom poluostrvu i Panonskoj niziji: revizija nomenklature, taksonomije i rasprostranjenja [doctoral thesis]. [Novi Sad, RS]: Univerzitet u Novom Sadu.

Redžić S, Barudanović S. 2010. The patterns of diversity of forest vegetation of the Crvanj Mountain in the Herzegovina (west Balkan Peninsula). Šumarski List. 134(5–6): 261-274.

Redžić S, Lakušić R, Muratspahić D, Barudanović S. 1996. Fitocenoze subalpinskog i alpinskog pojasa planine Crvanj u Hercegovini. Glasnik Zemaljskog Muzeja Bosne Hercegovine Prirodne Nauke Nova Serija. 31: 285-310.

Redžić S, Trakić S, Barudanović S. 2013. Patterns of vegetation diversity of grasslands and pastures – Crvanj Mt. (Herzegovina, Western Balkan). Sci Res Essays. 8(39): 1944-1965.

Ritter-Studnička H. 1952. Prilozi za floru Bosne i Hercegovine. Godišnjak Biološkog Instituta u Sarajevu. 5(1–2): 349-380.

Ritter-Studnička H. 1953. Prilozi za floru Bosne i Hercegovine II. Godišnjak Biološkog Instituta u Sarajevu. 6(1–2): 21-37.

Ritter-Studnička H. 1954. Flora i vegetacija livada kraških polja Bosne i Hercegovine. Godišnjak Biološkog Instituta u Sarajevu. 7(1–2): 25-109.

Ritter-Studnička H. 1955. O rasprostiranju nekih manje poznatih biljaka u kraškim poljima Bosne i Hercegovine. Radovi Naučnog Društva BiH. 1: 193-23.

Ritter-Studnička H. 1956. Prvo nalazište mesojedne biljke »*Drosera rotundifolia* L.« u NR Bosni i Hercegovini. Naše Starine. 3: 307-309.

Ritter-Studnička H. 1970. Die Flora der Serpentinvorkommen in Bosnien. Schweizerbart Science Publishers, Stuttgart.

Sagorski E. 191. Beitrag zur Flora der Herzegovina. Mittheilungen des Thüringischen Botanischen Vereins. 16: 33-50.

Sagorski E. 1912a. Neue Beiträge zur illyrischen Flora. Allgemeine Botanische Zeitschrift für Systematik, Floristik, Pflanzengeographie etc. 18(1–3): 10-18.

Sagorski E. 1912b. Neue Beiträge zur illyrischen Flora. Allgemeine Botanische Zeitschrift für Systematik, Floristik, Pflanzengeographie etc. 18(4–6): 48-54.

Sagorski E. 1914a. Vierter Beitrag zur illyrischen Flora. Allgemeine Botanische Zeitschrift für Systematik, Floristik, Pflanzengeographie etc. 20(3): 33-36.

Sagorski E. 1914b. Vierter Beitrag zur illyrischen Flora. Allgemeine Botanische Zeitschrift für Systematik, Floristik, Pflanzengeographie etc. 20(5): 65-74.

Schumacker R, Váňa J. 205. Identification keys to the liverworts and hornworts of Europe and Macaronesia (distribution and status). 2nd ed. Sorus, Poznań, Poland.

Šilić Č. 1996. Spisak biljnih vrsta (*Pteridophyta* i *Spermatophyta*) za Crvenu knjigu Bosne i Hercegovine. Glasnik Zemaljskog Muzeja Bosne Hercegovine Prirodne Nauke Nova Serija. 31: 323-367.

Speta F. 1990. *Ornithogalum gussonei* Ten., *O. collinum* Guss. und *O. exscapum* Ten., drei häufig verkannte, aus Italien beschriebene Arten (Hyacinthaceae). Phyton Austria. 30(1):97–171.

Struschka H. 1880. Die Umgebung Mostars (Eine geographisch-naturwissenschaftliche Studie). Programm K K Staats-Gymn Kremsier Veroffentlicht Am Schlusse Schuljahres. 187980: 3-43.

Tutin TG, Heywood VH, Burges NA, Valentine DH, Walters SM, Webb DA. 201. Flora Europaea on CD-ROM. Cambridge, UK: Cambridge University Press.

Uredba o strogo zaštićenim i zaštićenim divljim vrstama. 2020. Služ Glas Repub Srp. 65/20:2–33.

Vandas K. 1889. Beiträge zur Kenntniss der Flora von Süd-Hercegovina. Österreische Botanische Zeitung. 39(7): 266-269.

Vandas K. 1909. Reliquiae Formanekianae. Eunumeratio critica plantarum vascularium, quas itineribus in Haemo peninsula et Asia Minore (Bithynia) factis collegit dr Ed. Formanek, professor Gymnasii Brunensis Bohemici. Brunae: Typis Jos. Jelinek.

[WFO] World Flora Online. 2024 *Myosotis sicula* Guss; [accessed on 19. 9. 2024]. http://www.worldfloraonline.org/taxon/wfo-0000368533

SUPPLEMENTARY MATERIAL

Table S1. Localities in the Upper Neretva River valley and the Zalomka River valley with surroundings (Bosnia and Herzegovina), where we studied vascular plants and bryophytes in June 2023. We produced either species lists or phytosociological relevés, of which only the species lists are presented in the article. The coordinates and elevations correspond mostly to the centres of the study plots.

Tabela S1. Nahajališča v dolini zgornje Neretve in dolini reke Zalomke z okolico (Bosna in Hercegovina), kjer smo junija 2023 preučevali vaskularne rastline in mahove. Izdelali smo bodisi sezname vrst bodisi popise združb, od katerih so v članku predstavljeni le seznami vrst. Koordinate in nadmorske višine večinoma ustrezajo središčem preučevanih ploskev.

Tabela S1. Lokaliteti u dolini gornjeg toka rijeke Neretve i doline rijeke Zalomke sa okolinom (Bosna i Hercegovina), gdje su proučavane vaskularne biljke i mahovine u junu 2023. godine. Napravili smo ili liste vrsta ili fitocenološke snimke, od kojih su samo liste vrsta predstavljene u članku. Koordinate i nadmorske visine uglavnom odgovaraju centrima proučavanih ploha.

No	Locality	Latitude	Longitude	Habitat	Date	Source	Elevation
			Upper Neretva River valley				
N1	Carina near Ulog (Površ)	43.420206	18.306599	Meso-thermophilous *Quercus cerris* forest	5. 6. 2023	relevé	725
N2	Ulog - settlement (Površ)	43.416709	18.309037	Roadside chanal	5. 6. 2023	floristic list	690
N3	Ulog - under mosque (Zelengora)	43.413317	18.314367	*Salix eleagnos* riparian shrub	1. 6. 2023	relevé	645
N4	Ulog - under Pearnik (Zelengora)	43.41457	18.31484	*Salix eleagnos* riparian forest	1. 6. 2023	relevé	645
N5	Under Pearnik 1 (Zelengora)	43.410822	18.315616	*Salix eleagnos-Alnus rohlenae* riparian forest	1. 6. 2023	relevé	647
N6	Under Pearnik 2 (Zelengora)	43.410804	18.316579	Mesophyllous *Quercus cerris* forest	1. 6. 2023	relevé	655
N7	Vidikovac above Nedavić (Zelengora)	43.448664	18.316856	Limestone cliffs and outcrops	4. 6. 2023	floristic list	810
N8	Pearnik (Zelengora)	43.410584	18.319001	Road margin	5. 6. 2023	floristic list	675
N9	Confluence of Paleški potok 1 (Zelengora)	43.405176	18.323485	*Alnus rohlenae* riparian forest	1. 6. 2023	relevé	650
N10	Pearnik-Kovačići (Zelengora)	43.41389	18.324169	*Quercus cerris* forest	4. 6. 2023	floristic list	880
N11	Ćetović - under Grbovac (Zelengora)	43.402047	18.324334	*Carpinus orientalis* thermophilous shrub	2. 6. 2023	relevé	660
N12	Ćetović - under Zli do (Zelengora)	43.397731	18.328138	*Salix alba* riparian forest	2. 6. 2023	relevé	665
N13	Kovačići (Zelengora)	43.41639	18.33056	*Quercus cerris* forest	4. 6. 2023	floristic list	1000
N14	Jablanići (Zelengora)	43.400807	18.33296	Meso-thermophilous *Quercus cerris* forest	2. 6. 2023	relevé	820
N15	Kunište above Jasen (Zelengora)	43.419136	18.33323	*Quercus cerris* forest	4. 6. 2023	floristic list	1160
N16	Ćetović - along Neretva (Zelengora)	43.398082	18.33325	*Salix alba* riparian forest	2. 6. 2023	relevé	670

No	Locality	Latitude	Longitude	Habitat	Date	Source	Elevation
N17	Ćetović - under Jablanići (Zelengora)	43.399238	18.333523	Shaded limestone rocks in forest	2. 6. 2023	relevé	760
N18	Kunište-Lisičjak (Zelengora)	43.418267	18.335783	Open rocky grassland	4. 6. 2023	floristic list	1190
N19	Lisičjak (Zelengora)	43.417176	18.335891	Closed grassland	4. 6. 2023	floristic list	1160
N20	Ćetović - confluence of Grabovik (Zelengora)	43.397033	18.336424	*Salix fragilis* riparian forest	2. 6. 2023	relevé	675
N21	Under Tuhobić - along Neretva (Površ)	43.379448	18.354495	*Salix alba* riparian forest	4. 6. 2023	relevé	685
N22	Under Cerova - along Neretva (Površ)	43.378151	18.357191	*Alnus rohlenae* riparian forest	4. 6. 2023	relevé	688
N23	Under Kovačuša - along Neretva (Površ)	43.376479	18.357853	*Alnus rohlenae* riparian forest	4. 6. 2023	relevé	688
N24	Under Rosulja - along Neretva (Površ)	43.376353	18.359123	*Alnus rohlenae* riparian forest	4. 6. 2023	relevé	690
N25	Međeđak stream under Zli do (Površ)	43.34256	18.35984	Shaded and wet rocks along the stream	6. 6. 2023	floristic list	1030
N26	Grčko groblje 1 (Površ)	43.356025	18.364488	Mesophyllous *Quercus cerris* forest	3. 6. 2023	relevé	1090
N27	Grčko groblje 2 (Površ)	43.355737	18.36468	Meadow + thermophilous *Fraxinus ornus* forest	3. 6. 2023	floristic list	1100
N28	Grčko groblje - Kovačević (Površ)	43.35669	18.366616	Termophilous *Carpinus orientalis-Fraxinus ornus* shrub	3. 6. 2023	relevé + floristic list	1000
N29	Kovačević-Borovića gaj 1 (Površ)	43.360644	18.368866	Forest clearing + *Quercus petraea-Carpinus betulus* mesophilous forest	3. 6. 2023	floristic list	830
N30	Kovačević-Borovića gaj 1 (Površ)	43.362456	18.37001	*Carpinus betulus* mesophilous forest	3. 6. 2023	floristic list	770
N31	Confluence od Tuniski potok (Zelengora)	43.36521	18.370254	*Salix purpurea-Salix eleagnos* riparian shrub	3. 6. 2023	floristic list	705
N32	Under Kovačević 1 (Površ)	43.36478	18.370636	*Carpinus betulus* mesophilous forest	3. 6. 2023	floristic list	720
N33	Under Kovačević 2 (Površ)	43.364001	18.371257	*Carpinus betulus* mesophilous forest	3. 6. 2023	relevé	710
N34	Under Tomišlja (Zelengora)	43.355174	18.385265	*Quercus cerris* forest	5. 6. 2023	floristic list	810
N35	Tomišlja (Zelengora)	43.358538	18.386474	Meadow and *Quercus cerris* forest	5. 6. 2023	floristic list	850
N36	Above Ruda glava (Zelengora)	43.374803	18.393778	*Fagus sylvatica* forest	5. 6. 2023	floristic list	1320
N37	Dubrava above Tomišlja (Zelengora)	43.368939	18.395032	Forest clearing	5. 6. 2023	floristic list	1180
N38	Babin do (Zelengora)	43.417882	18.397312	Mountain slope	6. 6. 2023	floristic list	1380
N39	Čengića bara (Zelengora)	43.420642	18.397514	Meadows with *Sesleria uliginosa*	6. 6. 2023	floristic list	1350
N40	Above Dubrava (Zelengora)	43.373956	18.401992	Mountain meadow	5. 6. 2023	floristic list	1320
N41	Dubrava-Crvene stijene (Zelengora)	43.377618	18.402595	Mountain meadow	5. 6. 2023	floristic list	1430
N42	Babin do - cote 1536 (Zelengora)	43.416316	18.404027	Mountain slope	6. 6. 2023	floristic list	1535
N43	Under Crvene stijene (Zelengora)	43.380966	18.40589	Mountain meadow	5. 6. 2023	floristic list	1500
N44	Crvene stijene (Zelengora)	43.383736	18.41128	Mountain meadow	5. 6. 2023	floristic list	1770
N45	Marčinkovo vrelo (Zelengora)	43.41906	18.412902	Mountain meadow and mountain slope	6. 6. 2023	floristic list	1360
N46	Kladopoljsko jezero (Zelengora)	43.417765	18.422724	Glacial lake and its surroundings	6. 6. 2023	floristic list	1385
N47	Čašica jama (Zelengora)	43.441546	18.326585	Cave entrance and in the cave	5.6. 2023	floristic list	1070
N48	Jama Golubnjača (Zelengora)	43.431611	18.332472	Cave entrance and in the cave	5.6. 2023	floristic list	1130
N49	The road by Tuniski potok (Zelengora)	43.367611	18.372056	On the gravel road	3.6. 2023	floristic list	720
N50	Ulog (Površ)	43.417361	18.311806	Orchard west from the bridge over Neretva	3.6. 2023	floristic list	645
N51	Nedavić (Zelengora)	43.460237	18.321882	In vegetation on the gravelly river bed	3.6. 2023	floristic list	600

No	Locality	Latitude	Longitude	Habitat	Date	Source	Elevation
				Zalomka River valley and surroundings			
Z1	Selište near Nevesinje (Nevesinjsko polje)	43.268458	18.10828	Neutrophilous *Quercus cerris* forest	5. 6. 2023	relevé	900
Z2	Vranjača (Nevesinjsko polje)	43.185801	18.115788	Cave entrance	5. 6. 2023	floristic list	810
Z3	Srednja voda (Nevesinjsko polje)	43.301212	18.117714	Mires	5. 6. 2023	floristic list	845
Z4	Vranjača-Ponor (Nevesinjsko polje)	43.18637	18.117906	Path to cave entrance	5. 6. 2023	floristic list	820
Z5	Jezerine near Batkovići (Nevesinjsko polje)	43.267353	18.159486	Thermo-acidophilous *Quercus cerris* forest	3. 6. 2023	relevé	860
Z6	Biogradski most (Nevesinjsko polje)	43.18542	18.163859	Willow shrub on the gravelly stream bed	4. 6. 2023	relevé	817
Z7	Rakova gomila (Trusina)	43.153647	18.173266	Neutrophilous F*agus sylvatica* forest	4. 6. 2023	relevé	920
Z8	Upsteam of Gvozdeni most (Nevesinjsko polje)	43.201033	18.205837	Willow shrub on the stony stream bed (river isle)	4. 6. 2023	relevé	840
Z9	Under Granice - along Zalomka (Crvanj)	43.285879	18.241329	Willow shrub on the gravelly stream bank	2. 6. 2023	relevé	865
Z10	Granice (Crvanj)	43.286823	18.24153	Calciphilous *Quercus cerris* forest	2. 6. 2023	relevé	895
Z11	Kunjak - along Zalomka (Površ)	43.25984	18.356402	Willow shrub on the gravelly stream bed	3. 6. 2023	relevé	930

Table S2. List of vascular plant species and bryophytes recorded in the Neretva and Zalomka River valleys (Bosnia and Herzegovina) in June 2023. Locality numbers correspond to the Appendix Table 1. Superscripts indicate plants (1) endemic to the Balkan Peninsula, (2) endangered in BiH according to Šilić (1996), (3) endangered in the Federation BiH according to Đug et al. (2013), and (4) protected in the Republic of Srpska.

Tabela S2. Seznam vrst vaskularnih rastlin in mahov, zabeleženih v dolinah rek Neretve in Zalomke (Bosna in Hercegovina) junija 2023. Številke nahajališč ustrezajo preglednici 1 v Dodatku. S številkami v nadpisih so označene vrste, ki so (1) endemične za Balkanski polotok, (2) ogrožene v BiH po Šiliću (1996), (3) ogrožene v Federaciji BiH po Đugu in sod. (2013) in (4) zavarovane v Republiki Srbski.

Tabela S2. Spisak vrsta vaskularnih biljaka i mahovina zabilježenih u dolinama rijeka Neretve i Zalomke (Bosna i Hercegovina) u junu 2023. godine. Brojevi lokaliteta odgovaraju Tabeli 1. Brojevi u natpisima označavaju vrste koje su (1) endemične za Balkansko poluostrvo, (2) ugrožene u Bosni i Hercegovini prema Šiliću (1996), (3) ugrožene u Federaciji Bosne i Hercegovine prema Đugu i sar. (2013) i (4) zaštićeni u Republici Srpskoj.

No	Species	Localities
	Neretva River valley	
	Bryoflora	
1	*Abietinella abietina* (Hedw.) M. Fleisch.	N7, N8, N19, N27, N38
2	*Alleniella besseri* (Lobarz.) S. Olsson, Enroth & D. Quandt	N9, N18, N51
3	*Alleniella complanata* (Hedw.) S. Olsson, Enroth & D. Quandt	N9, N11, N16, N20, N25, N28, N31, N48, N49, N51
4	*Amblystegium serpens* (Hedw.) Schimp.	N12, N16, N20, N48
5	*Anomodon viticulosus* (Hedw.) Hook. & Taylor	N12, N16, N17, N20, N25, N28, N31, N51
6	*Antitrichia curtipendula* (Hedw.) Brid.	N25, N31
7	*Aulacomnium palustre* (Hedw.) Schwägr.	N39
8	*Barbilophozia barbata* (Schreb.) Loeske	N38, N39
9	*Brachytheciastrum velutinum* (Hedw.) Ignatov & Huttunen	N28
10	*Brachythecium glareosum* (Spruce) Schimp.	N38
11	*Brachythecium mildeanum* (Schimp.) Schimp.	N39
12	*Brachythecium rutabulum* (Hedw.) Schimp.	N12, N16, N20, N25, N31, N48
13	*Brachythecium salebrosum* (F. Weber & D. Mohr) Schimp.	N31
14	*Brachythecium tommasinii* (Boulay) Ignatov & Huttunen	N25
15	*Bryoerythrophyllum recurvirostrum* (Hedw.) P. C. Chen	N12
16	*Bryum elegans* Brid.	N18
17	*Callicladium imponens* (Hedw.) Hedenäs, Schlesak & D. Quandt	N7
18	*Calliergonella cuspidata* (Hedw.) Loeske	N8, N20, N39, N48
19	*Campyliadelphus chrysophyllus* (Brid.) Kanda	N8, N28

No	Species	Localities
20	*Campylium protensum* (Brid.) Kindb.	N31
21	*Campylophyllopsis calcarea* (Crundw. & Nyholm) Ochyra	N31, N48
22	*Cephaloziella hampeana* (Nees) Loeske	N39
23	*Chiloscyphus pallescens* (Hoffm.) Dumort.	N31
24	*Cirriphyllum crassinervium* (Wilson) Loeske & M. Fleisch.	N7
25	*Climacium dendroides* (Hedw.) F. Weber & D. Mohr	N39, N50
26	*Ctenidium molluscum* (Hedw.) Mitt.	N7, N9, N11, N25, N28, N31, N38, N48, N49, N51
27	*Dicranum scoparium* Hedw.	N38
28	*Didymodon ferrugineus* (Besch.) M. O. Hill	N20
29	*Drepanocladus aduncus* (Hedw.) Warnst.	N39
30	*Encalypta streptocarpa* Hedw.	N7, N18
31	*Eurhynchiastrum pulchellum* (Hedw.) Ignatov & Huttunen (?)	N8
32	*Eurhynchium striatum* (Hedw.) Schimp.	N51
33	*Exsertotheca crispa* (Hedw.) S. Olsson, Enroth & D. Quandt	N11
34	*Fissidens bryoides* Hedw.	N38
35	*Fissidens dubius* P. Beauv.	N18
36	*Fissidens osmundoides* Hedw.	N18
37	*Fissidens taxifolius* Hedw.	N31, N48
38	*Flexitrichum flexicaule* (Schwägr.) Ignatov & Fedosov	N7, N19, N27
39	*Flexitrichum gracile* (Mitt.) Ignatov & Fedosov	N25
40	*Frullania dilatata* (L.) Dumort.	N9, N11, N12, N14, N16, N20, N28, N48, N49
41	*Frullania tamarisci* (L.) Dumort.	N11
42	*Grimmia dissimulata* E. Maier	N7, N27, N38
43	*Grimmia pulvinata* (Hedw.) Sm.	N19
44	*Homalia trichomanoides* (Hedw.) Brid.	N25
45	*Homalothecium lutescens* (Hedw.) H. Rob.	N7, N8, N9, N11, N17, N19, N25, N28, N38
46	*Homalothecium philippeanum* (Spruce) Schimp.	N12
47	*Homalothecium sericeum* (Hedwig) Schimp.	N7, N9, N11, N14, N16, N17, N19, N25, N27, N28, N47, N48, N49, N51
48	*Homomallium incurvatum* (Brid.) Loeske	N14
49	*Hygroamblystegium humile* (P. Beauv.) Vanderp., Goffinet & Hedenäs	N16
50	*Hygroamblystegium varium* (Hedw.) Mönk.	N12, N16
51	*Hylocomiadelphus triquetrus* (Hedw.) Ochyra & Stebel	N38
52	*Hypnum cupressiforme* Hedw.	N28
53	*Hypnum cupressiforme* var. *cupressiforme* Hedw.	N7, N9, N11, N14, N17, N31, N48, N49, N51
54	*Hypnum cupressiforme* var. *lacunosum* Brid.	N19, N27, N28, N38
55	*Hypnum vaucheri* Lesq.	N19
56	*Isothecium alopecuroides* (Dubois) Isov.	N16, N49
57	*Kindbergia praelonga* (Hedw.) Ochyra	N47
58	*Lejeunea cavifolia* (Ehrh.) Lindb.	N9, N11, N31, N49, N51
59	*Lescuraea incurvata* (Hedw.) E. Lawton	N18
60	*Leskea polycarpa* Hedw.	N20
61	*Leucodon sciuroides* (Hedw.) Schwägr.	N9, N11, N14, N16, N17, N20, N25, N28, N31, N49, N51
62	*Lewinskya affinis* (Brid.) F. Lara, Garilleti & Goffinet	N12, N16
63	*Lewinskya speciosa* (Nees) F. Lara, Garilleti & Goffinet	N20

No	Species	Localities
64	*Lewinskya striata* (Hedw.) F. Lara, Garilleti & Goffinet	N11, N28, N48
65	*Lophocolea bidentata* (L.) Dumort.	N31
66	*Lophocolea heterophylla* (Schrad.) Dumort.	N9
67	*Marchantia quadrata* Scop.	N38
68	*Metzgeria conjugata* Lindb.	N51
69	*Metzgeria furcata* (L.) Corda	N49
70	*Mnium marginatum* (Dicks.) P. Beauv.	N9, N25
71	*Mnium stellare* Hedw.	N25, N31, N38
72	*Orthotrichum cupulatum* Brid.	N18, N38
73	*Orthotrichum pallens* Brid.	N49
74	*Orthotrichum pumilum* Schimp.	N28
75	*Orthotrichum stramineum* Brid.	N11
76	*Oxyrrhynchium hians* (Hedw.) Loeske	N11, N12, N16, N31, N47, N48
77	*Palustriella commutata* (Hedw.) Ochyra	N39
78	*Philonotis fontana* (Hedw.) Brid.	N39
79	*Philonotis tomentella* Molendo	N39
80	*Plagiochila porelloides* (Nees) Lindenb.	N7, N9, N11, N25, N28, N31, N47, N49, N51
81	*Plagiomnium cuspidatum* (Hedw.) T. J. Kop.	N12
82	*Plagiomnium elatum* (Brusch & Schimp.) T. J. Kop.	N31, N39
83	*Plagiomnium ellipticum* (Brid.) T. J. Kop.	N20
84	*Plagiomnium rostratum* (Schrad.) T. J. Kop.	N12, N16, N25, N31
85	*Plagiomnium undulatum* (Hedw.) T. J. Kop.	N12, N20, N25, N31, N48, N49
86	*Plasteurhynchium meridionale* (Schimp.) M. Fleisch.	N47
87	*Plasteurhynchium striatulum* (Spruce) M. Fleisch.	N47, N48
88	*Platygyrium repens* (Brid.) Schimp.	N28
89	*Polytrichum juniperinum* Hedw.	N7, N19, N39
90	*Porella platyphylla* (L.) Pfeiff.	N31
91	*Pseudanomodon attenuatus* (Hedw.) Ignatov & Fedosov	N9, N11, N12, N16, N17, N20, N25, N31, N48, N49, N51
92	*Pseudoamblystegium subtile* (Hedw.) Vanderp. & Hedenäs	N11
93	*Pseudoleskeella catenulata* (Schrad.) Kindb.	N9, N18
94	*Pseudoleskeella nervosa* (Brid.) Nyholm	N25
95	*Pseudoscleropodium purum* (Hedw.) M. Fleisch.	N9, N11
96	*Pterigynandrum filiforme* Hedw.	N14, N25, N51
97	*Ptychostomum capillare* (Hedw.) Holyoak & N. Pedersen	N49
98	*Ptychostomum capillare* agg.	N19
99	*Ptychostomum compactum* Hornsch.	N38
100	*Ptychostomum pseudotriquetrum* (Hedw.) Holyoak & N. Pedersen	N39, N48
101	*Pulvigera lyellii* (Hook. & Taylor) Plášek, Sawicki & Ochyra	N14, N16, N20, N48
102	*Racomitrium canescens* (Hedw.) Brid.	N38
103	*Racomitrium ericoides* (Brid.) Brid.	N7, N19, N27
104	*Radula complanata* (L.) Dumort.	N9, N12, N16, N25, N28, N49
105	*Reboulia hemisphaerica* (L.) Raddi	N7, N38
106	*Rhizomnium punctatum* (Hedw.) T. J. Kop.	N12
107	*Rhynchostegiella litorea* (De Not.) Limpr.	N39
108	*Rhynchostegium murale* (Hedwig) Schimp.	N25

No	Species	Localities
109	*Rhytidiadelphus squarrosus* (Hedw.) Warnst.	N38
110	*Rhytidium rugosum* (Hedw.) Kindb.	N38, N39
111	*Scapania aspera* M. Bernet & Bernet	N25
112	*Schistidium apocarpum* (Hedw.) Bruch & Schimp.	N27
113	*Schistidium confertum* (Funck) Bruch & Schimp.	N11, N25, N48
114	*Schistidium elegantulum* H. H. Blom	N27
115	*Schistidium robustum* (Nees & Hornsch.) H. H. Blom	N28
116	*Sciuro-hypnum starkei* (Brid.) Ignatov & Huttunen	N9
117	*Syntrichia ruraliformis (Besch.) Mans.*	N19
118	*Syntrichia ruralis* (Hedw.) F. Weber & D. Mohr	N14, N17, N18, N27, N50
119	*Thamnobryum alopecurum* (Hedw.) Gangulee	N25, N47, N48
120	*Thuidium assimile* (Mitt.) A. Jaeger	N7, N11,
121	*Tortella fasciculata* (Culm.) Culm.	N27, N28
122	*Tortella inclinata* (R. Hedw.) Limpr.	N19
123	*Tortella pseudofragilis* (Thér.) Köckinger & Hedenäs	N25
124	*Tortella tortuosa* (Hedw.) Limpr. s.lat	N7, N9, N17, N19, N27, N28, N31, N38, N47
125	*Tortula subulata* Hedw.	N11
126	*Ulota crispa* (Hedw.) Brid.	N9, N20, N48
127	*Zygodon viridissimus* (Dicks.) Brid.	N49
	Vascular flora	
128	*Abies alba* Mill.	N32
129	*Acer campestre* L.	N1, N4-N6, N9, N11-N14, N16, N19-N24, N26, N29, N31-N34
130	*Acer monspessulanum* L.	N18, N28
131	*Acer platanoides* L.	N9, N21, N23, N26, N30, N36
132	*Acer pseudoplatanus* L.	N3, N5, N9, N12, N20-N24, N29, N31, N33, N37, N38
133	*Achillea millefolium* L. subsp. *collina* (Wirtg.) Oborny	N19, N27, N39
134	*Achillea millefolium* L. subsp. *millefolium*	N26, N27, N31, N34
135	*Actaea spicata* L.	N23, N42
136	*Adoxa moschatellina* L.	N30
137	*Aegonychon purpurocaeruleum* (L.) Holub	N11, N13, N28, N31, N32
138	*Aegopodium podagraria* L.	N4, N5, N10, N16, N21-N24, N29, N31-N33, N38, N43
139	*Aethionema saxatile* (L.) W. T. Aiton	N18, N43
140	*Aethusa cynapium* L.	N31
141	*Agrimonia eupatoria* L.	N4, N9, N13, N19, N27, N34
142	*Agrostis capillaris L.*	N39
143	*Agrostis stolonifera* L.	N34, N46
144	*Ajuga genevensis* L.	N27, N35, N46
145	*Ajuga reptans* L.	N3-N6, N10, N12, N13, N16, N21-N24, N29, N31, N32, N34
146	*Alchemilla glaucescens* Wallr.	N38, N43
147	*Alchemilla xanthochlora* Rothm.	N39, N41
148	*Alisma lanceolatum* With.	N39
149	*Alliaria petiolata* (M.Bieb.) Cavara & Grande	N13, N20, N31, N35
150	*Allium carinatum* L.	N27
151	*Allium ursinum* L.	N5, N9, N12, N20-N24, N27, N32

No	Species	Localities
152	*Alnus rohlenae* Vít, Douda & Mandák[1]	N3, N5, N9, N20-N24, N31
153	*Alopecurus aequalis* Sobol.	N46
154	*Alopecurus geniculatus* L.	N39
155	*Alopecurus pratensis* L.	N39, N43
156	*Alyssoides utriculata* (L.) Medik.	N7, N18
157	*Alyssum alyssoides* (L.) L.	N19, N27, N35
158	*Alyssum bosniacum* Beck1	N18, N39, N40
159	*Amelanchier ovalis* Medik.	N44, N45
160	*Anacamptis morio* (L.) R.M.Bateman, Pridgeon & M.W.Chase	N19, N35, N39
161	*Anacamptis pyramidalis* (L.) Rich.[2,4]	N35
162	*Androsace villosa* L.	N38, N43
163	*Anemone nemorosa* L.	N10, N22, N23, N26, N28, N29, N32, N39, N43
164	*Anemone ranunculoides* L.	N32, N38
165	*Angelica sylvestris* L.	N3, N12, N16, N20, N31
166	*Antennaria dioica* (L.) Gaertn.	N39
167	*Anthemis arvensis* L.	N27
168	*Anthoxanthum odoratum* L.	N19, N27, N37, N39
169	*Anthriscus cerefolium* (L.) Hoffm.	N10
170	*Anthriscus sylvestris* (L.) Hoffm.	N10, N13, N23, N35
171	*Anthyllis montana* L. subsp. *jacquinii* (Rchb.f.) Rohlena	N39, N43
172	*Anthyllis vulneraria* L. subsp. *polyphylla* (DC.) Nyman	N27, N39, N40
173	*Anthyllis vulneraria* L. subsp. *weldeniana* (Rchb.) Cullen[4]	N19
174	*Aposeris foetida* (L.) Less.	N1, N5, N6, N9, N10, N22, N29, N31-N33, N41
175	*Aquilegia nigricans* Baumg.	N9, N31, N36
176	*Arabidopsis thaliana* (L.) Heynh.	N18
177	*Arabis caucasica* Willd.	N38, N43
178	*Arabis ciliata* Clairv.	N18, N43
179	*Arabis hirsuta* (L.) Scop.	N20, N24, N45
180	*Arabis sagittata* (Bertol.) DC.	N19, N27, N31, N38, N34
181	*Arctium lappa* L.	N13, N35
182	*Arctium nemorosum* Lej.[4]	N36
183	*Arctostaphylos uva-ursi* (L.) Spreng.	N43
184	*Aremonia agrimonoides* (L.) DC.	N1, N6, N13, N26, N28, N29, N30, N32, N33, N35, N38, N39
185	*Arenaria gracilis* Waldst. & Kit.[1,2,4]	N45
186	*Arenaria serpyllifolia* L. aggr.	N19, N27, N28, N35, N39
187	*Aria edulis* (Willd.) M.Roem	N27, N35
188	*Aristolochia lutea* Desf.	N26, N28, N29
189	*Arrhenatherum elatius* (L.) P.Beauv. ex J.Presl & C.Presl	N35
190	*Artemisia alba* Turra	N18
191	*Artemisia vulgaris* L.	N31, N35
192	*Arum maculatum* L.	N5, N6, N12, N16, N18, N22, N23, N28-N30, N36
193	*Aruncus dioicus* (Walter) Fernald	N9, N32
194	*Asarum europaeum* L.	N18, N21-N23, N32, N33, N38, N41
195	*Asperula taurina* L.[4]	N5, N9, N16, N22, N23, N32

No	Species	Localities
196	*Asphodelus albus* Mill.[4]	N19, N28, N37, N39, N46
197	*Asplenium ceterach* L.	N7, N11, N17, N19, N28, N35, N38
198	*Asplenium ruta-muraria* L.	N19, N27, N38, N43
199	*Asplenium trichomanes* L.	N11, N18, N26, N28, N38, N43
200	*Astragalus depressus* L.[4]	N27
201	*Astragalus glycyphyllos* L.	N11, N13, N31, N38
202	*Astragalus hypoglottis* L. subsp. *hypoglottis*	N34
203	*Astragalus vesicarius* L. subsp. *carniolicus* (A. Kern.) Chater	N19, N38, N41
204	*Astrantia major* L.	N10, N28, N29, N32, N33, N37, N38
205	*Athyrium filix-femina* (L.) Roth	N36
206	*Atropa bella-donna* L.	N36
207	*Avenula pubescens* (Huds.) Dumort.	N18, N27, N39
208	*Barbarea intermedia* Boreau	N39
209	*Barbarea vulgaris* W. T. Aiton	N20, N24, N31
210	*Bellardiochloa variegata* (Lam.) Kerguélen	N27
211	*Bellis perennis* L.	N15, N19, N35, N46
212	*Betonica alopecuros* L.	N45
213	*Betonica officinalis* L.	N6, N26, N28, N30, N37, N39
214	*Bistorta officinalis* Delarbre[4]	N39
215	*Blitum bonus-henricus* (L.) Rchb.	N44
216	*Brachypodium pinnatum* (L.) P. Beauv.	N11, N15, N26, N28, N29, N34, N39
217	*Brachypodium rupestre* (Host) Roem. & Schult.	N13, N19
218	*Brachypodium sylvaticum* (Huds.) P. Beauv.	N3-N6, N9, N11-N14, N16, N19-N24, N28, N29, N31, N32, N34
219	*Briza media* L.	N13, N27, N34, N39
220	*Bromus commutatus* Schrad.	N18
221	*Bromus hordeaceus* L.	N13, N19
222	*Bromus pannonicus* Kumm. et Sendtn.	N13, N19, N27, N28, N34, N39
223	*Bromus ramosus* Huds.	N24, N31
224	*Bromus sterilis* L.	N13, N34
225	*Buglossoides arvensis* (L.) I.M.Johnst.	N40
226	*Bunium alpinum* Waldst. et Kit. subsp. *montanum* (W. D. J. Koch) P. W. Ball[4]	N26, N37, N38
227	*Caltha palustris* L.	N41
228	*Calystegia sepium* (L.) R. Br.	N20, N21, N31
229	*Campanula bononiensis* L.	N13, N28, N34
230	*Campanula glomerata* L.	N38
231	*Campanula lingulata* Waldst. & Kit.	N7, N8, N13
232	*Campanula patula* L.	N18, N37, N38
233	*Campanula persicifolia* L.	N1, N28, N36, N38
234	*Campanula rapunculoides* L.	N35
235	*Campanula scheuchzeri* Vill.	N44
236	*Campanula trachelium* L.	N9-N11, N14, N20, N23, N24, N31-N34
237	*Capsella bursa-pastoris* (L.) Medik.	N13, N18, N46
238	*Cardamine bulbifera* (L.) Crantz	N10, N12, N16, N20-N23, N26, N28, N29, N31-N33, N35, N38
239	*Cardamine enneaphyllos* (L.) Crantz	N38

No	Species	Localities
240	*Cardamine hirsuta* L.	N18, N28, N31, N35
241	*Cardamine impatiens* L.	N16, N20, N31, N32, N36
242	*Carduus collinus* Waldst. et Kit.	N15, N18, N27, N37
243	*Carex caryophyllea* Latourr.	N19, N27, N34, N39
244	*Carex diandra* Schrank[4]	N46
245	*Carex digitata* L.	N4, N5, N11, N28, N31, N36, N45
246	*Carex distans* L.	N35, N46
247	*Carex flacca* Schreb. subsp. *flacca*	N3, N4, N13, N15, N31, N34
248	*Carex halleriana* Asso	N7, N13, N19, N34, N42
249	*Carex hirta* L.	N39, N41
250	*Carex humilis* Leyss.	N43
251	*Carex kitaibeliana* Degen ex Bech.	N43, N45
252	*Carex lepidocarpa* Tausch[4]	N39, N41, N46
253	*Carex muricata* L.	N13, N46
254	*Carex nigra* (L.) Reichard[2, 4]	N39, N46
255	*Carex oederi* Retz.[4]	N39
256	*Carex ornithopoda* Willd.	N43
257	*Carex otrubae* Podp.	N2, N36
258	*Carex pallescens* L.	N39
259	*Carex panicea* L.[4]	N39, N41
260	*Carex paniculata* L.	N41, N46
261	*Carex remota* L.	N2, N36
262	*Carex rostrata* Stokes	N46
263	*Carex spicata* Huds.	N29, N35, N46
264	*Carex sylvatica* Huds.	N5, N6, N13, N16, N29, N30
265	*Carex tomentosa* L.	N29, N34, N46
266	*Carlina acanthifolia* All.	N19, N37
267	*Carlina acaulis* L.	N27, N37
268	*Carlina vulgaris* L.	N27, N43
269	*Carpinus betulus* L.	N1, N3-N6, N9-N12, N14, N21-N24, N26, N29, N31-N33, N41
270	*Carpinus orientalis* Mill.	N1, N3-N6, N9-N11, N18, N34
271	*Carum carvi* L.	N39, N46
272	*Centaurea jacea* L. subsp. *angustifolia* (DC.) Gremli	N19, N27
273	*Centaurea jacea* L. subsp. *jacea*	N13, N31, N34, N38
274	*Centaurea micrantha* Hoffmanns. & Link	N19, N27
275	*Centaurea scabiosa* L.	N27, N37
276	*Centaurea triumfettii* All.	N44
277	*Cephalanthera damasonium* (Mill.) Druce[2, 4]	N10, N18, N30, N35
278	*Cephalanthera longifolia* (L.) Fritsch[2, 3, 4]	N13, N35
279	*Cephalaria pastricensis* Dörfl. & Hayek[1, 2, 3, 4]	N31
280	*Cerastium arvense* L.	N39, N43
281	*Cerastium brachypetalum* Desp. ex Pers.	N19, N27, N28, N31, N35, N39
282	*Cerastium decalvans* Schloss. et Vuk.[1, 2, 4]	N38, N43
283	*Cerastium grandiflorum* Waldst. et Kit.[1, 2, 4]	N7, N43, N46

No	Species	Localities
284	*Cerastium holosteoides* Fr.	N19, N29, N39
285	*Cerastium malyi* (T.Georgiev) Niketić subsp. *malyi*[1, 4]	N38
286	*Cerastium pumilum* Curtis	N19
287	*Cerastium sylvaticum* Waldst. et Kit.	N22, N24, N31
288	*Chaerophyllum aromaticum* L.	N12, N21, N23, N31
289	*Chaerophyllum aureum* L.	N30, N37, N46
290	*Chaerophyllum bulbosum* L.	N35
291	*Chaerophyllum coloratum* L.[1, 2, 3, 4]	N7, N27
292	*Chaerophyllum hirsutum* L.	N20-N22, N24, N31
293	*Chaerophyllum temulum* L.	N13, N31, N35
294	*Chamaecytisus hirsutus* (L.) Link	N1, N13, N15, N31, N34, N38
295	*Chamaecytisus supinus* (L.) Link	N13
296	*Chelidonium majus* L.	N16, N31, N36
297	*Chondrilla juncea* L.	N27
298	*Cicerbita pancicii* Beauverd[1, 2, 3, 4]	N32, N41
299	*Cichorium intybus* L.	N13, N19, N31, N35
300	*Circaea lutetiana* L.	N5, N12, N16, N20, N22, N23
301	*Cirsium acaulon* (L.) Scop.	N19, N27, N34
302	*Cirsium arvense* (L.) Scop.	N31, N37
303	*Cirsium candelabrum* Griseb.	N31
304	*Cirsium vulgare* (Savi) Ten.	N13, N15, N34, N46
305	*Clematis vitalba* L.	N1, N3-N6, N9, N13-N15, N20, N21, N23, N24, N31, N33, N34, N42
306	*Clinopodium acinos* (L.) Kuntze	N19, N27, N34
307	*Clinopodium album* (Waldst. & Kit.) Bräuchler & Govaerts[2, 4]	N18
308	*Clinopodium alpinum* (L.) Kuntze	N27, N39, N40
309	*Clinopodium vulgare* L.	N1, N4, N13, N14, N26, N28, N34, N38
310	*Cnidium silaifolium* (Jacq.) Simonk.	N1, N13, N15, N16, N28, N31, N32, N34
311	*Colchicum autumnale* L.	N13, N15, N27, N34, N39
312	*Colutea arborescens* L.	N28, N35
313	*Convallaria majalis* L.[2, 4]	N27, N45
314	*Convolvulus arvensis* L.	N19, N27, N31, N34
315	*Cormus domestica* (L.) Spach	N9, N11
316	*Cornus mas* L.	N1, N4, N6, N9, N11, N13, N14, N22, N28, N32-N34
317	*Cornus sanguinea* L.	N3-N5, N8, N9, N12, N13, N15, N19-N21, N23, N31, N32, N34
318	*Coronilla vaginalis* Lam.	N43, N45
319	*Coronilla varia* L.	N13, N28, N31, N34
320	*Corydalis cava* (L.) Schweigg. & Körte	N28, N38, N43
321	*Corylus avellana* L.	N1, N5, N6, N10, N12-N14, N16, N20-N24, N26, N32-N34
322	*Cotoneaster integerrimus* Medik.	N18, N38, N43, N45
323	*Cotoneaster tomentosus* (Aiton) Lindl.	N9, N26
324	*Crataegus laevigata* (Poir.) DC.	N27
325	*Crataegus monogyna* Jacq.	N1, N4-N6, N9, N11, N13, N14, N19, N21-N24, N26, N28, N31-N33, N46
326	*Crepis biennis* L.	N31
327	*Crepis froelichiana* DC. subsp. *dinarica* (Beck) Gutermann[2,3,4]	N39, N45

No	Species	Localities
328	*Crepis neglecta* L.	N7
329	*Crocus vernus* (L.) Hill	N18
330	*Cruciata glabra* (L.) Opiz	N1, N13, N15, N19, N23, N32, N34, N39
331	*Cruciata laevipes* Opiz	N13, N19, N28, N29, N35, N39, N46
332	*Cruciata pedemontana* (Bellardi) Ehrend.	N19, N27, N46
333	*Crupina vulgaris* Pers. ex Cass.	N15, N27, N40
334	*Cuscuta epithymum* (L.) L.	N27?, N37, N38
335	*Cynanchica aristata* (L.f.) P.Caputo & Del Guacchio subsp. *scabra* (C.Presl) P.Caputo & Del Guacchio	N18, N31
336	*Cynanchica pyrenaica* (L.) P.Caputo & Del Guacchio subsp. *cynanchica* (L.) P.Caputo & Del Guacchio	N3
337	*Cynoglossum creticum* Mill.[4]	N10, N18, N46
338	*Cynoglottis barrelieri* (All.) Vural et Kit Tan	N43
339	*Cynosurus cristatus* L.	N19, N46
340	*Cystopteris fragilis* (L.) Bernh.	N26, N27, N38, N43, N45
341	*Dactylis glomerata* L. subsp. *glomerata*	N1, N4-N6, N11, N13, N14, N16, N19, N21, N24, N26-N28, N31, N33, N34
342	*Dactylis glomerata* L. subsp. *lobata* (Drejer) H.Lindb.	N28, N32
343	*Dactylorhiza maculata* (L.) Soó subsp. *fuchsii* (Druce) Hyl.	N9, N22, N23, N29, N32, N43
344	*Dactylorhiza sambucina* (L.) Soó[4]	N39
345	*Daphne alpina* L.	N18, N38, N43
346	*Daphne mezereum* L.	N23
347	*Daucus carota* L.	N3, N6, N13, N21, N22, N24, N31, N34
348	*Deschampsia cespitosa* (L.) P.Beauv.	N39
349	*Dianthus carthusianorum* L. subsp. *sanguineus* (Vis.) Hegi[1, 2]	N19, N27, N35
350	*Dianthus sylvestris* Wulfen	N31, N43, N45
351	*Dichoropetalum carvifolia* (Vill.) Pimenov & Kljuykov	N27
352	*Digitalis ferruginea* L.	N27
353	*Dioscorea communis* (L.) Caddick & Wilkin	N5, N6, N13, N22, N29, N30, N34
354	*Dipsacus fullonum* L.	N31
355	*Doronicum columnae* Ten.	N38, N43
356	*Draba lasiocarpa* Rochel[4]	N19, N42, N43
357	*Draba muralis* L.	N19, N27, N35, N38
358	*Draba nemorosa* L.	N28
359	*Draba verna* L.	N19, N39, N43
360	*Dryas octopetala* L.[2, 3, 4]	N44
361	*Dryopteris filix-mas* (L.) Schott	N5, N32, N41
362	*Dryopteris villarii* (Bellardi) Woyn. ex Schinz & Thell.	N38, N43
363	*Drypis spinosa* L.[4]	N37
364	*Echinops ritro* L.	N27
365	*Echium vulgare* L.	N31, N35
366	*Edraianthus graminifolius* (L.) A.DC. ex Meisn.[4]	N38, N43, N45
367	*Eleocharis mamillata* (H.Lindb.) H.Lindb.?	N39, N46
368	*Eleocharis palustris* (L.) Roem. & Schult.?	N46
369	*Elymus caninus* (L.) L.	N31
370	*Epilobium angustifolium* L.	N46
371	*Epilobium hirsutum* L.	N16, N20

No	Species	Localities
372	*Epilobium montanum* L.	N36
373	*Epilobium parviflorum* Schreb.	N46
374	*Equisetum arvense* L.	N10, N20, N21, N24, N31, N41, N46
375	*Equisetum palustre* L.	N46
376	*Equisetum ramosissimum* Desf.	N46
377	*Equisetum telmateia* Ehrh.	N10, N16, N41
378	*Erigeron annuus* (L.) Desf.	N35
379	*Erodium cicutarium* (L.) L'Hér.	N19, N35
380	*Eryngium amethystinum* L.	N19, N27, N34
381	*Eryngium palmatum* Pančić & Vis.[1, 2, 4]	N28
382	*Erysimum odoratum* Ehrh.	N39
383	*Erythronium dens-canis* L.[2]	N26, N28, N30, N38
384	*Euonymus europaeus* L.	N12, N22-N24, N35
385	*Euonymus verrucosus* Scop.	N11, N28
386	*Eupatorium cannabinum* L.	N9, N20, N31, N35
387	*Euphorbia amygdaloides* L.	N1, N4, N5, N11, N13, N15, N22, N26, N28, N29, N31, N34
388	*Euphorbia cyparissias* L.	N26-N28
389	*Euphorbia exigua* L.	N35
390	*Euphorbia montenegrina* (Bald.) K.Malý[1, 2, 3, 4]	N37
391	*Euphorbia myrsinites* L.	N27, N40, N45
392	*Euphorbia platyphyllos* L.	N13, N20, N23, N36
393	*Euphorbia stricta* L.	N10, N13, N31, N35
394	*Fagus sylvatica* L.	N5, N9, N13, N16, N21-N24, N29, N31, N32, N35, N38
395	*Ferulago sylvatica* (Besser) Rchb.	N27, N35, N46
396	*Festuca bosniaca* Kumm. & Sendtn.[2, 3, 4]	N18, N38, N43
397	*Festuca heterophylla* Lam.	N13, N14, N26, N28, N29, N32-N34
398	*Festuca nigrescens* Lam.	N13, N18
399	*Festuca rubra* L.	N38, N39
400	*Festuca rupicola* Heuff.	N13?, N19, N34
401	*Festuca valesiaca* Schleich. ex Gaudin	N26-N28
402	*Filago arvensis* L.	N19, N35
403	*Filipendula vulgaris* Moench	N19, N26-N29, N34, N39
404	*Fragaria moschata* Duchesne ex Weston	N4, N13, N18, N28, N29, N31, N34
405	*Fragaria vesca* L.	N1, N3, N9, N11, N13, N14, N23, N26, N28, N31-N34, N38
406	*Fragaria viridis* Weston	N19, N27, N39, N40
407	*Frangula rupestris* (Scop.) Schur	N18
408	*Fraxinus excelsior* L.	N3-N5, N9, N13, N18, N20-N24, N26, N29, N31-N34
409	*Fraxinus ornus* L.	N1, N3, N9, N11, N14, N17, N18, N24, N26, N28, N34
410	*Fritillaria montana* Hoppe ex W. D. J. Koch[2, 3, 4]	N18, N43
411	*Fumana procumbens* (Dunal) Gren. & Godr.	N34
412	*Gagea villosa* (M.Bieb.) Sweet	N18
413	*Galanthus nivalis* L.[2]	N38
414	*Galeopsis speciosa* Mill.	N31
415	*Galium anisophyllon* Vill.	N39

No	Species	Localities
416	*Galium aparine* L.	N13, N16, N28, N29, N35
417	*Galium intermedium* Schult.	N10, N14, N31, N32
418	*Galium lucidum* All. subsp. *corrudifolium* (Vill.) Bonnier	N7, N19, N27, N31, N35, N39, N45
419	*Galium mollugo* L.	N13, N31
420	*Galium odoratum* (L.) Scop.	N41
421	*Galium palustre* L.	N46
422	*Galium spurium* L.	N15, N28, N35
423	*Galium sylvaticum* L.	N1, N5, N6, N14, N21, N24, N33
424	*Galium verum* L.	N13, N19, N27, N29, N34, N39
425	*Gelasia villosa* (Scop.) Cass.	N19, N27, N37, N38
426	*Genista januensis* Viv.	N27, N45
427	*Genista sagittalis* L.	N13, N19, N27, N34, N39
428	*Genista tinctoria* L.	N1, N8, N13, N19, N34
429	*Gentiana cruciata* L.	N27, N37
430	*Gentiana verna* L. subsp. *tergestina* (Beck) Hayek[1, 4]	N39, N43
431	*Geocaryum cynapioides* (Guss.) Engstrand[4]	N28
432	*Geranium columbinum* L.	N13, N19, N27, N28, N34
433	*Geranium dissectum* L.	N31, N35
434	*Geranium lucidum* L.	N17, N18, N26, N28, N35
435	*Geranium molle* L.[2, 4]	N19
436	*Geranium phaeum* L.	N16, N31, N32
437	*Geranium pusillum* L.	N35, N46
438	*Geranium pyrenaicum* Burm.f.	N15, N46
439	*Geranium robertianum* L.	N13, N16, N18, N21, N22, N24, N31, N32, N38, N41, N45
440	*Geranium sanguineum* L.	N18, N26-N28, N34
441	*Geranium sylvaticum* L.	N39
442	*Geum molle* Vis. & Pančić	N19, N38, N41
443	*Geum rivale* L.	N39
444	*Geum urbanum* L.	N5, N6, N13, N16, N19-N22, N27, N28, N31, N35, N45, N46
445	*Glechoma hederacea* L.	N5, N23
446	*Glechoma hirsuta* Waldst. & Kit.	N4, N5, N10, N21, N22, N27, N28, N33
447	*Globularia meridionalis* (Podp.) O.Schwarz	N19, N37, N39
448	*Glyceria notata* Chevall.	N46
449	*Grafia golaka* (Hacq.) Rchb.[2, 4]	N40
450	*Gymnadenia conopsea* (L.) R.Br.	N39, N46
451	*Hedera helix* L.	N5, N9-N11, N28, N30
452	*Hedlundia austriaca* (Beck) Sennikov & Kurtto4	N37
453	*Helianthemum canum* (L.) Hornem.	N19, N38, N43
454	*Helianthemum nummularium* (L.) Mill.	N13, N19, N27, N31, N34, N39
455	*Helictochloa blaui* (Asch. & Janka) Romero Zarco[1, 2, 4]	N18
456	*Heliosperma pusillum* (Waldst. & Kit.) Rchb.	N45
457	*Helleborus odorus* Waldst. et Kit. ex Willd. subsp. *odorus*	N1, N4-N6, N11, N13, N14, N17, N22, N23, N26-N28, N31-N34, N39
458	*Heracleum sphondylium* L.	N16, N31, N35
459	*Herniaria glabra* L.	N38

No	Species	Localities
460	*Herniaria incana* Lam.	N19, N35
461	*Hesperis laciniata* All.	N18
462	*Hieracium laevigatum* Willd.	N4, N5, N9
463	*Hieracium murorum* L. agg.	N1, N11, N14, N30, N35
464	*Hieracium racemosum* Waldst. & Kit. ex Willd.	N9, N14
465	*Hieracium sabaudum* L.	N11
466	*Hieracium waldsteinii* Tausch[1, 2, 3, 4]	N18, N45
467	*Hippocrepis comosa* L.	N13, N15, N19, N27, N34, N39
468	*Holcus lanatus* L.	N15
469	*Humulus lupulus* L.	N3, N12, N20
470	*Hylotelephium maximum* (L.) Holub	N17, N28, N35
471	*Hypericum barbatum* Jacq.	N27, N38
472	*Hypericum hirsutum* L.	N36
473	*Hypericum maculatum* Crantz	N39, N43
474	*Hypericum perforatum* L.	N13, N18, N27, N31, N34
475	*Hypochaeris maculata* L. subsp. *pelivanovicii* (Velen.) Hayek[1, 2, 3, 4]	N18, N27, N38
476	*Hypochaeris radicata* L.	N19
477	*Iris graminea* L.	N14, N18, N28, N32, N37
478	*Iris pallida* Lam.	N7
479	*Iris reichenbachii* Heuff.	N18, N44
480	*Isopyrum thalictroides* L.	N23
481	*Juglans regia* L.	N13
482	*Juncus conglomeratus* L.	N39
483	*Juncus effusus* L.	N39
484	*Juncus inflexus* L.	N35, N46
485	*Juncus tenuis* Willd.	N35
486	*Juniperus communis* L.	N11, N18, N31, N35, N38, N43, N45
487	*Juniperus sabina* L.[2, 4]	N37, N42
488	*Jurinea mollis* (L.) Rchb.	N7, N18, N43, N45
489	*Kernera saxatilis* (L.) Sweet[2, 3, 4]	N43, N45
490	*Knautia albanica* Briq.[1, 2, 3, 4]	N27, N37
491	*Knautia dinarica* (Murb.) Borbás[1, 2, 4]	N39, N44
492	*Knautia drymeja* Heuff.	N3, N31
493	*Knautia visianii* Szabó[1, 2]	N13, N28, N31, N34
494	*Koeleria splendens* C. Presl	N13, N19, N27, N28, N34, N39
495	*Lactuca muralis* (L.) Gaertn.	N17, N18, N21, N22, N24, N31, N33, N41
496	*Lactuca saligna* L.	N13, N18
497	*Lactuca serriola* L.	N13, N31, N34
498	*Lamium galeobdolon* (L.) Crantz subsp. *flavidum* (F.Herm.) Á.Löve & D.Löve	N42
499	*Lamium galeobdolon* (L.) Crantz subsp. *montanum* (Pers.) Hayek	N5, N16, N32
500	*Lamium hybridum* Vill.	N15, N19
501	*Lamium maculatum* (L.) L.	N16, N17, N21, N31, N35
502	*Lapsana communis* L.	N13, N21, N23, N31, N35
503	*Laserpitium krapfii* Crantz	N9, N10, N30, N41
504	*Lathyrus cicera* L.	N27

No	Species	Localities
505	*Lathyrus latifolius* L.	N13, N15, N29, N34
506	*Lathyrus niger* (L.) Bernh.	N1, N11, N13, N14, N26, N28, N32-N34
507	*Lathyrus nissolia* L.	N18, N34
508	*Lathyrus pratensis* L.	N13, N15, N31, N34, N39
509	*Lathyrus tuberosus* L.	N35
510	*Lathyrus venetus* (Mill.) Wohlf.	N6, N11, N13, N14, N18, N26, N28, N32, N35
511	*Lathyrus vernus* (L.) Bernh.	N11
512	*Leontodon crispus* Vill.	N7, N19, N21, N24, N27, N38, N46
513	*Leontodon hispidus* L.	N27, N31, N38, N39
514	*Lepidium campestre* (L.) W. T. Aiton	N31
515	*Lepidium ruderale* L.	N13, N34
516	*Leucanthemum adustum* (W.D.J.Koch) Gremli	N24, N31
517	*Leucanthemum vulgare* Lam.	N4, N13, N34, N39
518	*Ligustrum vulgare* L.	N4-N6, N9, N10, N23, N24, N31-N34
519	*Lilium bosniacum* (Beck) Fritsch[1, 2, 4]	N43, N45
520	*Lilium martagon* L.[2]	N1, N11, N18, N22, N26, N28, N32, N41
521	*Linaria vulgaris* Mill.	N3, N29, N36
522	*Linum alpinum* Jacq.	N39
523	*Linum capitatum* Kit. ex Schult.[1, 4]	N37
524	*Linum catharticum* L.	N27, N35
525	*Lithospermum officinale* L.	N10, N27
526	*Lolium giganteum* (L.) Darbysh.	N12, N16, N20, N31, N36
527	*Lolium perenne* L.	N15
528	*Lolium pratense* (Huds.) Darbysh.	N27, N31, N35
529	*Lonicera alpigena* L.	N41
530	*Lonicera caprifolium* L.	N31-N33
531	*Lonicera xylosteum* L.	N11, N27
532	*Lophiolepis eriophora* (L.) Del Guacchio, Bureš, Iamonico & P.Caputo	N19, N39
533	*Lotus corniculatus* L.	N13, N19, N27, N31, N34, N39
534	*Lotus germanicus* (Gremli) Peruzzi	N19, N27, N39
535	*Lotus herbaceus* (Vill.) Jauzein	N13, N19, N34
536	*Lunaria rediviva* L.	N20
537	*Luzula campestris* (L.) DC.	N19, N27
538	*Luzula forsteri* (Sm.) DC.	N13, N28, N30, N35
539	*Luzula luzulina* (Vill.) Racib.	N6
540	*Luzula luzuloides* (Lam.) Dandy & Wilmott	N6, N32, N36, N37
541	*Luzula taurica* (V.I.Krecz.) Novikov	N27, N39
542	*Lycopus europaeus* L.	N20, N36
543	*Lysimachia arvensis* (L.) U.Manns & Anderb.	N13
544	*Lysimachia nummularia* L.	N4, N5, N12, N16, N20, N21, N32, N39, N41
545	*Lysimachia punctata* L.	N29
546	*Lysimachia vulgaris* L.	N3, N20
547	*Lythrum salicaria* L.	N3
548	*Malcolmia orsiniana* (Ten.) Ten. subsp. *angulifolia* (Boiss. & Orph.) Stork[1, 2, 3, 4]	N46
549	*Malus sylvestris* (L.) Mill.	N1, N22-N24, N33, N34

No	Species	Localities
550	*Malva setigera* K.F.Schimp. & Spenn.	N35
551	*Malva sylvestris* L.	N35
552	*Marrubium incanum* Desr.	N7, N27
553	*Medicago arabica* (L.) Huds.	N36
554	*Medicago falcata* L.	N19, N27, N34, N38
555	*Medicago lupulina* L.	N3, N13, N19, N27, N31, N34, N38
556	*Medicago minima* (L.) Bartal.	N18, N27
557	*Medicago orbicularis* (L.) Bartal.	N35
558	*Medicago truncatula* Gaertn.	N35
559	*Melampyrum nemorosum* L.	N10, N31, N32
560	*Melampyrum pratense* L.	N3-N6, N9, N21, N22
561	*Melica nutans* L.	N1, N28, N30
562	*Melica uniflora* Retz.	N18, N22-N24, N26, N28, N32, N33, N35
563	*Melilotus albus* Medik.	N31
564	*Melilotus officinalis* (L.) Lam.	N13, N31
565	*Melissa officinalis* L.[4]	N13, N35
566	*Melittis melissophyllum* L.	N1, N10, N11, N26, N28, N29, N32, N35
567	*Mentha aquatica* L.	N31, N46
568	*Mentha arvensis* L.	N20
569	*Mentha longifolia* (L.) L.	N20, N31, N35, N39, N46
570	*Mentha pulegium* L.	N39
571	*Mercurialis ovata* Sternb. & Hoppe	N18, N41, N45
572	*Mercurialis perennis* L.	N5, N9, N11, N12, N22, N23, N28, N32
573	*Minuartia bosniaca* (Beck) K.Malý[1, 2, 3, 4]	N7, N19, N38, N43, N46
574	*Moehringia muscosa* L.	N17, N38, N41
575	*Moehringia trinervia* (L.) Clairv.	N30
576	*Moenchia mantica* (L.) Bartl.	N39
577	*Molinia caerulea* (L.) Moench	N41
578	*Muscari comosum* (L.) Mill.	N27
579	*Muscari neglectum* Guss. ex Ten.	N19, N27, N37, N39
580	*Mutarda arvensis* (L.) D.A.German	N13
581	*Myosotis alpestris* F. W. Schmidt subsp. *suaveolens* (Waldst. & Kit. ex Willd.) Strid[1, 4]	N38, N43, N45
582	*Myosotis arvensis* (L.) Hill	N19, N27, N31, N35
583	*Myosotis ramosissima* Rochel ex Schult.	N19, N27, N46
584	*Myosotis scorpioides* L.	N41
585	*Myosotis sicula* Guss.	N39
586	*Myosotis stricta* Link ex Roem. & Schult.[4]	N18, N39, N40
587	*Myosotis sylvatica* Ehrh. ex Hoffm.	N27, N28
588	*Nardus stricta* L.	N39
589	*Nasturtium officinale* W.T.Aiton	N46
590	*Neotinea tridentata* (Scop.) R.M.Bateman, Pridgeon & M.W.Chase[4]	N19, N39
591	*Neotinea ustulata* (L.) R.M.Bateman, Pridgeon & M.W.Chase[4]	N38, N46
592	*Neottia nidus-avis* (L.) Rich.	N6, N13, N14, N30, N35
593	*Neottia ovata* (L.) Hartm.	N23, N33, N41, N46

No	Species	Localities
594	*Nepeta nuda* L. subsp. *nuda*	N19, N27, N37, N46
595	*Noccaea perfoliata* (L.) Al-Shehbaz	N13, N19, N28
596	*Noccaea praecox* (Wulfen) F.K.Mey.	N18, N27, N38-N40
597	*Nuphar lutea* (L.) Sm.[2, 3, 4]	N46
598	*Odontarrhena muralis* (Waldst. & Kit.) Endl.	N15, N18, N35, N46
599	*Omalotheca sylvatica* (L.) Sch. Bip. et F. W. Schultz	N36
600	*Ononis spinosa* L.	N31
601	*Onopordum acanthium* L.	N15
602	*Ophioglossum vulgatum* L.[4]	N39
603	*Ophrys apifera* Huds.[4]	N8
604	*Orchis mascula* (L.) L. subsp. *speciosa* (Mutel) Hegi[4]	N18, N27, N37, N38
605	*Origanum vulgare* L.	N28, N35
606	*Orlaya grandiflora* (L.) Hoffm.	N7, N27, N28, N35
607	*Ornithogalum dalmaticum* Speta[1]	N19, N35, N38, N46
608	*Ornithogalum orthophyllum* Ten. subsp. *kochii* (Parl.) Zahar.	N7, N19, N39
609	*Orobanche alsatica* Kirschl.	N37
610	*Orobanche caryophyllacea* Sm.	N46
611	*Orobanche gracilis* Sm.	N13, N34
612	*Orobanche lutea* Baumg.	N27, N34
613	*Orobanche pancicii* Beck[2, 3, 4]	N19
614	*Ostrya carpinifolia* Scop.	N9, N13, N18, N31, N32, N34
615	*Papaver dubium* L.	N13
616	*Papaver rhoeas* L.	N35
617	*Parietaria officinalis* L.	N12, N20
618	*Paris quadrifolia* L.	N23, N29, N30
619	*Paronychia kapela* (Hacq.) A. Kern.	N19, N38, N43
620	*Pastinaca sativa* L.	N14, N21, N24, N31
621	*Pentanema germanicum* (L.) D.Gut.Larr., Santos-Vicente, Anderb., E.Rico & M.M.Mart.Ort.	N1, N26
622	*Pentanema hirtum* (L.) D.Gut.Larr., Santos-Vicente, Anderb., E.Rico & M.M.Mart. Ort.	N15, N18
623	*Pentanema oculus-christi* (L.) D.Gut.Larr., Santos-Vicente, Anderb., E.Rico & M.M.Mart.Ort.	N19, N37, N46
624	*Pentanema salicinum* (L.) D.Gut.Larr., Santos-Vicente, Anderb., E.Rico & M.M.Mart.Ort.	N29, N34
625	*Pentanema spiraeifolium* (L.) D.Gut.Larr., Santos-Vicente, Anderb., E.Rico & M.M.Mart.Ort.[4]	N37
626	*Petasites albus* (L.) Gaertn.	N21
627	*Petasites hybridus* (L.) G.Gaertn., B.Mey. & Scherb.	N12, N16, N20, N24, N31, N41
628	*Petasites kablikianus* Bercht.[2, 3, 4]	N21, N23, N24, N31, N41
629	*Petrorhagia saxifraga* (L.) Link	N7, N19, N27
630	*Phleum phleoides* (L.) H. Karst.	N18, N27
631	*Picris hieracioides* L.	N13, N19, N31, N34
632	*Pilosella hoppeana* (Schult.) F.W.Schultz & Sch.Bip.	N19, N27, N39
633	*Pilosella piloselloides* (Vill.) Soják	N27, N34
634	*Pimpinella major* (L.) Huds.[4]	N29
635	*Pimpinella saxifraga* L.	N3
636	*Pimpinella serbica* (Vis.) Benth. & Hook.f. ex Drude[1, 2, 3, 4]	N38, N40

No	Species	Localities
637	*Pinus mugo* Turra	N45
638	*Pinus sylvestris* L.	N38
639	*Plantago argentea* Chaix	N39, N42, N43
640	*Plantago holosteum* Scop.	N19, N27, N34, N39, N42
641	*Plantago lanceolata* L.	N3, N13, N19, N27, N31, N34
642	*Plantago major* L.	N13, N20, N31
643	*Plantago media* L.	N13, N19, N20, N27, N34, N39
644	*Platanthera bifolia* (L.) Rich.[2, 4]	N1, N10, N13, N32
645	*Platanthera chlorantha* (Custer) Rchb.[2, 4]	N27, N34
646	*Poa alpina* L.	N43
647	*Poa angustifolia* L.	N15, N27, N34, N39
648	*Poa annua* L.	N15, N35
649	*Poa bulbosa* L.	N7, N13, N19, N27, N28, N35, N39
650	*Poa compressa* L.	N13, N26, N27, N34
651	*Poa nemoralis* L.	N3, N10, N20, N22, N28, N31, N40
652	*Poa pratensis* L.	N13, N15, N29, N34, N39
653	*Poa trivialis* L.	N3, N35, N46
654	*Poa ursina* Velen.	N19, N43, N45
655	*Polygala amarella* Crantz	N39
656	*Polygala major* Jacq.	N37
657	*Polygala nicaeensis* Risso ex W. D. J. Koch	N27, N36
658	*Polygala vulgaris* L.	N13, N19, N34, N39
659	*Polygonatum multiflorum* (L.) All.	N9, N16, N28, N32, N33, N41
660	*Polygonatum odoratum* (Mill.) Druce	N11, N43
661	*Polypodium vulgare* L.	N11, N32, N33
662	*Populus tremula* L.	N33, N37
663	*Potamogeton natans* L.	N46
664	*Potentilla argentea* L.	N27, N37, N46
665	*Potentilla erecta* (L.) Raeusch.	N39
666	*Potentilla heptaphylla* L.	N18, N27, N35, N39
667	*Potentilla micrantha* Ramond ex DC.	N1, N6, N11, N13, N14, N26, N28, N31, N33, N34
668	*Potentilla recta* L.	N19, N27, N28, N34
669	*Potentilla reptans* L.	N4, N26, N31, N34, N39, N46
670	*Prenanthes purpurea* L.	N32, N33, N36
671	*Primula intricata* Gren. & Godr.[2, 4]	N27
672	*Primula veris* L. subsp. *columnae* (Ten.) Maire & Petitm.	N11, N13, N18, N26-N28, N37
673	*Primula vulgaris* Huds.	N1, N4-N6, N10, N14, N16, N29, N31, N33, N35, N38
674	*Prunella laciniata* (L.) L.	N34
675	*Prunella vulgaris* L.	N1, N5, N12, N13, N21, N24, N31, N34
676	*Prunus avium* (L.) L.	N1, N6, N13, N14, N22, N26, N29, N31-N33, N35
677	*Prunus cerasifera* Ehrh.	N9
678	*Prunus spinosa* L.	N4, N6, N13, N14, N27, N31, N34
679	*Pseudopodospermum hispanicum* (L.) Zaika, Sukhor. & N.Kilian	N37
680	*Pseudoturritis turrita* (L.) Al-Shehbaz L.	N11, N24, N26-N28, N31, N35
681	*Pteridium aquilinum* (L.) Kuhn	N13, N15, N27, N35

No	Species	Localities
682	*Pulmonaria officinalis* L.	N4-N6, N10-N12, N16, N22, N23, N26, N32, N33, N41
683	*Pyrus communis* L. subsp. *communis*	N1, N4, N6, N9, N13, N19, N26-N28, N30, N31, N33, N34, N39, N46
684	*Quercus cerris* L.	N1, N4-N6, N13, N14, N19, N26-N29, N31, N33, N34
685	*Quercus petraea* (Matt.) Liebl.	N1, N6, N10, N11, N14, N29, N31, N33, N34
686	*Quercus pubescens* Willd.	N34
687	*Rabelera holostea* (L.) M.T.Sharples & E.A.Tripp	N1, N11, N13-N15, N26, N28, N30, N35
688	*Ranunculus acris* L.	N13, N31, N39, N46
689	*Ranunculus auricomus* L. aggr.[2, 3, 4]	N39
690	*Ranunculus bulbosus* L.	N3, N13, N19, N27, N28, N37
691	*Ranunculus carinthiacus* Hoppe	N39, N43
692	*Ranunculus circinatus* Sibth.[4]	N39
693	*Ranunculus ficaria* L.	N4-N6, N9, N12, N15, N16, N20-N23, N30, N33, N39
694	*Ranunculus lanuginosus* L.	N5, N20, N22
695	*Ranunculus millefoliatus* Vahl	N19, N27, N28, N39, N43
696	*Ranunculus platanifolius* L.	N23, N30, N41
697	*Ranunculus repens* L.	N12, N21, N31, N39
698	*Ranunculus sardous* Crantz	N4, N31, N34
699	*Ranunculus trichophyllus* Chaix	N39
700	*Ranunculus tuberosus* Lapeyr.	N39
701	*Rhamnus cathartica* L.	N31, N34
702	*Rhamnus fallax* Boiss.	N3, N9, N23, N31, N38, N43
703	*Rhinanthus freynii* (Sterneck) Fiori	N37
704	*Rhinanthus minor* L.	N27, N46
705	*Rhinanthus rumelicus* Velen.	N27
706	*Rhizomatophora aegopodioides* (Boiss.) Pimenov[1, 4]	N10, N32
707	*Ribes alpinum* L.	N38, N43
708	*Rorippa islandica* (Oeder) Borbás	N46
709	*Rorippa lippizensis* (Wulfen) Rchb.	N19, N27, N35, N39
710	*Rosa arvensis* Huds.	N3, N4, N6, N13, N14, N21-N24, N26, N30, N34
711	*Rosa canina* L.	N1, N5, N13, N19, N26, N31-N34, N38
712	*Rosa gallica* L.	N10, N34
713	*Rosa glauca* Pourr.	N27, N37, N39, N45
714	*Rosa pendulina* L.	N28, N43
715	*Rosa spinosissima* L.	N14
716	*Rubus caesius* L.	N3-N5, N9, N12, N14, N16, N20-N24, N31, N35
717	*Rubus idaeus* L.	N37
718	*Rumex acetosa* L.	N29, N39
719	*Rumex acetosella* L.	N19, N37, N39
720	*Rumex arifolius* All.	N37, N45
721	*Rumex obtusifolius* L.	N13, N20, N35, N46
722	*Rumex sanguineus* L.	N20, N35
723	*Rumex scutatus* L.	N43
724	*Sabulina verna* (L.) Rchb.	N27, N39, N40
725	*Salix* × *fragilis* L.	N16, N20, N21, N31, N46

No	Species	Localities
726	*Salix alba* L.	N9, N12, N16, N20, N21, N41
727	*Salix caprea* L.	N27, N35, N45, N46
728	*Salix cinerea* L.	N46
729	*Salix eleagnos* Scop.	N3-N5, N21, N31, N34, N46
730	*Salix purpurea* L.	N21, N31, N41, N46
731	*Salix triandra* L.	N23, N24
732	*Salvia glutinosa* L.	N9, N23, N24, N32
733	*Salvia pratensis* L.	N13, N19, N27, N34
734	*Salvia verticillata* L.	N3, N4, N13, N27, N29, N34
735	*Sambucus ebulus* L.	N2, N41
736	*Sambucus nigra* L.	N6, N12, N20, N22-N24, N35
737	*Sanguisorba minor* Scop.	N13, N19, N28, N31, N34, N39
738	*Sanicula europaea* L.	N6, N10, N30, N41
739	*Saponaria officinalis* L.	N21, N31
740	*Satureja montana* L.	N19, N46
741	*Saxifraga adscendens* L.	N38
742	*Saxifraga blavii* (Engl.) Beck[1, 4]	N42
743	*Saxifraga bulbifera* L.[4]	N19
744	*Saxifraga paniculata* Mill.	N43, N45
745	*Saxifraga tridactylites* L.	N19, N27, N28, N38, N39, N43
746	*Scabiosa cinerea* Lam. subsp. *cinerea*	N19, N27, N37, N39
747	*Scirpus sylvaticus* L.	N22, N41
748	*Scleranthus annuus* L.	N19, N46
749	*Scorzonera rosea* Waldst. & Kit.	N37, N39
750	*Scrophularia canina* L.	N31, N35
751	*Scrophularia nodosa* L.	N14, N16, N20, N21, N31, N32, N35
752	*Scrophularia scopolii* Hoppe ex Pers.[2, 4]	N38
753	*Scutellaria altissima* L.	N4, N5, N22-N24, N28, N29, N31
754	*Sedum acre* L.	N7, N27, N38
755	*Sedum album* L.	N7, N46
756	*Sedum dasyphyllum* L.	N18, N38, N43, N45
757	*Sedum hispanicum* L.	N38
758	*Sedum ochroleucum* Chaix	N19, N38, N43
759	*Sedum sexangulare* L.	N13, N19, N27, N34
760	*Sempervivum heuffelii* Schott[2, 4]	N18
761	*Sempervivum marmoreum* Griseb.	N18, N43
762	*Senecio ovatus* (P. Gaertn., B. Mey. et Scherb.) Willd.	N32
763	*Senecio sylvaticus* L.	N36
764	*Seseli pallasii* Besser	N18, N34
765	*Sesleria autumnalis* (Scop.) F. W. Schultz	N1, N11, N13-N15, N26, N28, N31, N32, N34
766	*Sesleria interrupta* Vis.[1]	N43, N45
767	*Sesleria robusta* Schott, Nyman & Kotschy[1, 4]	N43
768	*Sesleria uliginosa* Opiz	N39
769	*Sherardia arvensis* L.	N19, N35, N46
770	*Silene acaulis* (L.) Jacq.	N43

No	Species	Localities
771	*Silene dioica* (L.) Clairv.	N13, N14
772	*Silene latifolia* Poir.	N13, N31, N35
773	*Silene nutans* L.	N11, N13, N15, N19, N26-N28, N35, N38
774	*Silene otites* (L.) Wibel	N18
775	*Silene saxifraga* L.	N18, N38
776	*Silene sendtneri* Boiss.[1, 2, 4]	N27, N38-N40
777	*Silene vulgaris* (Moench) Garcke	N28, N31, N34
778	*Siler garganicum* (Ten.) Thell.	N43, N45
779	*Smyrnium perfoliatum* L.	N13, N22, N30
780	*Solanum dulcamara* L.	N20, N24, N31
781	*Solidago virgaurea* L.	N9, N11, N21, N22, N31, N33
782	*Sonchus arvensis* L.	N35
783	*Sonchus asper* (L.) Hill	N13, N35
784	*Sonchus oleraceus* L.	N13
785	*Sorbus aucuparia* L.	N9, N23, N26, N31, N35, N46
786	*Stachys alpina* L. subsp. *dinarica* Murb.[1, 4]	N39, N41
787	*Stachys germanica* L.	N7, N27, N35
788	*Stachys recta* L. subsp. *recta*	N31
789	*Stachys recta* L. subsp. *subcrenata* (Vis.) Briq.[1, 4]	N27, N28, N46
790	*Stachys sylvatica* L.	N13, N16, N24, N30, N33, N36
791	*Stellaria aquatica* (L.) Scop.	N20
792	*Stellaria graminea* L.	N29, N39
793	*Stellaria media* (L.) Vill.	N15, N20, N41, N46
794	*Stellaria neglecta* (Lej.) Weihe	N19
795	*Stellaria nemorum* L.	N5
796	*Stipa pennata* L. subsp. *pennata*	N18
797	*Succisa pratensis* Moench	N39
798	*Symphytum tuberosum* L.	N4-N6, N11, N13, N14, N22, N23, N26, N28, N32, N33, N37
799	*Tanacetum corymbosum* (L.) Sch. Bip.	N11, N26, N28, N32, N33, N35
800	*Taraxacum* sect. *Erythrosperma* Dahlst.	N19, N27, N35, N38
801	*Taraxacum janchenii* Kirschner & Štěpánek	N18
802	*Taraxacum* sect. *Taraxacum* F.H.Wigg.	N3, N13, N18, N31, N34
803	*Taraxacum paludosum* (Scop.) Crépin[4]	N39
804	*Telekia speciosa* (Schreb.) Baumg.[2, 3, 4]	N12, N16
805	*Tephroseris papposa* (Rchb.) Schur[4]	N18, N27, N37, N38
806	*Teucrium chamaedrys* L.	N13, N19, N26-N28, N31, N34, N38
807	*Teucrium montanum* L.	N19, N43, N45
808	*Thalictrum minus* L.	N26-N28, N34, N46
809	*Thalictrum simplex* L.[4]	N29, N39
810	*Thesium linophyllon* L.	N19, N27
811	*Thesium parnassi* A.DC.[2, 3, 4]	N38
812	*Thliphthisa purpurea* (L.) P.Caputo & Del Guacchio	N13, N34, N46
813	*Thymus jankae* Čelak.[1, 4]	N13, N19, N34, N39
814	*Thymus longicaulis* C. Presl	N7, N13, N19, N27, N35, N39

No	Species	Localities
815	*Thymus pulegioides* L.	N4, N31, N34
816	*Thymus striatus* Vahl. subsp. *acicularis* (Waldst. & Kit.) Ronniger	N7
817	*Tilia cordata* Mill.	N4, N5, N9
818	*Tilia tomentosa* Moench	N23
819	*Torilis japonica* (Houtt.) DC.	N13, N31
820	*Torminalis glaberrima* (Gand.) Sennikov & Kurtto	N1, N10, N14, N28, N34
821	*Tragopogon balcanicus* Velen.[4]	N7, N19
822	*Tragopogon orientalis* L.	N13, N19, N27, N34
823	*Traunsteinera globosa* (L.) Rchb.[2,4]	N40
824	*Trifolium alpestre* L.	N18, N27, N37, N38
825	*Trifolium arvense* L.	N13, N18, N19, N27, N43
826	*Trifolium campestre* Schreb.	N7, N19, N27, N35, N46
827	*Trifolium dalmaticum* Vis.[1,4]	N18
828	*Trifolium incarnatum* L.	N19
829	*Trifolium medium* L.	N21, N28, N31, N35
830	*Trifolium montanum* L.	N13, N19, N27, N34, N39
831	*Trifolium pannonicum* Jacq.	N4, N37
832	*Trifolium patulum* Tausch	N7, N10, N13, N14, N31, N34, N38
833	*Trifolium pratense* L.	N13, N15, N31, N34, N46
834	*Trifolium repens L.*	N19, N39
835	*Trifolium striatum* L.	N27
836	*Trinia glauca* (L.) Dumort.	N40, N45
837	*Tripleurospermum inodorum* (L.) Sch.Bip.	N13
838	*Trollius europaeus* L.[2,4]	N39, N40
839	*Turritis glabra* L.	N35
840	*Tussilago farfara* L.	N3, N21, N22, N24, N31, N34, N46
841	*Typha latifolia* L.	N46
842	*Ulmus glabra* Huds.	N5, N22, N41
843	*Ulmus minor* Mill.	N6, N10, N35
844	*Urtica dioica* L.	N12, N16, N18, N20, N24, N39
845	*Vaccinium myrtillus* L.	N38
846	*Valeriana* × *braunii-blanquetii* Lakušić[1]	N45
847	*Valeriana montana* L.	N28
848	*Valeriana officinalis* L. subsp. *officinalis*	N3, N21-N24, N26
849	*Valeriana rimosa* (Bastard) Christenh. & Byng	N27
850	*Valeriana stolonifera* Czern. subsp. *angustifolia* Soó	N28
851	*Valeriana tuberosa* L.	N7, N19, N38, N43
852	*Veratrum album* L.	N39, N40
853	*Veratrum nigrum* L.	N18, N26, N28, N30, N40
854	*Verbascum lanatum* Schrad. subsp. *lanatum*	N13, N15, N38
855	*Verbascum lychnitis* L.	N18, N46
856	*Verbascum nigrum* L.	N14, N26, N27
857	*Verbena officinalis* L.	N34
858	*Veronica arvensis* L.	N19, N27, N40
859	*Veronica austriaca* L. subsp. *jacquinii* (Baumg.) Watzl	N19, N27, N28, N34

No	Species	Localities
860	*Veronica beccabunga* L.	N41, N46
861	*Veronica chamaedrys* L.	N1, N4, N13, N14, N17, N19, N24, N26, N31, N32, N35, N39
862	*Veronica fruticans* Jacq.[2, 4]	N43, N45
863	*Veronica montana* L.	N12, N16, N20
864	*Veronica officinalis* L.	N4, N13, N24, N35, N38
865	*Veronica persica* Poir.	N35
866	*Veronica scutellata* L.4	N39
867	*Veronica serpyllifolia* L.	N13, N20, N35, N39
868	*Veronica teucrium* L.	N39
869	*Veronica urticifolia* Jacq.	N32, N36
870	*Viburnum lantana* L.	N4, N6, N8, N9-N11, N26, N31, N33, N34
871	*Viburnum opulus* L.	N9, N20, N22, N24, N31
872	*Vicia cracca* L.	N1, N13, N31, N34
873	*Vicia grandiflora* Scop.	N10, N34
874	*Vicia hirsuta* (L.) Gray	N35
875	*Vicia incana* Gouan	N3, N18, N27-N29, N34, N39
876	*Vicia lathyroides* L.	N18, N39
877	*Vicia onobrychioides* L.	N27
878	*Vicia sativa* L. subsp. *cordata* (Wulfen ex Hoppe) Batt.	N27, N28, N31
879	*Vicia sativa* L. subsp. *nigra* Ehrh.	N27, N35
880	*Vicia sativa* L. subsp. *sativa*	N27
881	*Vicia sepium* L.	N3, N4, N6, N13, N14, N26-N28, N31, N35
882	*Vicia sylvatica* L.	N31
883	*Vicia tetrasperma* (L.) Schreb.	N18, N27
884	*Vincetoxicum fuscatum* (Hornem.) Endl.	N18, N27
885	*Vincetoxicum hirundinaria* Medik.	N45
886	*Viola alba* Besser subsp. *alba*	N22
887	*Viola arvensis* Murray	N18, N27
888	*Viola canina* L.	N37, N39
889	*Viola hirta* L.	N4, N11
890	*Viola odorata* L.	N1
891	*Viola elegantula* Schott[1, 2, 3, 4]	N18
892	*Viola reichenbachiana* Jord. ex Boreau	N1, N4, N13, N21, N26, N28, N29, N31-N33
893	*Viola riviniana* Rchb.	N5, N9, N34, N38
894	*Viola suavis* M. Bieb.	N6, N13, N19, N28, N34
895	*Viola tricolor* L.	N13, N27, N37, N39
896	*Viscaria vulgaris* Bernh.	N38
897	*Viscum album* L. subsp. *album*	N18
	Zalomka River valley	
	Bryoflora	
1	*Abietinella abietina* (Hedw.) M. Fleisch.	Z4
2	*Alleniella besseri* (Lobarz.) S. Olsson, Enroth & D. Quandt	Z2
3	*Alleniella complanata* (Hedw.) S. Olsson, Enroth & D. Quandt	Z2, Z4
4	*Anomodon viticulosus* (Hedw.) Hook. & Taylor	Z4

No	Species	Localities
5	*Aulacomnium palustre* (Hedw.) Schwägr.	Z3
6	*Brachythecium mildeanum* (Schimp.) Schimp.	Z2
7	*Brachythecium rutabulum* (Hedw.) Schimp.	Z3
8	*Chiloscyphus polyanthos* (L.) Corda	Z2
9	*Cololejeunea calcarea* (Lib.) Steph.	Z2
10	*Conocephalum salebrosum* Szweyk., Buczk. & Odrzyk.	Z2
11	*Distichium capillaceum* (Hedw.) Bruch & Schimp.	Z2
12	*Exsertotheca crispa* (Hedw.) S. Olsson, Enroth & D. Quandt	Z2
13	*Fissidens gracilifolius* Brugg.-Nann. & Nyholm	Z2
14	*Flexitrichum gracile* (Mitt.) Ignatov & Fedosov	Z2
15	*Homalia trichomanoides* (Hedw.) Brid.	Z2
16	*Hypnum cupressiforme* var. *cupressiforme* Hedw.	Z4
17	*Jungermannia atrovirens* Dumort.	Z2
18	*Mesoptychia bantriensis* (Hook.) L. Söderstr. & Váňa	Z2
19	*Neckera menziesii* Drumm.	Z2
20	*Orthothecium intricatum* (Hartm.) Schimp.	Z2
21	*Orthothecium rufescens* (Brid.) Schimp.	Z2
22	*Oxyrrhynchium hians* (Hedw.) Loeske	Z2
23	*Pedinophyllum interruptum* (Nees) Kaal.	Z2
24	*Plagiomnium rostratum* (Schrad.) T. J. Kop.	Z2
25	*Plagiomnium undulatum* (Hedw.) T. J. Kop.	Z2, Z4
26	*Pseudanomodon attenuatus* (Hedw.) Ignatov & Fedosov	Z2
27	*Seligeria trifaria* (Brid.) Lindb.	Z2
28	*Solenostoma hyalinum* (Lyell) Mitt.	Z2
29	*Sphagnum auriculatum* Schimp.	Z3
30	*Sphenolobus minutus* (Schreb.) Berggr.	Z2
31	*Thamnobryum alopecurum* (Hedw.) Gangulee	Z2
32	*Thuidium delicatulum* (Hedw.) Schimp.	Z4
	Vascular flora	
33	*Acer campestre* L.	Z1, Z7-Z11
34	*Acer pseudoplatanus* L.	Z7
35	*Acer tataricum* L.	Z5
36	*Achillea millefolium* L. subsp. *millefolium*	Z8
37	*Aegonychon purpurocaeruleum* (L.) Holub	Z10
38	*Aegopodium podagraria* L.	Z11
39	*Agrimonia eupatoria* L.	Z8, Z9, Z11
40	*Agrostis stolonifera* L.	Z9, Z11
41	*Ajuga reptans* L.	Z10
42	*Alisma plantago-aquatica* L.	Z8
43	*Alliaria petiolata* (M.Bieb.) Cavara & Grande	Z11
44	*Alopecurus pratensis* L.	Z8
45	*Anemone nemorosa* L.	Z1, Z5, Z7
46	*Angelica sylvestris* L.	Z11
47	*Anthriscus sylvestris* (L.) Hoffm.	Z1, Z8, Z11
48	*Aremonia agrimonoides* (L.) DC.	Z7, Z10

No	Species	Localities
49	*Aristolochia pallida* Willd.	Z10
50	*Asplenium trichomanes* L.	Z7
51	*Astrantia major* L.	Z1, Z10
52	*Barbarea vulgaris* W. T. Aiton	Z8, Z11
53	*Brachypodium pinnatum* (L.) P. Beauv.	Z1, Z10
54	*Brachypodium sylvaticum* (Huds.) P. Beauv.	Z10, Z11
55	*Bunium alpinum* Waldst. et Kit. subsp. *montanum* (W. D. J. Koch) P. W. Ball	Z1, Z10
56	*Campanula trachelium* L.	Z1, Z7
57	*Cardamine bulbifera* (L.) Crantz	Z1, Z7
58	*Cardamine impatiens* L.	Z6, Z8, Z9, Z11
59	*Carex acutiformis* Ehrh.	Z8, Z11
60	*Carex brizoides* L.	Z5
61	*Carex flacca* Schreb. subsp. *flacca*	Z10
62	*Carex hirta* L.	Z11
63	*Carex spicata* Huds.	Z8
64	*Carex sylvatica* Huds.	Z7
65	*Carpinus betulus* L.	Z5, Z9, Z10
66	*Carpinus orientalis* Mill.	Z1
67	*Carum carvi L.*	Z11
68	*Centaurea jacea* L. subsp. *jacea*	Z6, Z8, Z9, Z11
69	*Cerastium sylvaticum* Waldst. et Kit.	Z11
70	*Chaerophyllum hirsutum* L.	Z11
71	*Chamaecytisus hirsutus* (L.) Link	Z5
72	*Clematis vitalba* L.	Z1, Z9, Z11
73	*Clinopodium menthifolium* (Host) Merino	Z10
74	*Clinopodium vulgare* L.	Z1, Z5, Z10
75	*Cnidium silaifolium* (Jacq.) Simonk.	Z10
76	*Colchicum autumnale* L.	Z8
77	*Cornus mas* L.	Z1, Z7, Z10
78	*Cornus sanguinea* L.	Z8, Z9, Z11
79	*Corylus avellana* L.	Z1, Z5, Z7-Z11
80	*Crataegus monogyna* Jacq.	Z1, Z5-Z11
81	*Cruciata glabra* (L.) Opiz	Z1, Z5, Z10, Z11
82	*Cruciata laevipes* Opiz	Z11
83	*Dactylis glomerata* L. subsp. *glomerata*	Z1, Z5, Z10, Z11
84	*Dichoropetalum carvifolia* (Vill.) Pimenov & Kljuykov	Z1, Z10, Z11
85	*Elymus repens* (L.) Gould	Z8
86	*Epilobium hirsutum* L.	Z11
87	*Equisetum arvense* L.	Z8, Z11
88	*Euonymus europaeus* L.	Z1, Z6, Z8, Z9-Z11
89	*Euphorbia amygdaloides* L.	Z10
90	*Fagus sylvatica* L.	Z7
91	*Festuca heterophylla* Lam.	Z1, Z5, Z10
92	*Filipendula vulgaris* Moench	Z1, Z10
93	*Fragaria vesca* L.	Z5

No	Species	Localities
94	*Fraxinus excelsior* L.	Z1, Z8, Z11
95	*Fraxinus ornus* L.	Z7, Z10
96	*Galium mollugo* L.	Z6, Z8, Z9, Z11
97	*Galium palustre* L.	Z11
98	*Galium verum* L.	Z8
99	*Geranium robertianum* L.	Z7, Z11
100	*Geranium sanguineum* L.	Z10
101	*Geum urbanum* L.	Z9, Z11
102	*Hedera helix* L.	Z7, Z9
103	*Helleborus multifidus* Vis.[1, 2, 3, 4]	Z1, Z5, Z7, Z10
104	*Heracleum sphondylium* L.	Z11
105	*Hieracium racemosum* Waldst. & Kit. ex Willd.	Z10
106	*Holcus lanatus* L.	Z5
107	*Humulus lupulus* L.	Z8, Z9, Z11
108	*Hypochaeris maculata* L.	Z1
109	*Iris graminea* L.	Z10
110	*Lactuca muralis* (L.) Gaertn.	Z1, Z7
111	*Lamium galeobdolon* (L.) Crantz	Z7
112	*Lamium maculatum* (L.) L.	Z11
113	*Lapsana communis* L.	Z9, Z11
114	*Laser trilobum* (L.) Borkh.[2, 4]	Z7
115	*Lathyrus niger* (L.) Bernh.	Z1, Z5, Z10
116	*Lathyrus venetus* (Mill.) Wohlf.	Z1, Z7, Z10
117	*Lilium martagon* L.	Z7
118	*Linaria vulgaris* Mill.	Z9
119	*Lolium giganteum* (L.) Darbysh.	Z6, Z9
120	*Lolium pratense* (Huds.) Darbysh.	Z8
121	*Lonicera caprifolium* L.	Z10
122	*Lotus corniculatus* L.	Z9
123	*Luzula forsteri* (Sm.) DC.	Z10
124	*Lysimachia nummularia* L.	Z8, Z9, Z11
125	*Lythrum salicaria* L.	Z11
126	*Malus sylvestris* (L.) Mill.	Z1, Z10
127	*Melampyrum bihariense* A. Kern.	Z5
128	*Melica uniflora* Retz.	Z1, Z10
129	*Melittis melissophyllum* L.	Z1, Z10
130	*Mentha aquatica* L.	Z8, Z11
131	*Mentha longifolia* (L.) L.	Z8, Z11
132	*Moehringia trinervia* (L.) Clairv.	Z11
133	*Neottia nidus-avis* (L.) Rich.	Z10
134	*Oenanthe silaifolia* M. Bieb.	Z8
135	*Ostrya carpinifolia* Scop.	Z7
136	*Paeonia officinalis* L.[2, 3]	Z7
137	*Pastinaca sativa* L.	Z11

No	Species	Localities
138	*Pentanema salicinum* (L.) D.Gut.Larr., Santos-Vicente, Anderb., E.Rico & M.M.Mart.Ort.	Z10
139	*Peucedanum austriacum* (Jacq.) W. D. J. Koch	Z10
140	*Peucedanum oreoselinum* (L.) Moench	Z1
141	*Picris hieracioides* L.	Z11
142	*Pimpinella major* (L.) Huds.	Z11
143	*Pimpinella saxifraga* L.	Z8
144	*Plantago lanceolata* L.	Z8
145	*Plantago major* L.	Z8
146	*Platanthera chlorantha* (Custer) Rchb.	Z10
147	*Poa angustifolia* L.	Z7, Z9
148	*Poa trivialis* L.	Z6, Z8, Z9, Z11
149	*Polygonatum multiflorum* (L.) All.	Z1
150	*Potentilla reptans* L.	Z8, Z9, Z11
151	*Primula veris* L. subsp. *columnae* (Ten.) Maire & Petitm.	Z1, Z5
152	*Primula vulgaris* Huds.	Z7, Z10
153	*Prunella vulgaris* L.	Z9, Z11
154	*Prunus avium* (L.) L.	Z1, Z5, Z10
155	*Prunus spinosa* L.	Z10, Z11
156	*Pteridium aquilinum* (L.) Kuhn	Z1
157	*Pyrus communis* L. subsp. *communis*	Z7, Z8, Z10
158	*Quercus cerris* L.	Z1, Z5, Z7, Z10
159	*Rabelera holostea* (L.) M.T.Sharples & E.A.Tripp	Z1, Z7
160	*Ranunculus ficaria* L.	Z9
161	*Ranunculus repens* L.	Z8, Z9, Z11
162	*Rosa arvensis* Huds.	Z1, Z5-Z11
163	*Rubus caesius* L.	Z6, Z8, Z11
164	*Rumex acetosa* L.	Z8
165	*Rumex crispus* L.	Z6, Z8, Z9, Z11
166	*Salix alba* L.	Z8, Z11
167	*Salix eleagnos* Scop.	Z8, Z9, Z11
168	*Salix purpurea* L.	Z6, Z8, Z9, Z11
169	*Salix triandra* L.	Z11
170	*Sanguisorba minor* Scop.	Z11
171	*Scilla litardierei* Breistr.[1, 2, 3, 4]	Z8
172	*Scutellaria altissima* L.	Z11
173	*Sedum hispanicum* L.	Z11
174	*Sesleria autumnalis* (Scop.) F. W. Schultz	Z7, Z10
175	*Silene coronaria* (L.) Clairv.	Z5
176	*Silene italica* (L.) Pers.	Z1, Z5
177	*Silene latifolia* Poir.	Z1, Z9
178	*Silene vulgaris* (Moench) Garcke	Z8, Z9, Z11
179	*Smyrnium perfoliatum* L.	Z1, Z11
180	*Solanum dulcamara* L.	Z8
181	*Symphytum tuberosum* L.	Z1, Z5, Z10

No	Species	Localities
182	*Taraxacum officinale* F. H. Wigg. agg.	Z6, Z8, Z9, Z11
183	*Thalictrum minus* L.	Z6, Z8
184	*Torminalis glaberrima* (Gand.) Sennikov & Kurtto	Z10
185	*Tragopogon orientalis* L.	Z8, Z9
186	*Trifolium alpestre* L.	Z1, Z10
187	*Trifolium pratense* L.	Z11
188	*Trifolium repens L.*	Z8
189	*Tussilago farfara* L.	Z11
190	*Urtica dioica* L.	Z6, Z9, Z11
191	*Valeriana officinalis* L. subsp. *officinalis*	Z6, Z9
192	*Veronica chamaedrys* L.	Z5, Z10
193	*Veronica officinalis* L.	Z7, Z10
194	*Veronica serpyllifolia* L.	Z9, Z11
195	*Vicia cracca* L.	Z1, Z5
196	*Vicia grandiflora* Scop.	Z10
197	*Vicia sepium* L.	Z1
198	*Viola alba* Besser subsp. *alba*	Z1, Z10
199	*Viola reichenbachiana* Jord. ex Boreau	Z5, Z7
200	*Viscaria vulgaris* Bernh.	Z5

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0I nternational License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 66–80
»Neretva Science Week 2023«

ZNANSTVENI ČLANEK /
SCIENTIFIC PAPER

DOI: 10.14720/ns.19740
Objavljeno na spletu / Published online: 8. 11. 2025

Prejeto / Received: 6. 9. 2024
Sprejeto / Accepted: 4. 2. 2025

Study of riparian forest and scrub vegetation of the Zalomka and Upper Neretva Rivers (Bosnia and Herzegovina)

*Vladimir STUPAR**,
Jugoslav BRUJIĆ,
Dragan KOLJANIN

University of Banja Luka, Faculty of Forestry, P. Bojovića 1A, 78000 Banja Luka, Bosnia and Herzegovina; E-mails: vladimir.stupar@sf.unibl.org, jugoslav.brujić@sf.unibl.org, dragankoljanin1@gmail.com

* Korespondenčni avtor / Corresponding author

KEY WORDS:

Alnus rohlenae, ecological classification, EU Habitats Directive, phytosociology, riparian vegetation, *Salix eleagnos*, syntaxonomy

KLJUČNE BESEDE:

Alnus rohlenae, ekološka klasifikacija, EU habitatna direktiva, fitosociologija, obrežna vegetacija, *Salix eleagnos*, sintaksonomija

KLJUČNE RIJEČI:

Alnus rohlenae, ekološka klasifikacija, EU Direktiva o staništima, fitocenologija, priobalna vegetacija, *Salix eleagnos*, sintaksonomija

ABSTRACT

This study investigates the riparian forest and scrub vegetation along the Zalomka and Upper Neretva rivers in Bosnia and Herzegovina (BiH). Despite the ecological significance of these rivers' riparian zones, they remain underexplored, particularly regarding their floristic composition and ecological dynamics. We conducted a short-term phytosociological study in June 2023, using the Central European phytosociological method to collect and analyze 17 relevés from these riverine environments. Statistical classification identified five ecologically and floristically distinct clusters, ranging from pioneer scrub communities dominated by *Salix eleagnos* and *Salix purpurea* on gravel bars, over riparian forests on finer sediment dominated by *Salix alba* and/or *S. euxina* and *Alnus rohlenae*, to *Salix eleagnos* scrub communities with diverse mesophilous and thermophilous species. The study provides a preliminary syntaxonomical framework, assigning these clusters into relevant alliances. The findings highlight the need for further research to refine the classification and support the conservation of these unique riparian habitats, several of which are listed in the EU Habitats Directive. The study contributes to a better understanding of riparian ecosystems in the Dinaric Alps, offering insights into their conservation and management.

IZVLEČEK

Študija obrežne gozdne in grmičaste vegetacije Zalomke in gornje Neretve (Bosna in Hercegovina)

V prispevku obravnavamo obrežno gozdno in grmičasto vegetacijo vzdolž rek Zalomke in gornje Neretve v Bosni in Hercegovini (BiH). Kljub izjemnemu ekološkemu pomenu, floristična sestava in ekološka dinamika obrežnih območij obravnavanih rek ni zadostno raziskana. Junija 2023 smo izvedli kratkotrajno fitocenološko študijo po srednjeevropski metodi, in zbrali ter analizirali 17 fitocenoloških popisov iz rečnih okolij gornje Neretve in Zalomke. Statistično smo opredelili pet ekološko in floristično različnih skupin, od prvih grmičev, v katerih prevladujeta *Salix eleagnos* in *Salix purpurea* na prodiščih, preko obrežnih gozdov na drobnejših usedlinah, v katerih prevladujeta *Salix alba* in/ali *S. euxina* in *Alnus rohlenae*, do grmičevih združb *Salix eleagnos* z raznolikimi mezofilnimi in termofilnimi vrstami. Študija zagotavlja predhodni sintaksonomski okvir, ki te skupine razvršča v ustrezne skupine. Rezultati kažejo, da so nujne nadaljnje raziskave za izboljšanje klasifikacije in podporo ohranjanju teh edinstvenih obrežnih habitatov, od katerih jih je več navedenih v Direktivi o habitatih EU. Študija prispeva k boljšemu razumevanju obrečnih ekosistemov v Dinarskem gorstvu ter ponuja vpogled v njihovo ohranjanje in upravljanje.

APSTRAKT

Studija vegetacije riječnih šuma i šibljaka rijeke Zalomke i gornjeg toka rijeke Neretve (Bosna i Hercegovina)

U radu se razmatra vegetacija priobalnih šuma i šibljaka duž rijeke Zalomke i gornjeg toka rijeke Neretve u Bosni i Hercegovini (BiH). Uprkos ekološkom značaju ovih priobalnih zona, ipak su ostale neistražene, naročito ako govorimo o florističkom sastavu i ekološkoj dinamici. Proveli smo kratkoročnu fitocenološku

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

studiju u junu 2023. godine, koristeći srednjeevropski fitocenološki metod da bismo sakupili i analizirali 17 fitocenoloških snimaka ovih riječnih staništa. Statistička klasifikacija identifikovala je pet posebnih ekoloških i florističkih klastera, rangiranih od pionirskih zajednica u kojima dominiraju *Salix eleagnos* i *Salix purpurea* na šljunčanim sprudovima, preko priobalnih šuma na sitnijem sedimentu u kojima dominiraju vrste *Salix alba* i/ili *S. euxina* i *Alnus rohlenae*, pa sve do *Salix eleagnos* zajednica sa različitim mezofilnim i termofilnim vrstama. Studija pruža preliminarni sintaksonomski okvir koji ove klastere svrstava u relevantne sveze. Rezultati ističu potrebu za daljim istraživanjima kako bi se jasnije definisala klasifikacija i podržalo očuvanje ovih jedinstvenih priobalnih staništa, od kojih je nekoliko navedeno u Direktivi o staništima EU. Studija doprinosi boljem razumijevanju priobalnih ekosistema u Dinaridima i nudi uvid u njihovo očuvanje i upravljanje.

INTRODUCTION

Riparian zones represent vital ecological systems that support high biodiversity and offer essential ecosystem services, including flood regulation, water filtration, and habitat provision (Riis et al. 2020). These areas are particularly significant in dynamic riverine environments with varying hydrological conditions, such as fast flowing, small to medium sized montane streams, where periodic flooding, drying and sediment deposition create unique conditions for the development of diverse vegetation communities, which often have patchy and mosaic distribution pattern. Riparian forests and scrubs, especially in mountainous and submontane areas, have been recognized as crucial for maintaining the structural and functional integrity of aquatic and terrestrial ecosystems (Gregory et al. 1991). Several habitats of this type are listed under the EU Habitats Directive (EC 1992) which highlights the relevance of these habitats in the context of European biodiversity conservation. They are classified as vulnerable in the European Red List of Habitats, based on the criterion of a large reduction in the habitat area over the last 50 years (Janssen et al. 2016).

Although there are some recent contributions to the knowledge of riparian vegetation of BiH (Milanović & Stupar 2017; Koljanin et al. 2023), riparian vegetation along the fast flowing montane and submontane streams in Bosnia and Herzegovina (BiH) remains relatively underexplored, especially in the context of its ecology and syntaxonomical classification. Several studies from the past mentioned this type of vegetation from Treskavica and Bjelašnica Mts. (Fukarek 1957), Vranica Mt. (Lakušić et al. 1979), Čemernica Mt. (Redžić et al. 1986), Neretva River valley (Redžić et al. 1992), but with very little detail – only one relevé was published until present (Redžić et al. 1992), leaving a knowledge gap concerning their floristic composition, ecology and dynamics (Milanović & Stupar 2019). The upper Neretva River valley, along with the neighboring Zalomka River, are no exception to this, as they have received no attention in the past.

By conducting a short term phytosociological study along the upper Neretva River and the Zalomka River, we aimed to identify and classify the present plant communities, assess their relationship with environmental factors such as soil reaction, moisture, light, and nutrients, and provide a preliminary syntaxonomical framework for these communities. Given the ecological importance of riparian zones and limited research in BiH, our findings aim to enhance understanding and support their conservation and management.

MATERIAL AND METHODS

STUDY AREA

The study was conducted over a few days in early June 2023 in the riparian tree and scrub vegetation of the Upper Neretva River valley from Tuhobić to Ulog (elevation ranges between 650 and 700 m), as well as along the Zalomka River from the headwaters near Fojnica to the Ponor sink in Biograd (Nevesinjsko polje; elevation ranges between 650 and 700 m) (Fig. 1). The study included narrow streamside forests, gravel bar formations or woodland of wider floodplains, dominated by any of the following species: *Alnus rohlenae*, *Salix alba*, *Salix euxina*, *Salix eleagnos* and *Salix purpurea*. In this upper section, Neretva is fast and flows in a gravel bed, mostly through narrow steep valleys, flat flood plains are rare and small. In the upstream half of its stream, the Zalomka River is similar, mainly a gravel-bed river. At Kifino Selo, the Zalomka enters Nevesinjsko Polje and continues across mostly smooth terrain up to its termination at the Ponor sink. The sediments in this part consist of much finer gravel, sand and mud. The main hydrological difference between these two rivers is that Neretva is permanent, while Zalomka is an intermittent river for most of its course, with an average of 213 active days per year at the Rilja section (the first quarter of its course) (Milanović 2023).

DATA COLLECTION AND ANALYSIS

Field sampling was conducted using the Central European phytosociological method (Braun-Blanquet 1964). A total of 17 relevés were collected in the field (Tab. 1). During sampling, the vertical structure was recorded across seven vegetation layers: upper tree layer (A1 > 20 m), middle tree layer (A2 < 20 m and > 10 m), lower tree layer (A3 < 10 m and > 5 m), upper shrub layer (B1 < 5 m and > 1.5 m), lower shrub layer (B2 < 1.5 m), herb layer (C), and moss layer (D). For numerical analysis, all layers were merged into a single layer, except the

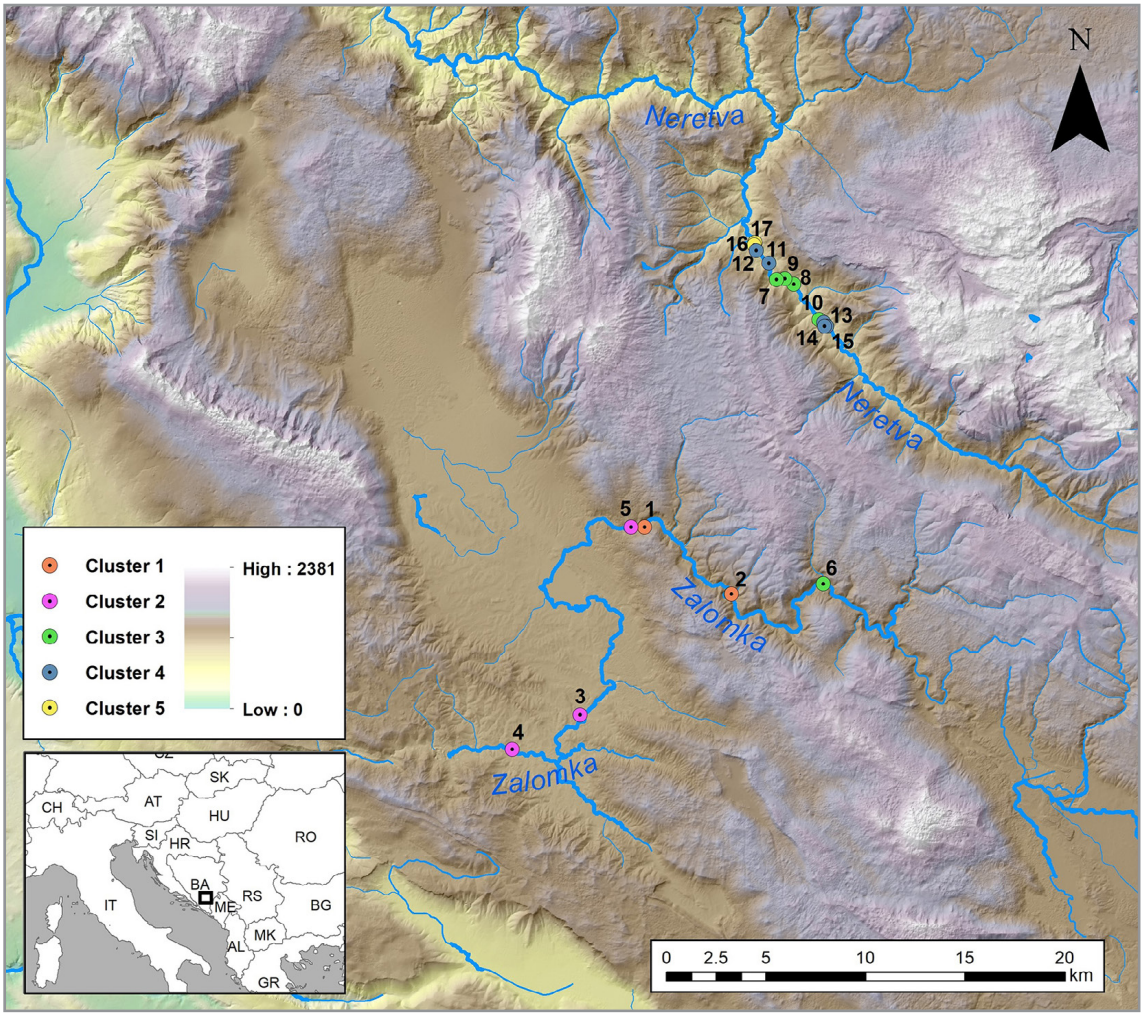

Figure 1. Study area with the location of the relevés. Relevé numbers correspond to those in Tabs. 1–2 and Fig. 2.

Slika 1. Preučevano območje z lokacijami fitocenoloških popisov. Oznake popisov so enake kot v tabelah 1 in 2 ter na sliki 2.

Slika 1. Područje istraživanja sa lokacijama fitocenoloških snimaka. Oznake snimaka su iste kao u tabelama 1 i 2 i na slici 2.

moss layer which was excluded due to inconsistent sampling. The original layers were retained for use in the text and relevés summary table (Tab. 2).

The hierarchical classification of dataset was conducted with the TWINSPAN algorithm (Hill 1979), employing three pseudo-species cut levels (0, 5, 25), a minimum group size of two, and a maximum division level of three. At the third level, all neighboring clusters were merged, except for clusters four and five, resulting in five clusters that, at conceptual level, we considered as associations or subassociations, and interpreted them ecologically and floristically (Fig. 2).

Diagnostic species for the clusters were identified using the species fidelity measure (phi value; Chytrý et al. 2002) in the JUICE software (Tichý 2002). Fischer's exact test was also applied, assigning a phi value of zero to species with $P > 0.05$. A threshold phi value was arbitrarily set to 0.50 for a species to be considered diagnostic.

Ordination analysis was performed using R software (R 2019) to examine patterns in floristic composition. All relevés were plotted in a nonmetric multidimensional scaling (NMDS) ordination space based on the Bray-Curtis distance measure, with plant species cover data square-root transformed to reduce the influence of dominant species. Species ecological indicator values (EIVs) for temperature, light, moisture, soil reaction, and nutrients (Pignatti et al. 2005) were first averaged across species for each relevé and then laid over the NMDS plot to reveal potential ecological gradients influencing vegetation patterns (Fig. 2). The strength and significance of correlations between EIVs and NMDS relevé scores were tested using the Kendall tau coefficient in Statistica software (StatSoft, Inc. 2014).

Taxonomy and nomenclature of vascular plants followed Stupar et al. (2021), while syntaxonomical concepts and nomenclature of higher syntaxa, as well as species affiliation to syntaxonomic classes (as given in Tab. 2) followed (Mucina et al. 2016).

Table 1. Localities, coordinates and dates of the recorded relevés. Relevé numbers correspond to those in Tab. 2 and Figs. 1–2.
Tabela 1. Lokacije, koordinate in datumi izvedenih fitocenoloških popisov. Oznake popisov ustrezajo tabeli 2 ter slikama 1 in 2.
Tabela 1. Lokacije, koordinate i datumi zabilježenih fitocenoloških snimaka. Oznake snimaka odgovaraju tabeli 2 i slikama 1 i 2.

Relevé no.	Locality	Latitude	Longitude	Date
1	Zalomka, Vranovine	43.285553	18.241846	2. 6. 2023
2	Zalomka, Rilje	43.255530	18.299402	3. 6. 2023
3	Zalomka, upstream from Gvozdeni most	43.201033	18.205837	4. 6. 2023
4	Zalomka, upstream from Biogradski most	43.185420	18.163859	4. 6. 2023
5	Zalomka, Vranovine	43.285879	18.241329	2. 6. 2023
6	Zalomka, Slivlja	43.25984	18.356402	3. 6. 2023
7	Neretva, Jezero	43.397731	18.328138	2. 6. 2023
8	Neretva, Ćetović	43.395591	18.338869	2. 6. 2023
9	Neretva, Ćetović	43.398082	18.333250	2. 6. 2023
10	Neretva, Tuhobići	43.379448	18.354495	4. 6. 2023
11	Neretva, k. 648	43.405176	18.323485	1. 6. 2023
12	Neretva, Ulog	43.410822	18.315616	1. 6. 2023
13	Neretva, Tuhobići	43.378151	18.357191	4. 6. 2023
14	Neretva, Tuhobići	43.376479	18.357853	4. 6. 2023
15	Neretva, Tuhobići	43.376353	18.359123	4. 6. 2023
16	Neretva, Ulog	43.413317	18.314367	1. 6. 2023
17	Neretva, Ulog	43.414570	18.314840	1. 6. 2023

RESULTS AND DISCUSSION

CLASSIFICATION AND ORDINATION

Numerical classification resulted in five floristically separate clusters (Fig. 2, Tab. 2), which were also ecologically distinct: relatively open scrub communities dominated by bitter (*Salix eleagnos*) and/or red willow (*S. purpurea*), up to five meters in height, developed mainly over gravel bars of Zalomka River (clusters 1 and 2) and, higher stands dominated by *Salix alba* and/or *S. euxina* or by *Alnus rohlenae* above finer sediments, mainly in Neretva River valley (clusters 3 and 4). Transitional, dry and thermophilous, scrub dominated by *S. elaeagnos* and other mesophilous and thermophilous shrubs and trees on slopes were classified in cluster 5. Each group was distinguished by a unique floristic composition and clearly defined lists of diagnostic species (Tab. 2). Results of the cluster analysis were confirmed by NDMS (Fig. 2), which also identified the main ecological factors driving the variation in the floristic composition, namely light and soil reactions that were positively correlated to the first axis of the two-dimensional ordination. On the other hand, nutrients, moisture and temperature emerged as significant for the cluster differentiation along the second gradient (first two being positively correlated to the second axis, while the last one negatively) (Fig. 2). The suggested syntaxonomic interpretation of the clusters is:

SALICETEA PURPUREAE, SALICETALIA PURPUREAE

Salicion eleagno-daphnoidis

1 – *Salix eleagnos-Salix purpurea* first stage pioneer community

2 – *Salix eleagnos-Salix purpurea* second stage pioneer community

ALNO GLUTINOSAE-POPULETEA ALBAE, ALNO-FRAXINETALIA EXCELSIORIS

Alnion incanae

3 – *Salix alba-Salix euxina* community

4 – *Alnus rohlenae* community

CRATAEGO-PRUNETEA, PRUNETALIA SPINOSAE

Berberidion vulgaris

5 – Thermophilous *Salix eleagnos* community

Table 2. Summary table of surveyed vegetation. Diagnostic species (phi values higher than 0.50) for each cluster are shaded. Cluster numbers correspond to those used throughout the text. Species affiliation to syntaxonomic classes is also given.

Tabela 2. Fitocenološka tabela popisane vegetacije. Diagnostične vrste za vsako skupino (vrednosti phi višje od 0,50) so osenčene. Oznake skupin so skladne z oznakami v besedilu. Podana je tudi vrstna pripadnost sintaksonomskim razredom.

Tabela 2. Fitocenološka tabela popisane vegetacije. Dijagnostičke vrste za svaku grupu (phi vrijednosti veće od 0,50) su zatamnjene. Oznake klastera odgovaraju oznakama u tekstu. Također je data pripadnost vrsta sinatksonomskim klasama.

Relevé number		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Altitude (m)		862	905	831	820	866	960	670	670	690	686	650	645	688	688	688	645	645
Total cover (%)		80	50	100	100	100	50	95	100	95	100	0	100	100	100	100	70	50
Mean vegetation height (m)		2	2	5	4	5	10	30	31	29	17	32	10	23	31	31	7	5
Rock cover		90	90	50	100	0	0	0	15	50	10	60	0	0	40	70	95	0
***Cluster 1 – Salix eleagnos-Salix purpurea* first stage pioneer community**																		
Salix eleagnos	B2	4	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Silene vulgaris	C	+	r	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Agrostis stolonifera	C	2	2	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+
***Cluster 2 – Salix eleagnos-Salix purpurea* second stage pioneer community**																		
Salix purpurea	B1	.	2	4	5	3	3	.	.	.	1	.	.	.	.	.	.	.
Taraxacum sect. *Taraxacum*	C	.	1	+	r	+	.	.	.	.	.	.	.	.	.	.	+	.
Centaurea jacea ssp. *angustifolia*	C	1	1	1	r	+	.	.	.	.	.	.	.	.	.	.	.	.
Rumex crispus	C	+	1	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Galium mollugo	C	1	3	3	2	2	1	.	.	.	.	.	.	.	.	.	.	.
***Cluster 3 – Salix alba-Salix euxina* community**																		
Salix alba	A1	.	.	.	.	.	.	4	2	5	4	1	.	.	.	.	.	.
Salix alba	A3	.	.	1	.	.	2	.	1	.	.	.	.	.	.	.	.	.
Salix alba	B1	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.
Salix alba	B2	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Salix euxina	A1	.	.	.	.	.	.	.	4	1	3	.	.	.	.	.	.	.
Salix euxina	A3	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Salix euxina	A2	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Salix euxina	B1	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Veronica montana	C	.	.	.	.	.	.	1	+	3	.	.	.	.	.	.	.	.
Scrophularia nodosa	C	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.
Cardamine bulbifera	C	.	.	.	.	.	.	+	+	+	+	.	.	+	+	.	.	.
Angelica sylvestris	C	.	.	.	.	.	1	1	+	1	.	.	.	.	.	.	+	.
Lysimachia nummularia	C	.	.	+	.	1	+	+	+	+	r	.	+	.	.	.	.	+
***Cluster 4 – Alnus rohlenae* community**																		
Alnus rohlenae	A1	.	.	.	.	.	.	.	.	.	2	4	.	5	5	5	.	.
Alnus rohlenae	A2	.	.	.	.	.	.	.	2	.	.	.	2	2	.	2	.	.
Alnus rohlenae	B1	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.
Alnus rohlenae	B2	.	.	.	.	.	.	.	.	.	.	+	.	.	r	.	+	.
Mercurialis perennis	C	.	.	.	.	.	.	+	.	.	.	+	+	1	1	.	.	.
Asperula taurina	C	.	.	.	.	.	.	.	.	+	.	+	+	+	1	.	.	.
Salvia glutinosa	C	.	.	.	.	.	.	.	.	.	.	+	.	.	+	r	.	.
Fraxinus ornus	B2	.	.	.	.	.	.	.	.	.	.	+	r	.	.	r	.	.
Dactylorhiza maculata	C	.	.	.	.	.	.	.	.	.	.	r	.	+	+	.	.	.
Aposeris foetida	C	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.
Melica uniflora	C	.	.	.	.	.	.	.	.	.	.	.	.	+	r	+	.	.
Allium ursinum	C	.	.	.	.	.	.	+	+	.	+	+	+	1	+	+	.	.
Acer pseudoplatanus	B2	.	.	.	.	.	.	+	.	.	1	+	1	.	1	+	.	.
Ligustrum vulgare	B2	.	.	.	.	.	.	.	.	.	.	+	+	.	r	r	.	+
Acer pseudoplatanus	C	.	.	.	.	.	.	+	.	.	.	+	+	+	+	.	r	.
Scutellaria altissima	B2	.	.	.	.	.	+	.	.	.	.	.	+	r	+	r	.	+
***Cluster 5* – Thermophilous *Salix eleagnos* community**																		
Salix eleagnos	A3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3
Carex flacca	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1
Salvia verticillata	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	r
Vicia sepium	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+
Carpinus orientalis	C	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	+	+
Salicetea purpureae																		
Urtica dioica	C	.	1	.	1	+	+	+	+	+	.	.	.	.	.	+	.	.
Salix purpurea	B2	3	1	1	1	1	2	.	.	.	+	.	.	.	.	.	.	.
Salix eleagnos	A2	.	.	.	.	.	.	.	.	.	3	.	3	.	.	.	.	.

Relevé number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Salix eleagnos	B1	.	4	+	.	5	2	.	.	.	1	.	.	.	.	.	.	+
Humulus lupulus	C	.	+	1	.	1	r	r	+	.	.	.	.	.	.	.	.	.
Salix triandra	C	.	.	.	.	.	.	.	.	.	.	.	.	.	r	+	.	.
Alnion incanae																		
Rubus caesius	B2	.	2	1	2	.	1	1	1	3	2	+	+	3	+	1	+	+
Ficaria verna	C	.	.	.	.	+	.	3	1	2	+	+	2	1	+	.	.	+
Aegopodium podagraria	C	.	.	.	.	.	1	.	.	2	1	.	3	1	+	+	.	+
Cardamine impatiens	C	+	+	+	+	.	1	.	+	+	.	.	.	.	.	.	.	.
Geum urbanum	C	.	.	.	.	+	1	.	+	+	+	.	1	+	.	.	.	.
Circaea lutetiana	C	.	.	.	.	.	.	+	1	2	.	.	+	+	+	.	.	.
Schenodorus giganteus	C	.	.	.	+	r	.	r	+	+	.	.	.	.	.	.	.	.
Chaerophyllum hirsutum	C	.	.	.	.	.	2	.	1	.	r	.	.	r	.	+	.	.
Petasites hybridus	C	.	.	.	.	.	.	2	4	3	.	.	.	.	.	2	.	.
Solanum dulcamara	C	.	.	+	.	.	.	.	+	.	.	.	.	.	.	+	.	.
Cerastium sylvaticum	C	.	.	.	.	.	r	.	.	.	.	.	.	+	.	+	.	.
Chaerophyllum aromaticum	C	.	.	.	.	.	.	+	.	.	+	.	.	.	r	.	.	.
Lamium maculatum	C	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.
Telekia speciosa	C	.	.	.	.	.	.	r	.	+	.	.	.	.	.	.	.	.
Stachys sylvatica	C	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.
Viburnum opulus	B2	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.
Glechoma hederacea	C	.	.	.	.	.	.	.	.	.	.	.	r	.	+	.	.	.
Galium palustre	C	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Moehringia trinervia	C	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Stellaria media	C	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Rumex sanguineus	C	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Galium aparine	C	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Equisetum telmateia	C	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Petasites albus	C	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Stellaria nemorum	C	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Neottia ovata	C	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.
Carpino-Fagetea																		
Acer campestre	A2	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Acer campestre	A3	.	.	.	.	.	.	.	.	2	.	.	1	.	.	1	.	.
Acer campestre	B1	.	.	.	.	.	2	1	.	1	.	.	.	1	1	.	.	.
Acer campestre	B2	.	.	1	.	+	2	+	r	+	r	+	+	.	+	+	.	1
Acer campestre	C	.	.	.	.	.	.	.	.	.	+	.	+	+	.	+	.	+
Fraxinus excelsior	A2	.	.	.	.	.	.	.	.	2	.	.	2	.	.	.	.	.
Fraxinus excelsior	A3	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	+
Fraxinus excelsior	B1	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	+
Fraxinus excelsior	B2	.	.	+	.	.	1	.	+	+	1	+	+	+	+	+	r	+
Fraxinus excelsior	C	.	.	.	.	.	.	.	.	.	+	.	+	.	.	+	.	.
Brachypodium sylvaticum	C	.	.	.	.	.	2	+	+	+	+	1	2	+	+	+	+	2
Rosa arvensis	B2	.	+	1	+	+	1	.	.	.	+	.	.	+	r	r	r	+
Clematis vitalba	C	.	+	.	.	1	1	.	+	.	+	1	+	.	+	+	1	+
Corylus avellana	A3	.	.	.	.	.	.	1	.	1	.	.	2	.	1	1	.	.
Corylus avellana	B1	.	.	.	.	.	.	.	.	.	+	.	.	+	+	.	.	.
Corylus avellana	B2	.	.	1	.	+	+	.	+	+	+	.	+	.	+	.	.	.
Geranium robertianum	C	.	+	.	.	.	2	.	.	r	+	.	.	+	.	+	.	.
Pulmonaria officinalis	C	.	.	.	.	.	.	+	.	+	.	.	+	+	+	.	.	+
Carpinus betulus	A2	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Carpinus betulus	A3	.	.	.	.	.	.	.	.	.	.	3	2	.	2	.	.	+
Carpinus betulus	B1	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	1
Carpinus betulus	B2	.	.	.	.	+	.	.	.	.	.	+	+	.	+	.	+	.
Carpinus betulus	C	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	+
Acer pseudoplatanus	A2	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Acer pseudoplatanus	A3	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.
Acer pseudoplatanus	B1	.	.	.	.	.	.	+	+	.	+	.	.	2	1	.	.	.
Arum maculatum	C	.	.	.	.	.	.	+	.	+	.	.	+	+	+	.	.	.
Fagus sylvatica	A3	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Fagus sylvatica	B1	.	.	.	.	.	.	.	.	.	+	1	+	.	.	1	.	.
Fagus sylvatica	B2	.	.	.	.	.	.	.	.	r	+	+	.	.	+	+	.	.
Fagus sylvatica	C	.	.	.	.	.	.	.	.	+	.	+	.	.	.	+	.	.
Sambucus nigra	A3	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.

Relevé number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Sambucus nigra	B1	.	.	.	.	.	.	+	+	.	.	.	.	+	1	.	.	.
Sambucus nigra	B2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.
Campanula trachelium	C	.	.	.	.	.	.	.	+	.	.	+	.	.	+	r	.	.
Glechoma hirsuta	C	.	.	.	.	.	.	.	.	.	r	.	+	1	.	.	.	r
Symphytum tuberosum	C	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	+
Helleborus odorus	C	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	+
Alliaria petiolata	C	.	1	.	.	.	1	.	+	.	.	.	.	.	.	.	.	.
Pyrus communis ssp. *pyraster*	B1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Pyrus communis ssp. *pyraster*	B2	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	+
Hedera helix	C	.	.	.	.	+	.	.	.	.	.	2	2	.	.	.	.	.
Ranunculus lanuginosus	C	.	.	.	.	.	.	.	r	.	.	.	r	+	.	.	.	.
Primula acaulis	C	.	.	.	.	.	.	.	.	r	.	.	+	.	.	.	.	+
Galium sylvaticum	C	.	.	.	.	.	.	.	.	.	+	.	+	.	.	r	.	.
Cicerbita muralis	C	.	.	.	.	.	.	.	.	.	+	.	.	+	.	+	.	.
Acer platanoides	B1	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Acer platanoides	B2	.	.	.	.	.	.	.	.	.	r	2	.	.	+	.	.	.
Solidago virgaurea	C	.	.	.	.	.	.	.	.	.	r	+	.	r	.	.	.	.
Asarum europaeum	C	.	.	.	.	.	.	.	.	.	r	.	.	r	+	.	.	.
Tilia cordata	B2	.	.	.	.	.	.	.	.	.	.	+	r	.	.	.	.	r
Euphorbia amygdaloides	C	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	+
Heracleum sphondylium	C	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.
Cruciata glabra	C	.	.	.	.	.	+	.	.	.	.	.	.	.	r	.	.	.
Poa nemoralis	C	.	.	.	.	.	.	.	+	.	.	.	.	r	.	.	.	.
Lamium galeobdolon	C	.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.
Polygonatum multiflorum	C	.	.	.	.	.	.	.	.	r	.	+	.	.	.	.	.	.
Carex sylvatica	C	.	.	.	.	.	.	.	.	r	.	.	r	.	.	.	.	.
Viola reichenbachiana	C	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	+
Rhamnus alpina ssp. *fallax*	B1	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	+	.
Rhamnus alpina ssp. *fallax*	C	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Viola riviniana	C	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.
Carex digitata	C	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+
Anemone nemorosa	C	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.
Malus sylvestris	B1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Malus sylvestris	B2	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Malus sylvestris	C	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.
Veronica chamaedrys	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	r
Lunaria rediviva	C	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Geranium phaeum	C	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Aruncus dioicus	C	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Sorbus aucuparia	A3	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Sorbus aucuparia	B1	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Aquilegia vulgaris	C	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.
Ulmus glabra	A3	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Ulmus glabra	B2	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Dryopteris filix-mas	C	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.
Lilium martagon	C	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Prunus avium	B2	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.
Paris quadrifolia	C	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Actaea spicata	C	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.
Daphne mezereum	C	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.
Isopyrum thalictroides	C	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.
Tilia tomentosa	C	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.
Knautia drymeia	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.
Molinio-Arrhenatheretea																		
Ajuga reptans	C	.	.	.	.	.	.	+	.	+	+	.	+	+	+	+	r	1
Poa trivialis	C	+	+	2	3	+	1	.	.	.	.	.	.	.	.	.	+	.
Ranunculus repens	C	.	2	+	.	+	+	+	.	.	+	.	.	.	.	.	.	.
Prunella vulgaris	C	.	.	.	.	+	+	+	.	.	+	.	+	.	.	+	.	.
Dactylis glomerata	C	.	.	.	.	.	1	.	.	+	+	.	+	.	.	+	.	+
Potentilla reptans	C	.	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.	+
Barbarea vulgaris	C	.	1	r	.	.	1	.	r	.	.	.	.	.	.	+	.	.
Pastinaca sativa	C	.	+	.	.	.	.	.	.	.	r	.	.	.	.	+	.	.
Anthriscus sylvestris	C	.	.	1	.	.	2	.	.	.	.	.	.	.	+	.	.	.

Relevé number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Veronica serpyllifolia	C	.	.	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.
Lotus corniculatus	C	+	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Trifolium pratense	C	.	+	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.
Lythrum salicaria	C	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	r	.
Lysimachia vulgaris	C	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	r	.
Pimpinella major	C	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rumex acetosa	C	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex hirta	C	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Plantago media	C	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Leucanthemum adustum	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Poa pratensis	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Plantago lanceolata	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Ranunculus bulbosus	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.
Ranunculus sardous	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Leucanthemum vulgare	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Crataego-Prunetea																		
Crataegus monogyna	A3	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Crataegus monogyna	B1	.	.	.	1	.	2	.	.	.	.	.	.	+	.	1	.	1
Crataegus monogyna	B2	.	.	5	+	+	2	.	.	.	+	+	+	+	+	.	+	+
Crataegus monogyna	C	.	.	.	.	.	.	.	.	.	r	+	.	.	.	.	.	+
Cornus sanguinea	B1	.	.	1	.	.	1	+	1	.	+	.	1	.	.	.	+	2
Cornus sanguinea	B2	.	.	.	.	2	1	.	+	.	.	+	+	.	+	.	+	+
Cornus sanguinea	C	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Euonymus europaeus	B1	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Euonymus europaeus	B2	.	+	1	1	r	.	+	.	.	.	.	.	+	.	+	.	.
Euonymus europaeus	C	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.
Prunus spinosa	B2	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.
Viburnum lantana	B2	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+
Cotoneaster tomentosus	B2	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Prunus cerasifera	B2	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Rosa canina	B2	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Ligustrum vulgare	B1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Trifolio-Geranietea sanguinei																		
Melampyrum bihariense	C	.	.	.	.	.	.	.	.	.	r	+	+	r	.	.	+	+
Agrimonia eupatoria	C	.	.	r	.	+	+	.	.	.	.	r	.	.	.	.	.	+
Trifolium medium	C	.	.	.	.	.	.	.	+	.	.	.	.	+	.	+	.	.
Arabis hirsuta	C	.	.	.	.	.	.	.	r	.	.	.	.	.	.	r	.	.
Thalictrum minus	C	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Dichoropetalum carvifolia	C	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Selinum silaifolium	C	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Trifolium medium	C	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Laserpitium krapfii ssp. *krapfii*	C	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Pseudoturritis turrita	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.
Vicia incana	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.
Fragaria moschata	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Trifolium pannonicum	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r
Quercetea pubescentis																		
Carpinus orientalis	A3	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Carpinus orientalis	B1	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	1
Carpinus orientalis	B2	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	+	.
Hieracium laevigatum	C	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	r
Cornus mas	A3	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Cornus mas	B1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+
Cornus mas	B2	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.
Dioscorea communis	C	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.
Fraxinus ornus	C	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	+	.
Ostrya carpinifolia	A2	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Hieracium racemosum	C	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Sorbus domestica	B2	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Quercus cerris	B2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Quercus cerris	C	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.
Viola alba	C	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Medicago lupulina	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.

Relevé number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Pimpinella saxifraga	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.
Viola hirta	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Clinopodium vulgare	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r
***Epilobietea angustifolii* and species of other affiliations**																		
Valeriana officinalis	C	.	.	.	r	.	.	.	.	.	r	.	.	+	+	+	r	.
Tussilago farfara	C	.	1	.	.	.	.	.	.	.	+	.	.	+	.	+	1	.
Equisetum arvense	C	.	.	r	.	.	+	.	+	.	+	.	.	.	.	+	.	.
Epilobium hirsutum	C	.	+	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.
Lapsana communis	C	.	.	.	.	r	+	.	.	.	+	.	.	.	+	.	.	.
Daucus carota	C	.	.	.	.	.	.	.	.	.	+	.	.	r	.	+	+	.
Petasites kablikianus	C	.	.	.	.	.	.	.	.	.	2	.	.	.	r	+	.	.
Fragaria vesca	C	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	+	.
Mentha aquatica	C	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plantago major	C	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Mentha longifolia	C	.	.	r	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Linaria vulgaris	C	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	r	.
Smyrnium perfoliatum	C	.	.	.	.	.	r	.	.	.	.	.	.	r	.	.	.	.
Parietaria officinalis	C	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.
Calystegia sepium	C	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.
Eupatorium cannabinum	C	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.
Euphorbia platyphyllos	C	.	.	.	.	.	.	.	+	.	.	.	.	.	r	.	.	.
Leontodon crispus	C	.	.	.	.	.	.	.	.	.	r	.	.	.	.	+	.	.
Veronica officinalis	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	r
Silene latifolia	C	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Picris hieracioides	C	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sanguisorba minor	C	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sedum hispanicum	C	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium verum	C	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa angustifolia	C	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Tragopogon pratensis ssp. *orientalis*	C	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Carex acutiformis	C	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Cruciata laevipes	C	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.
Lycopus europaeus	C	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Rumex obtusifolius	C	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Myosoton aquaticum	C	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Mentha spicata	C	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.
Mentha arvensis	C	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.
Chelidonium majus	C	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Euphorbia stricta	C	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Saponaria officinalis	C	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Ranunculus platanifolius	C	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Bromopsis ramosa	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.
Sisymbrium strictissimum	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.
Hypericum perforatum	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Asperula cynanchica	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.
Thymus pulegioides	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+

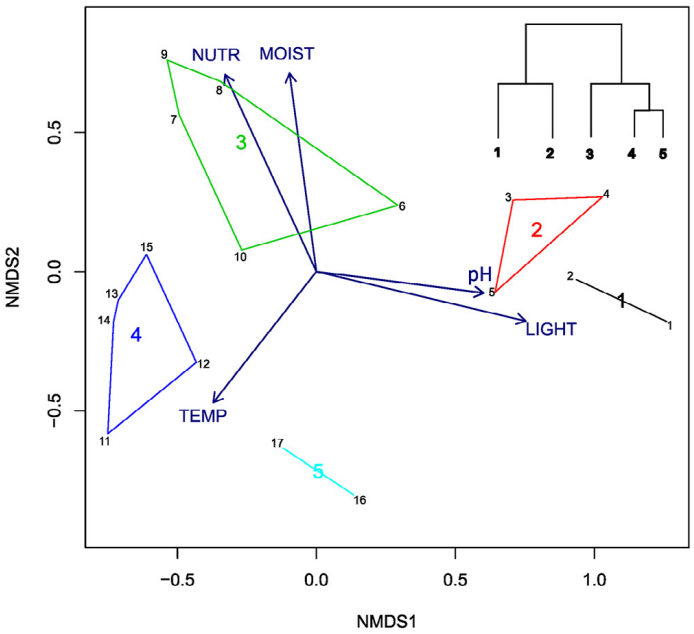

Figure 2. NDMS ordination diagram with EIVs passively projected. The TWINSPAN classification dendrogram is shown in the upper right corner. Numbers of the groups as well as numbers of relevés correspond to those used throughout the text and in Tabs. 1–2 and Fig. 1.

Slika 2. Ordinacijski diagram NDMS s pasivno projiciranimi EIV. Klasifikacijski dendrogram TWINSPAN je prikazan v zgornjem desnem kotu. Številke skupin in številke fitocenoloških popisov ustrezajo tistim, ki se uporabljajo v besedilu in v Tab. 1 in 2 ter na Sl. 1.

Slika 2. Dijagram ordinacije NDMS sa pasivno projektovanim EIV-ovima. Dendrogram klasifikacije TWINSPAN prikazan je u gornjem desnom uglu. Brojevi grupa kao i brojevi fitocenoloških snimaka odgovaraju onima korišćenim u tekstu i u Tab. 1 i 2 i na Sl. 1.

Cluster 1 is composed of relevés of scrub dominated by *Salix eleagnos* and/or *S. purpurea* (lower shrub layer) (Tab. 2, Fig. 3) found on the gravel bars from Zalomka river. The debris is coarse, and the water table experiences high fluctuations throughout the year. However, the water dynamics are not as pronounced as in the Neretva River valley, allowing these pioneer communities, albeit they are the most heliophilous in the study area (Fig. 2), to have a more closed canopy. Diagnostic species for this cluster is *Salix eleagnos* in lower shrub layer, followed by *Silene vulgaris* and *Agrostis stolonifera* in the herb layer. Constant species occurring in the lower shrub layer are both *Salix eleagnos* and *S. purpurea*. Both species can tolerate strong periodical fluctuations of the water table as well as water current. Constant species that occur in the herb layer are species of wet meadows or tall herb vegetation *Cardamine impatiens*, *Centaurea jacea* subsp. *angustifolia*, *Galium mollugo*, *Poa trivialis* and *Rumex crispus*.

This community belongs to the alliance *Salicion eleagno-daphnoidis*, however, we do not have sufficient data to classify this community into a particular association, partly because of the relative poverty of the herb layer, which can be due to the fact that relevés were recorded just after the water level dropped, so it was too early (although it was early June).

Cluster 2 represents the next phase in the succession of the vegetation on the gravelly stream banks (Fig. 4). The impact of high water is much lower here, so the sediment is much less coarse, with gravel, but also sand and clay. These stands are higher (up to five meters) than those from the cluster 1 albeit they have the same edifiers (bitter and red willow), and are much less heliophilous compared with cluster 1 (Fig. 2).

Diagnostic species for the shrub layer is *Salix purpurea* (upper shrub layer) with several other light demanding herb species such as *Centaurea jacea* subsp. *angustifolia*, *Galium mollugo*, *Rumex crispus*, *Taraxacum* sect. *Taraxacum* (Tab. 2). Apart from *Salix purpurea*, constant species in the upper shrub lay-

Figure 3. First stage pioneer bitter/red willow communities on Zalomka River (cluster 1).

Slika 3. Pionirske združbe sive/rdeče vrbe prve stopnje na reki Zalomki (skupina 1).

Slika 3. Prvi stadijum pionirske zajednice sive vrbe i rakite na rijeci Zalomki (klaster 1).

Figure 4. Second stage pioneer bitter/red willow communities on Zalomka River (cluster 2).
Slika 4. Pionirske združbe sive/rdeče vrbe druge stopnje na reki Zalomki (skupina 2).
Slika 4. Drugi stadijum pionirske zajednice sive vrbe i rakite na rijeci Zalomki (klaster 2).

er are mesophilous trees and shrubs such as *Acer campestre, Corylus avellana*, *Crataegus monogyna*, *Euonymus europaeus*, *Rosa arvensis*, *Rubus caesius* indicating tendency of transition to next succession stage. Constant species in the herb layer are light demanding as well as somewhat shade tolerant herb species such as: *Agrimonia eupatoria*, *Cardamine impatiens*, *Humulus lupulus*, *Lysimachia nummularia*, *Poa trivialis*, *Potentilla reptans*, *Ranunculus repens*, *Rumex crispus*, *Schenodorus giganteus*, *Silene vulgaris* and *Urtica dioica*. This community has a transitional character towards *Alnion incanae*, however, similar communities from the region were mainly classified inside *Salicion eleagno-daphnoidis*.

Cluster 3 is the next stage of vegetation succsession in the riparian zone of Neretva and Zalomka Rivers which is characterized by domination of white (*Salix alba*) and/or eastern cracked willow (*Salix euxina*) in the upper tree layer, with stand height ranging between 10 and 30 m (Tab. 2, col. 3, Fig. 5). The stands have closed canopy and are developed along riverbeds with permanent flow, on finer sandy deposits that are not subject to extreme dry phases as it is case with clusters 1 and 2.

The diagnostic species in the tree layer are tall willows (*Salix alba* and *Salix euxina*). On the other hand, diagnostic species from the herb layer are mostly shade tolerant species such as *Angelica sylvestris*, *Cardamine bulbifera*, *Lysimachia nummularia*, *Scrophularia nodosa* and *Veronica montana* which is in clear contrast to clusters 1 and 2. Constant species of the shrub layers are mostly mesophites such as *Acer campestre*, *Acer pseudoplatanus*, *Cornus sanguinea*, *Corylus avellana*, *Fraxinus excelsior* and *Rubus caesius*. Constant species in the herb layer are mesohygrophites and mesophites such as *Aegopodium podagraria*, *Ajuga reptans*, *Allium ursinum*, *Angelica sylvestris*, *Brachypodium sylvaticum*, *Cardamine impatiens*, *Chaerophyllum hirsutum*, *Circaea lutetiana*, *Clematis vitalba*, *Dactylis glomerata*, *Epilobium hirsutum*, *Equisetum arvense*, *Ficaria verna*, *Geranium robertianum*, *Geum urbanum*, *Humulus lupulus*, *Petasites hybridus*, *Prunella vulgaris*, *Ranunculus repens*, *Schenodorus giganteus* and *Urtica dioica*. Many of those are also nutrient demanding, which makes this cluster the most nutrient and moisture demanding while in the same time the least thermophilous (Fig. 2). This community, although edifiers and several species of herb layer are characteristic for *Salicion albae,* has a herb and especially shrub layer that is mainly composed and dominated by species characteristic for mesic forests which is characteristic of *Alnion incanae*.

Figure 5. White and cracked willow community of Neretva River (cluster 3).
Slika 5. Združba bele i krhke vrbe na reki Neretvi (skupina 3).
Slika 5. Zajednica bijele i krte vrbe na rijeci Neretvi (klaster 3).

Cluster 4 includes narrow strips of high stands of *Alnus rohlenae* along the river banks of Upper Neretva River (Fig. 6). These rather mesophilous communities are shortly flooded only during the highest water levels, while the amount of the new sediment deposited is reduced. Sometimes, new sediment is brought by erosion from nearby slopes. Soils are mostly composed of fractions varying from medium sized gravel to stones.

Figure 6. *Alnus rohlenae* community from Neretva River (cluster 4).
Slika 6. Združba *Alnus rohlenae* na reki Neretvi (skupina 4).
Slika 6. Zajednica *Alnus rohlenae* na rijeci Neretvi (klaster 4).

Alnus rohlenae is the diagnostic species in the tree layer (Tab. 2, col. 4), it is also very well differentiated from other clusters by the species in the shrub and herb layers which are mainly of nemoral character such as *Acer pseudoplatanus*, *Fraxinus ornus*, *Ligustrum vulgare*, *Acer pseudoplatanus*, *Allium ursinum*, *Aposeris foetida*, *Asperula taurina*, *Dactylorhiza maculata*, *Melica uniflora*, *Mercurialis perennis*, *Salvia glutinosa* and *Scutellaria altissima.* Apart from *Alnus rohlenae* in the tree layer, other species are constantly present and numerous in the shrub layer*: Alnus rohlenae*, *Carpinus betulus*, *Corylus avellana*, *Fagus sylvatica, Fraxinus excelsior*, *Fraxinus ornus*, *Acer campestre*, *Acer pseudoplatanus*, *Cornus sanguinea*, *Crataegus monogyna*, *Ligustrum vulgare*, *Rosa arvensis* and *Rubus caesius*, as well as in the herb layer: *Scutellaria altissima*; *Acer campestre*, *Acer pseudoplatanus*, *Aegopodium podagraria*, *Ajuga reptans*, *Allium ursinum*, *Aposeris foetida*, *Arum maculatum*, *Asperula taurina*, *Brachypodium sylvaticum*, *Campanula trachelium*, *Circaea lutetiana*, *Clematis vitalba*, *Dactylorhiza maculata*, *Ficaria verna*, *Helleborus odorus*, *Melampyrum bihariense*, *Melica uniflora*, *Mercurialis perennis*, *Pulmonaria officinalis*, *Salvia glutinosa*, *Scutellaria altissima*, *Symphytum tuberosum*, *Valeriana officinalis*. High cover of tree and shrub layers makes this community the most shade loving (Fig. 2).

Cluster 5 is the most thermophilous (Fig. 2). It is represented by two relevés of tall scrub found on the river banks of Neretva. Those stands are at the transitional position between pioneer communities of *Salicion eleagno-daphnoidis*, thermo-mesophilous scrub communities of *Berberidion* and thermophilous forests of *Quercetea pubescentis* with diagnostic and constant species supporting this ecological heterogeneity (Tab. 2, col. 5). The only constant species in the lower tree layer is *Salix eleagnos*, probably surviving as a relict from times when the gravel bars were regularly flooded. The shrub layer is rich and usually consists of the following constant species: *Cornus sanguinea*, *Crataegus monogyna*, *Fraxinus excelsior*, *Rosa arvensis*, *Clematis vitalba* and *Rubus caesius.* The herb layer is ecologically diverse and several species are constant: *Ajuga reptans*, *Brachypodium sylvaticum*, *Carex flacca*, *Carpinus orientalis*, *Melampyrum bihariense*, *Salvia verticillata* and *Vicia sepium.* As its floristic composition does not correspond to any previously described bitter willow community, its syntaxonomical position is yet to be determined.

GENERAL OVERVIEW

Although we recorded only 17 relevés, we tried to encompass the total heterogeneity of riparian forest and scrub communities along the Upper Neretva and Zalomka rivers, in order to be able to analyze it floristically and ecologically and to present its syntaxonomical scheme for the study area at the level of alliances and subordinated communities that correspond to the level of associations and subassociations. However, since the knowledge about this type of forest vegetation in BiH is at a low level, the number of recorded relevés per habitat type was not sufficient to explicitly determine the association to which the relevés should be ascribed, or to describe obviously new associations, as is the case with *Alnus rohlenae* dominated community (cluster 4).

Alnus rohlenae is a relatively recently discovered polyploid species of the *Alnus glutinosa* complex, described from the Tara River canyon in Montenegro (Vít et al. 2017). Not knowing about this discovery, Milanović & Stupar (2017) reported several communities dominated by *Alnus glutinosa* from the Sutjeska National Park in the same year. It is now apparent that the latter actually reffer to *Alnus rohlenae*, so there are likely three new associations dominated by this species that should be described from this area of BiH (groups 2, 3 and 4 in the paper by Milanović & Stupar 2017), one of which is very similar and probably corresponds to our cluster 4 (group 3 from the same paper). The classification problem of these communities is even more pronounced by spontaneous hybridization of *Alnus glutinosa* and *A. rohlenae*, which is frequent where both species occur together. However, this taxonomical problem is out of the scope of this paper and should be studied in more detail.

Relative spatial proximity of the study area and Sutjeska National Park (around 30 km air distance) explains some floristic and habitat similarities, especially the absence of *Alnus incana*, the species otherwise common in similar habitats across the surrounding areas in BiH (Fukarek 1957; Lakušić et al. 1978; Barudanović 2003; Šilić 2005). It could be that *Alnus rohlenae*, a species from the *Alnus glutinosa* complex, is, at the study area, ecologically more similar to *A. incana* and hence occupies its habitats in this particular area.

White and cracked willow forest stands developed on finer deposits (cluster 3) lack *Alnus rohlenae* completely in the upper tree layer unlike the similar community in Sutjeska National Park (Milanović & Stupar 2017). However, the herb layers of these two communities are very similar consisting of a mixture of mesophilous and hygrophilous species. To our knowl-

edge, similar communities were only rarely reported in Europe. Pekanović (1991) described it from NE Serbia (Vršačke planine), however, later on, Jovanović (1997) classified them inside *Salicion albae*. Milanović & Stupar (2017) are not being explicit about similar communities from Sutjeska National Park, and they consider them transitional between *Salicion albae* and *Alnion incanae*. However, Borhidi et al. (2012) assigned these communities from Hungary (Mecsek hills), to *Alnion incanae* (ass. *Petasito hybridi-Salicetum fragilis*; Kevey 2008) with certainty. We are inclined to follow the latter approach.

Another similarity between Sutjeska National Park and our study area is our cluster 5 and group 5 in Milanović & Stupar (2017), with one difference being that our relevés lack *Ostrya carpinifolia* and *Sesleria autumnalis*. Another thermo-mesophilous scrub of bitter willow in BiH is reported from the lower Neretva (Diva Grabovica) (Redžić et al. 1992). Although this community also lacks *Ostrya carpinifolia*, it contains several species that are not present in our cluster 5 (*Ficus carica*, *Fraxinus angustifolia*, *Frangula alnus*, *Petteria ramentacea*, *Coronilla emeroides* etc.). Albeit there are differences between the mentioned communities and nothing floristically similar has been described in Europe, the *Salici eleagni-Juniperetum communis*, an association described from Italy (Poldini et al. 2020) and classified into *Berberidion vulgaris* of *Rhamno-Prunetea*, shows similar traits as a mixture of mesophilous, xerothermophilous species and members the of *Salicion eleagno-daphnoidis*. It is also found on gravel river terraces, among the driest communities subject to episodic flooding. For this reason, we classified relevés from cluster 5 into *Berberidion vulgaris*. However, it is important to emphasize that further research on this intriguing vegetation type is necessary to accurately place it within the correct syntaxonomical context.

Other bitter willow communities (clusters 1 and 2), that belong to *Salicion eleagno-daphnoidis* were recorded exclusively on gravel and sandy bed of the Zalomka River. There are suitable habitats for such communities to develop along the Neretva River as well, but they are mainly covered by the early-successional vegetation from the class *Epilobietalia fleischeri*, often with only a few seedlings and saplings of bitter willow. The reason for this could be that seasonal water dynamics of the Upper Neretva are too intense for the vegetation to develop beyond the early successional stages. On the other hand, calmer flow of the Zalomka River along with its intermittent nature, allows this type of vegetation to develop into scrubs of *Salix eleagnos* on coarser gravelly sediments in the upper part of the stream and of *Salix purpurea* on the finer sandy sediment in the lower part of the stream.

All studied vegetation types, except cluster 5, are listed in Annex I of the EU Habitats Directive (EC 1992), clusters 1 and 2 being habitat 3240 while clusters 3 and 4 belong to the priority habitat *91E0. These results underscore the ecological significance of riparian communities along the Neretva and Zalomka rivers, emphasizing their high conservation value. The construction of hydropower plants and alterations to flow regimes, exacerbated by climate change, pose significant threats to these habitats, potentially leading to habitat degradation and loss of biodiversity. Such disturbances could disrupt the delicate balance of moisture and soil conditions crucial for the survival of these plant communities. Immediate actions, including stricter regulation of hydropower projects and targeted conservation efforts, are recommended to preserve the ecological integrity of these river systems. Additionally, further research is necessary to monitor changes in flow regimes and assess their impact on riparian vegetation, which is vital for designing effective management and protection strategies.

POVZETEK

Obrežna območja vzdolž gornjega toka rek Neretve in Zalomke v Bosni in Hercegovini (BiH) so vitalni ekosistemi, ki podpirajo visoko biotsko raznovrstnost in zagotavljajo bistvene ekosistemske storitve. Kljub pomembnosti ostajajo premalo raziskani, predvsem njihova floristična sestava in vegetacijska dinamika. Namen študije je zapolniti to vrzel, z izvedbo kratkoročne fitocenološke raziskave.

Terensko delo je bilo izvedeno v začetku junija 2023 s poudarkom na obrežni drevesni in grmičasti vegetaciji. S srednjeevropsko metodo je bilo zbranih 17 fitocenoloških popisov. Raziskovalno območje je vključevalo ozke obvodne gozdove, prodne formacije in gozdove v stalnih in presihajočih rečnih sistemih. Reka Neretva, za katero sta značilna hiter tok in prodnata struga, je drugačna od reke Zalomke, ki v prvi polovici toka občasno teče po prodišču, v drugi polovici pa po pesku in blatu.

Numerična klasifikacija podatkov je razkrila pet različnih skupin vegetacije. Skupini 1 in 2 so sestavljale pionirske skupnosti grmičevja, v katerih prevladujeta Salix eleagnos in Salix purpurea, ki uspevata na prodiščih reke Zalomke. Skupini 3 in 4 je sestavljala že uveljavljena gozdna vegetacija iz doline reke Neretve, s prevladujočimi vrstami *Salix alba*, *Salix euxina* in *Alnus rohlenae*. Skupina 5, najbolj topoljubna, je vključevala prehodno grmičevje na bregovih reke Neretve, ki združuje elemente *Salicion eleagno-daphnoidis*, *Quercetea pubescentis* in *Berberidion vulgaris*. Ordinacijski diagram NDMS je pokazal, da so svetloba, reakcija tal, vlaga in hranila glavni ekološki dejavniki, ki vplivajo na variacijo floristične sestave v teh skupinah.

Študija zagotavlja predhodno sintaksonomsko klasifikacijo za tovrstne rastlinske združbe in jih povezuje z ustreznimi zvezami. Poudarja tudi potrebo po nadaljnjih raziskavah, zlasti za izboljšanje klasifikacije določenih skupnosti in boljše razumevanje ekološke dinamike. Ugotovitve so pomembne za ohranjanje in upravljanje teh habitatov, od katerih so mnogi zaščiteni v skladu z Direktivo EU o habitatih.

SAŽETAK

Priobalna područja duž gornjeg toka rijeke Neretve i Zalomke u Bosni i Hercegovini (BiH) predstavljaju vitalne ekološke sisteme koji podržavaju visok biodiverzitet i pružaju esencijalne ekosistemske usluge. Uprkos svom značaju, one su i dalje nedovoljno istražene, posebno njihov floristički sastav i dinamika vegetacije. Svrha ove studije je da, kroz provođenje kratkoročnog fitocenološkog istraživanja, popuni prazninu u razumjevanju ovih ekosistema.

Terenski radovi obavljeni su početkom juna 2023. godine sa fokusom na obalnu vegetaciju drveća i grmlja. Centralnoevropskom metodom prikupljeno je 17 fitocenoloških snimaka. Područje istraživanja uključivalo je uske obalne šume, šljunkovite formacije i šume u stalnim i povremenim riječnim sistemima. Rijeka Neretva, koju karakteriše brza struja i šljunkovito korito, razlikuje se od rijeke Zalomke koja u prvoj polovini svog toka povremeno teče preko šljunka, a u drugoj po pijesku i mulju.

Numerička klasifikacija podataka otkrila je pet različitih vegetacijskih klastera. Klasteri 1. i 2. sastoje se od pionirskih zajednica šibljaka kojima dominiraju *Salix eleagnos* i *Salix purpurea*, koje uspijevaju na šljunčanim podlogama rijeke Zalomke. Klasteri 3. i 4. čine trajnija šumska vegetacija uz dolinu rijeke Neretve, sa dominantnim vrstama *Salix alba*, *Salix euxina* i *Alnus rohlenae*. Klaster 5. je najtermofilnija grupa koja uključuje prelazne zajednice šibljaka na obalama rijeke Neretve, kombinujući elemente *Salicion eleagno-daphnoidis*, *Quercetea pubescentis* i *Berberidion vulgaris*. NDMS ordinacioni dijagram pokazao je da su svjetlost, reakcija zemljišta, vlaga i hranjivi sastojci glavni ekološki faktori koji utiču na varijabilnost florističkog sastava u ovim klasterima.

Studija daje i preliminarnu sintaksonomsku klasifikaciju za ove vegetacijske tipove i povezuje ih sa odgovarajućim svezama. Takođe, naglašava potrebu za daljim istraživanjem, naročito da se razjasni klasifikacija određenih zajednica i da se bolje razumije ekološka dinamika. Rezultati su važni za očuvanje i upravljanje ovim staništima, od kojih su mnoga zaštićena Direktivom o staništima EU.

ACKNOWLEDGEMENTS

We are grateful to the organising team of »Neretva Science Week 2023« for inviting us to the event and offering the opportunity to study the vegetation of the Neretva and Zalomka Rivers.

REFERENCES

Barudanović S. 2003. Ekološko-vegetacijska diferencijacija lišćarsko-listopadnih šuma planine Vranice [Ph.D. thesis]. [Sarajevo, BA]: University of Sarajevo.

Borhidi A, Kevey B, Lendvai G. 2012. Plant communities of Hungary. Budapest: Akadémiai Kiadó.

Braun-Blanquet J. 1964. Pflanzensoziologie, Grundzüge der Vegetationskunde. 3rd ed. Wien: Springer Verlag.

Chytrý M, Tichý L, Holt J, Botta-Dukát Z. 2002. Determination of diagnostic species with statistical fidelity measures. Journal of Vegetation Science. 13(1): 79-90. https://doi.org/10.1111/j.1654-1103.2002.tb02025.x

[EC] Council of the European Communities. 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Communities. L206: 7-50.

Fukarek P. 1957. Radovi na istraživanju i kartiranju šumske vegetacije Bosne i Hercegovine (izvještaj Zavoda za šumarsku botaniku Poljoprivredno-šumarskog fakulteta - za 1956 i 1957 godinu). Narodni šumar. 11(10-12): 358-378.

Gregory SV, Swanson FJ, McKee WA, Cummins KW. 1991. An ecosystem perspective of riparian zones: Focus on links between land and water. BioScience. 41(8): 540-551. https://doi.org/10.2307/1311607

Hill MO. 1979. TWINSPAN - a Fortran program for arranging multivariate data in an ordered two way table by classification of the individuals and the attributes [computer program].

Janssen JAM, Rodwell JS, Garcia Criado M, Gubbay S, Haynes T, Nieto A, Sanders N, Landucci F, Loidi J, Ssymank A, et al. 2016. European red list of habitats - Part 2. Terrestrial and freshwater habitats. European Commission.

Jovanović B. 1997. Krajrečna aluvijalna vegetacija. In: Sarić MR, editor. Vegetacija Srbije II - Šumske zajednice 1. Beograd: Srpska akademija nauka i umetnosti, Odeljenje prirodno-matematičkih nauka. p. 107-158.

Koljanin D, Brujić J, Čarni A, Milanović Đ, Škvorc Ž, Stupar V. 2023. Classification of wetland forests and scrub in the Western Balkans. Diversity. 15(3): 370. https://doi.org/10.3390/d15030370.

Lakušić R, Pavlović D, Abadžić S, Grgić P. 1978. Prodromus biljnih zajednica Bosne i Hercegovine. Godišnjak Biološkog Instituta Univerziteta u Sarajevu. 30: 5-88.

Lakušić R, Pavlović D, Abadžić S, Kutleša L, Mišić L, Redžić S, Maljević D, Bratović S. 1979. Struktura i dinamika ekosistema planine Vranice u Bosni. In: Zbornik radova drugog kongresa ekologa Jugoslavije. Vol. 1. Zagreb, HR: Savez društava ekologa Jugoslavije. p. 605-714.

Milanović Đ, Stupar V. 2017. Riparian forest communities along watercourses in the Sutjeska National Park (SE Bosnia and Herzegovina). Glasnik Šumarskog fakulteta Univerze u Banjoj Luci. 26: 95-111. https://doi.org/10.7251/GSF1726095M

Milanović Đ, Stupar V. 2019. Checklist of vegetation classes of Bosnia and Herzegovina: How much do we know? Radovi Šumarskog fakulteta Univerziteta u Sarajevu. 49(2): 9-20. https://doi.org/10.54652/rsf.2019.v49.i2.31

Milanović P. 2023. Karst of East Herzegovina and Dubrovnik Littoral. Cham: Springer (Cave and Karst Systems of the World). https://doi.org/10.1007/978-3-031-28120-4

Mucina L, Bültmann H, Dierßen K, Theurillat J-P, Raus T, Čarni A, Šumberová K, Willner W, Dengler J, García RG, et al. 2016. Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. Appl Veg Sci. 19: 3-264. https://doi.org/10.1111/avsc.12257

Pekanović V. 1991. Šumska vegetacija Vršačkih planina. Monografije Vršačkih planina. Novi Sad, RS: Odeljenje za prirodne nauke, Matica srpska.

Pignatti S, Menegoni P, Pietrosanti S. 2005. Valori di bioindicazione delle piante vascolari della flora d'Italia. Braun-Blanquetia. 39: 1-97.

Poldini L, Vidali M, Castello M, Sburlino G. 2020. A novel insight into the remnants of hygrophilous forests and scrubs of the Po Plain biogeographical transition area (Northern Italy). Plant Sociology. 57(2): 17-69. https://doi.org/10.3897/pls2020572/01

[R] R Foundation for Statistical Computing. 2019. R: A Language and Environment for Statistical Computing. Version 3.6.1 [computer program].

Redžić S, Muratspahić D, Lakušić R. 1992. Neke fitocenoze šuma i šikara iz doline Neretve. Poljoprivreda i šumarstvo, Podgorica. 38(1-2): 95-101.

Redžić S, Omerović S, Golić S. 1986. Prilog poznavanju šumskih fitocenoza planine Čemernice. Prirodno-matematički fakultet, Univerza u Sarajevu. 39: 125-139.

Riis T, Kelly-Quinn M, Aguiar FC, Manolaki P, Bruno D, Bejarano MD, Clerici N, Fernandes MR, Franco JC, Pettit N, et al. 2020. Global Overview of Ecosystem Services Provided by Riparian Vegetation. BioScience. 70(6): 501-514. https://doi.org/10.1093/biosci/biaa041

StatSoft, Inc. 2014. STATISTICA (data analysis software system), version 12. [Computer Program].

Stupar V, Milanović Đ, Brujić J. 2021. Vaskularna flora Republike Srpske. Banja Luka, BA: Šumarski fakultet Univerziteta u Banjoj Luci.

Šilić Č. 2005. Atlas dendroflore (drveće i grmlje) Bosne i Hercegovine. Čitluk: Matica hrvatska.

Tichý L. 2002. JUICE, software for vegetation classification. Journal of Vegetation Science. 13(3): 451-453. https://doi.org/10.1111/j.1654-1103.2002.tb02069.x

Vít P, Douda J, Krak K, Havrdová A, Mandák B. 2017. Two new polyploid species closely related to *Alnus glutinosa* in Europe and North Africa – An analysis based on morphometry, karyology, flow cytometry and microsatellites. Taxon. 66(3): 567-583. https://doi.org/https://doi.org/10.12705/663.4

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0I nternational License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 81–92
»Neretva Science Week 2023«

ZNANSTVENI ČLANEK /
SCIENTIFIC PAPER

DOI: 10.14720/ns.19555
Objavljeno na spletu / Published online: 7. 11. 2025

Prejeto / Received: 17. 8. 2024
Sprejeto / Accepted: 14. 3. 2025

Preliminary mapping of forests of high conservation value along the Upper Neretva River, Bosnia and Herzegovina

Rhiannon GLOOR

ABSTRACT

The extent of temperate old-growth forests in temperate Europe is diminishing as a result of anthropogenic pressures, despite a mandate from the European Union (EU) calling for their strict protection under the Biodiversity Strategy for 2030. However, the exact extent of old-growth forests is currently unknown due to insufficient mapping, particularly in the EU candidate countries in the Balkans. Using a combined approach of dendrochronology and visual observations of old-growth structural indicators, this investigation was the first rapid survey of the forests of the Upper Neretva River in Bosnia and Herzegovina. Ten forest patches were sampled over the course of seven days. We note high heterogeneity in forest types, with a distinct gradient from the riparian zone to the upper slopes of the valley. Historical human activities, particularly coppicing and clearance for grazing pastures, were perceivable in many locations. However, through utilising visual observations and dendrochronological dating, we can estimate the abandonment of these activities over a century ago, which has resulted in a landscape rich in different habitat types, specifically large old trees essential for biodiversity. We identified the old-growth lichen indicator species *Lobaria pulmonaria* throughout the study area. Moreover, small patches of both *Fagus sylvatica* and *Quercus* spp. potential old-growth forests were present. We therefore recommend a moratorium on logging in the region to preserve these ecosystems as stipulated in Green Agenda for the Western Balkans – a key component of EU integration.

IZVLEČEK

Preliminarno kartiranje gozdov visoke ohranitvene vrednosti vzdolž Gornje Neretve, Bosna in Hercegovina

Obseg starodavnih gozdov zmernega pasu v Evropi se zmanjšuje zaradi antropogenih pritiskov, kljub zahtevi Evropske unije, ki poziva k njihovemu strogemu varovanju v okviru strategije biotske raznovrstnosti do leta 2030. Natančen obseg starodavnih gozdov trenutno ni znan zaradi nezadostnega kartiranja, zlasti v balkanskih državah kandidatkah za članstvo v EU. Z uporabo kombiniranega pristopa dendrokronologije in vizualnih opazovanj strukturnih indikatorjev starosti je to prva preliminarna raziskava gozdov Gornje Neretve v Bosni in Hercegovini. V sedmih dneh je bilo vzorčenih deset gozdnih zaplat. Opažamo visoko heterogenost tipov gozdov, z izrazitim gradientom od obrežnega pasu do zgornjih pobočij doline. Na številnih lokacijah so bile vidne zgodovinske dejavnosti človeka, zlasti pomlajevanje in krčenje za potrebe pašništva. Z našteto metodologijo smo ocenili, da so bil te dejavnosti opuščene pred več kot stoletjem, kar je rezultiralo v pokrajini, bogati z različnimi habitatnimi tipi, zlasti z velikimi, starimi habitatnimi drevesi, ki so bistvena za biotsko raznovrstnost. Identificirali smo indikatorsko vrsto stare rasti (*Lobaria pulmonaria*) na celotnem območju študije. Poleg tega so bile prisotne majhne zaplate potencialnih starih gozdov *Fagus sylvatica* in *Quercus*. Zato priporočamo moratorij na sečnjo v regiji, da se ohranijo ti ekosistemi, kot je določeno v Zeleni agendi za Zahodni Balkan – ključni komponenti integracije v Evropsko unijo.

Department of Forest Ecology, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Prague, Czech Republic; Email: gloor@fld.czu.cz

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

KEY WORDS:
biodiversity conservation, dendrochronology, *Fagus sylvatica*, forest protection, habitat trees, old-growth forests, *Quercus*

KLJUČNE BESEDE:
ohranjanje biotske raznovrstnosti, dendrokronologija, *Fagus sylvatica*, varstvo gozdov, habitatna drevesa, stari gozdovi, *Quercus*

KEY WORDS:
očuvanje biodiverziteta, dendrohronologija, *Fagus sylvatica*, zaštita šuma, stabla staništa, stare šume, *Quercus*

APSTRAKT

Preliminarno kartiranje šuma visoke zaštitne vrijednosti gornjeg toka rijeke Neretve, Bosna i Hercegovina

Površina starih šuma u kontinentalnom dijelu Evrope se smanjuje usled antropogenih uticaja, uprkos nalogu Evropske unije koji poziva na njihovu strogu zaštitu u okviru Strategije biodiverziteta do 2030. godinu. Međutim, tačan opseg starih šuma trenutno nije poznat zbog nedostatka podataka, posebno u balkanskim zemljama koje su kandidati za EU. Koristeći kombinovani pristup dendrohronologije i vizualnih posmatranja strukturnih pokazatelja starih šuma, ovo istraživanje bilo je prvo brzo istraživanje šuma gornje Neretve u Bosni i Hercegovini. Istraživanja su provedena na deset šumskih ploha u toku sedam dana. Zapažena je visoka heterogenost tipova šuma, sa izraženom poromjenom nagiba, od priobalne zone do gornjih padina. Istorijske ljudske aktivnosti, posebno sječa šuma i krčenje pašnjaka za ispašu, bile su vidljive na mnogim lokalitetima. Međutim, korištenjem metode vizuelnog opažanja i dendrohronološkog datiranja možemo reći da su te prakse napuštene već vjekovima, što je rezultiralo staništima bogatim različitim tipovima šuma, naročito onim sa velikim, starim stablima koja su bitna za biodiverzitet. Registrovali smo indikatorsku vrstu starih šuma (*Lobaria pulmonaria*) na cijelom području istraživanja. Povrh toga, prisutne su i male površine potencijalnih starih šuma *Fagus sylvatica* i *Quercus*. U skladu sa tim preporučujemo moratorij na sječu šuma u regiji kako bi se očuvali ovi ekosistemi, kako je propisano Zelenom agendom za Zapadni Balkan – ključnom komponentom integracije u Evropsku uniju.

INTRODUCTION

Forests are key terrestrial ecosystems essential in biodiversity maintenance, climate change mitigation, and soil erosion control, amongst other essential ecosystem services (Czerepko et al. 2021; Luyssaert et al. 2008; Mo et al. 2023). Natural forests, particularly primary and old-growth forests, are structurally complex, which provide integral habitats for threatened and specialist species, and promote long-term carbon storage (Ferenčík et al. 2022; Kozák et al. 2021; Mo et al. 2023; Gloor et al. 2024). High-conservation-value forests (HCVFs) retain similar structural complexity due to low anthropogenic disturbance, and provide comparable ecosystem services (Jennings et al. 2003; Munteanu et al. 2022). However, non-natural forests, including timber plantations, dominate the European landscape, while a drastic loss of natural forests is occurring (FAO 2024). Although the proportion of tree cover is increasing across the continent, this is largely attributed to the expansion of forest into abandoned agricultural land (Palmero-Iniesta et al. 2021), and these forests often differ from long-established forests in their species composition, structure and function (Espelta et al. 2020) and may exhibit greater sensitivity to climatic extremes (Alfaro-Sanchez et al. 2019). Considering the heightened vulnerability of younger and non-natural forests to the effects of climate change and the predicted increase of natural disturbances (Seidl et al. 2014; Patacca et al. 2023), as well as the marked absence of old-growth specialist species (Czerepko et al. 2021), restoring and maintaining HCVFs across the continent is a key step to help build resilience to future climate perturbations, as outlined in the EU Biodiversity Strategy for 2030, which mandates the strict protection of all primary and old-growth forests by 2029.

The term »old-growth forest«, whilst often contested, has been defined by the European Commission in the context of dense human habituation in continental Europe across the last several millennia, where more rigorous definitions best fitted for extensive intact forests (e.g. in the boreal and tropical zones) are not suitable. »A forest stand or area consisting of native tree species that have developed, predominantly through natural processes, structures, and dynamics normally associated with late-seral developmental phases in primary or undisturbed forests of the same type. Signs of former human activities may be visible. Still, they are gradually disappearing or are too limited to significantly disturb natural processes«, including even »forest stands that originate not only from natural regeneration but also from planted or sown native tree species« (EC 2023). This definition allows the recognition of forests in later seral stages as essential ecosystems that sustain biodiversity and other ecosystem services, which are absent elsewhere on the heavily managed continent. It also acknowledges the ability of managed forests to develop into old-growth forests when removed from management, allowing us to pinpoint the forests, which have the highest ecological value in the context of European history.

Only 1.4 million hectares of primary and old-growth forests are estimated to persist across Europe (Sabatini et al. 2018). However, the remaining patches are often small, isolated and fragmented and therefore vulnerable to edge effects, with their communities likely incurring an extinction debt (Kuussaari et al. 2009; Mikoláš et al. 2019). It is nonetheless estimated that more patches remain than what is mapped; however, they lack official old-growth status and remain unprotected, so legal logging of old-growth forests is rampant (Barredo et al. 2021; Munteanu et al. 2022; Mikoláš et al. 2023). Hence it is imperative

to sufficiently map forests of high conservation value so that they are not lost before they are identified.

The Dinaric Alps are a known hotspot of temperate old-growth forests (Sabatini et al. 2018). In Bosnia and Herzegovina (BiH), the most well-known sites are mixed beech-spruce-fir (*Fagus-Picea-Abies*) forests, such as Perućica; however, many areas have not been rigorously mapped (Ioras et al. 2009). BiH has a relatively high forest cover in the European context, with 42.73% of its territory forested, hence identifying areas with the highest conservation value is crucial to effectively safeguard their biodiversity and other ecosystem services. Through the centuries, human activity, like collecting firewood and felling for construction or creation of pastures, was commonplace in Bosnian forests. However, the effects of the Bosnian War (1992–95) and the widespread presence of mines has severely hindered forestry activity across the nation (Stelstra 2023). Whilst this has led to the preservation and natural regeneration of forested landscapes, the funding opportunities for large-scale engineering projects such as dam construction and the clearing of land mines are increasing, therefore increasing the vulnerability of HCVFs to land-use change. As a candidate country for European Union (EU), BiH has committed to the goals outlined by the Green Agenda for the Western Balkans, which include steps to reduce deforestation and protect nature and biodiversity. Fulfilling the goals outlined by the EU is essential for the EU integration of the country, hence protecting these habitats is an essential component of this accession process (RCC 2020).

We therefore conducted a preliminary survey of the forest types along the Upper Neretva River – an area recently shown to host high biodiversity but where the forests have not hitherto been mapped. Through combining dendrochronology and visual assessments of forest structural attributes, the main aims were to rapidly assess the presence of HCVF – in particular, old-growth forests – in the study area through gathering data on:

i. the age of the potentially oldest trees in several different areas
ii. the presence of old-growth structural attributes in different types of forest, and
iii. visible indications of past human management in contemporary forest structure.

MATERIAL AND METHODS

STUDY SITES

The research was conducted on the slopes of the Upper Neretva River, and around Ulosko Lake. The Neretva originates in the Dinaric Mountains and flows freely for 90 km through mountainous terrain until the first reservoir in Konjic and as such represents one of the few untouched watercourses in Europe (Singer et al. 2023). Although historical human activity was present in part of the region in the form of traditional pastoralism, high emigration from the area during the past century, and the subsequent land abandonment have left the ecosystems to natural successional processes, and the river and surrounding slopes are in a relatively natural state. The forests on the slopes are dominated by European beech (*Fagus sylvatica*) and thermophilic oak species (*Quercus cerris* and *petraea*), while in the riparian zone *Alnus* is the dominant genus. Apart from the site sampled around Ulosko Lake and the site cleared for the dam construction in Ulog, all sampling took place on the slopes bordering the Upper Neretva River. The research sites were selected based on previous visits and satellite images indicating a high degree of naturalness. See Fig. 1 for map of patch locations.

RAPID VISUAL-BASED FIELD SURVEYS

We used satellite images (Google Earth) to pinpoint areas of potential old-growth forests based upon canopy structural heterogeneity (gaps, diversity of tree size and species). Due to time and resource constraints, we could not categorise all forest types, but only those of special interest regarding conservation. The field visits took place between 30th May and 7th June 2023. Walks to the pinpointed locations took three hours from the Neretva River on average, either along abandoned forest trails or through the forest. Indications of human management along the way was noted, specifically (i) coppicing, (ii) homogenous vertical and horizontal forest structure, (iii) non-native tree species, (iv) absence or low amount of standing and lying deadwood, (v) clearings for meadows and pastures. At the sites of interest, simple visual inspections of old-growth forest structural attributes were noted according to the definition stipulated by the European Commission (2023) (Tab. 1). The GPS coordinates of the sites were recorded. We specifically noted the presence of the old-growth indicator lichen species *Lobaria pulmonaria*. This lichen species serves as an important biological indicator and an umbrella species (Ravera et al. 2023), with its presence correlating, for example, with increased occurrences of rare lichen species and cyanolichens across different Italian forest types (e.g. Nascimbene et al. 2010). It also serves as an exceptional indicator of undisturbed forest ecosystems and ecological continuity (Brunialti et al. 2010), considering its long-life cycle (it requires up to 35 years to reach sexual maturity) (Jüriado et al. 2009), limited dispersal abilities (Belinchón et al. 2017) and sensitivity to environmental conditions, including changes in microclimate due to logging (e.g. Di Nuzzo et al. 2022).

DENDROCHRONOLOGY

At the sites of interest, we extracted increment tree core samples from the potentially oldest trees absent of injuries (e.g. rot holes) – features which decrease accurate tree age estimations. In total, 29 samples were collected across all sites. The trees were selected by size (larger) and bark properties, which can be indicative of greater age. Tree species, diameter at breast height (DBH) (cm), GPS location, and the presence of *Lobaria pulmonaria* of each cored tree were recorded. For standardisation, the core sample was extracted using an increment borer at 1 m height. To reduce potential errors associated with reaction wood and to facilitate precise dating, the samples were extracted perpendicular to the slope. The cores were

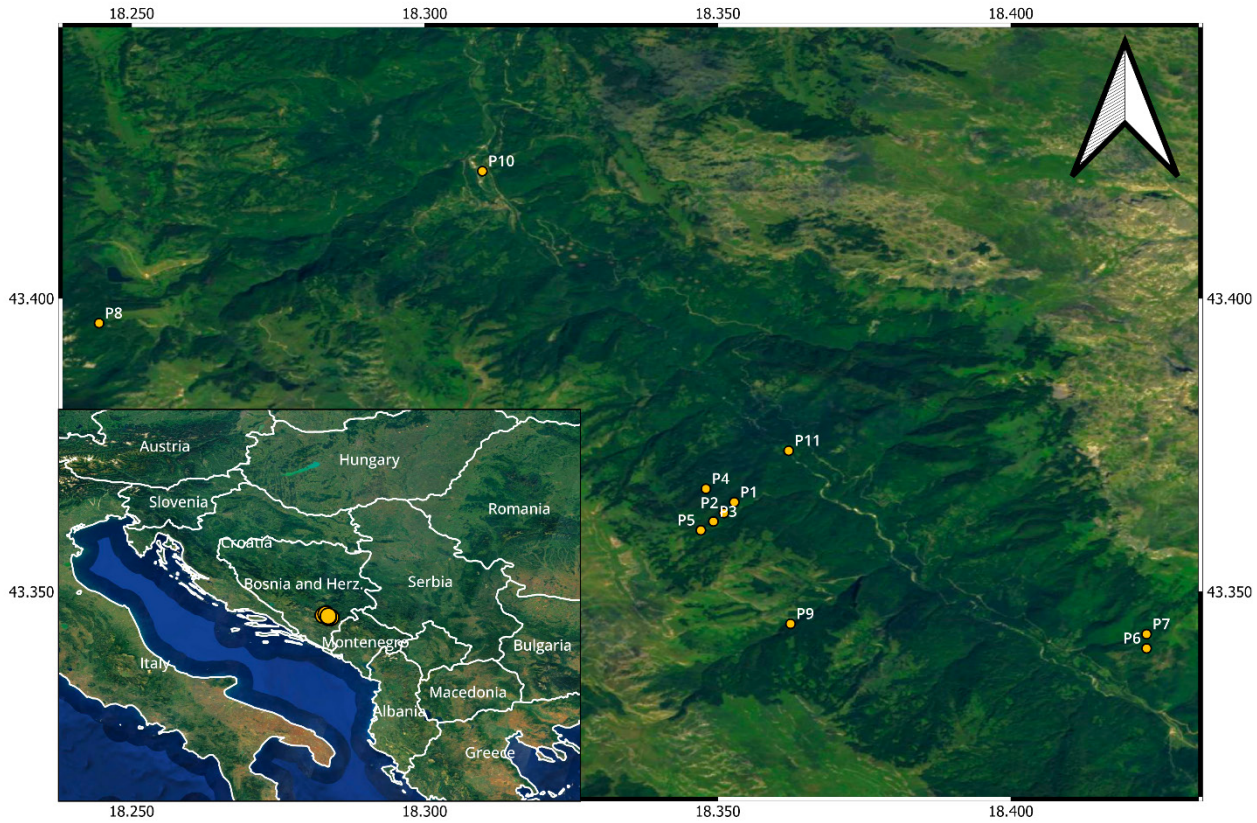

Figure 1. Map of the visited forest patch locations (orange circles) along the Upper Neretva River, with the labels indicating the assigned number of the patch. The map inset shows the location of sites (orange circles) in a larger context.

Slika 1. Zemljevid obiskanih lokacij gozdnih zaplat (oranžni krogi) ob Gornji Neretvi z oznakami zaplat. Vložek zemljevida prikazuje lokacijo najdišč (oranžni krogi) v širšem kontekstu.

Slika 1. Karta posjećenih lokaliteta (narandžasti krugovi) uz Gornju Neretvu sa oznakama ploha. Dodatna karta prikazuje poziciju lokaliteta (narandžasti krugovi) unutar šireg konteksta.

Table 1. List of old-growth forest structural indicators, their basic description, and further considerations (EC 2023).

Tabela 1. Seznam strukturnih indikatorjev starodavnih gozdov, njihov osnovni opis in nadaljnji premisleki (EC 2023).

Tabela 1. Spisak strukturnih indikatora starih šuma, njihov osnovni opis i dalja razmatranja (EC 2023).

Indicator	Description	Considerations
Native species	Only native species should be present.	A small number of non-native trees may be present only if they do not significant disturb the ecological processes
Deadwood	High proportion and diversity of standing and lying deadwood.	The amount and type of deadwood varies depending on forest type, local environmental conditions, and the areas disturbance history.
Old or large trees	Often high volume of large and/ or old trees relative to earlier developmental stages.	Depends on local growing conditions and the areas disturbance history.
Stand origin	Originates from natural regeneration.	Sown or planted forests can become old-growth after enough time.
Structural complexity	High structural complexity in the canopy layer, horizontal structural diversity, and soil microrelief structures (pit-and-mound) caused by uprooting.	Depends on tree species and natural disturbance history.
Habitat trees	High density and diversity of tree-related microhabitats (TreMs) (Larrieu et al. 2022).	Depends on tree species and natural disturbance history.
Indicator species	The presence of species specific to old-growth structures in a given environment.	

processed ex-situ following standard dendrochronological procedures. The LintabTM sliding stage and TsapWin software (RINNTECH, https://www.rinntech.com) were used to measure tree-ring widths, with the cores then visually cross-dated using COFECHA (Holmes 1983) to accurately derive the age of the sampled trees. Samples were only collected from *Fagus* and *Quercus* specimens to allow for robust cross-dating. We additionally visited the site of dam construction in Ulog. The visit lasted approximately one hour. Technical constraints did not allow collection of core samples; however, ten trees were more thoroughly inspected, and age estimations based upon tree rings visible on the cut stems and the presence of tree-related microhabitats were noted.

FOREST PATCH CATEGORISATION

Based on the visual observations of the old-growth characteristics (Tab. 1), visible indications of past human management, and dendrochronological samples, we categorised the visited forests into ten patches (Tab. 2). These patches were designated based on an area sharing the dominant tree species (beech, oak or alder), and past management intensity. For patches showing old-growth characteristics, polygons were delineated on Google Earth Pro and their area in hectares were noted, to provide a rough size estimation.

All data figures were created using the ggplot2 package in R Studio (version 2023.06.0+421), and the map was created using QGIS (version 3.34.2-Prizren).

Table 2. Basic description of the visited sites. Beech refers to *Fagus sylvatica* and oak to *Quercus* spp. (predominately *Quercus petraea*). Alnus is likely *Alnus rohlenae*.

Tabela 2. Osnovni opis obiskanih lokacij. Bukev se nanaša na vrsto *Fagus sylvatica*, hrast pa na razne vrste *Quercus* (predvsem *Quercus petraea*). Jelša je verjetno *Alnus rohlenae*.

Tabela 2. Osnovni opis posjećenih lokacija. Bukva se odnosi na vrstu *Fagus sylvatica*, dok se hrast odnosi na razne vrste roda *Quercus* (uglavnom *Quercus petraea*). Joha je vjerovatno *Alnus rohlenae*.

Patch number	Location	Latitude (N)	Longitude (E)	Elevation (m a.s.l)	Aspect (radians)	Slope (°)	Tree species
P1	Upper Neretva slopes	43.365265	18.35283	1020	0	5	Mixed beech and oak
P2	Upper Neretva slopes	43.363412	18.35106	1080	47	5	Oak
P3	Upper Neretva slopes	43.361966	18.34927	1100	32	5	Mixed beech and oak
P4	Upper Neretva slopes	43.367544	18.34800	1038	13	30	Beech
P5	Upper Neretva slopes	43.360464	18.34713	1166	4	35	Beech
P6	Upper Neretva slopes	43.340318	18.42319	1065	236	20	Oak
P7	Upper Neretva slopes	43.342745	18.42319	1075	317	37	Beech
P8	Ulosko	43.395803	18.24445	1280	103	20	Beech
P9	Upper Neretva slopes	43.344513	18.36243	1027	38	45	Beech
P10	Upper Neretva banks	43.374037	18.3621134	700	NA	0	Alnus
P11*	Upper Neretva dam construction site, Ulog	43.421725	18.30985	650	NA	NA	Mixed

* The site was heavily degraded due to land clearance for dam construction, therefore it is not possible to ascertain the origin of the felled trees in the area. Tree species present included *F. sylvatica*, *Quercus* spp., *Acer pseudoplatanus*, *Alnus* sp.

RESULTS AND DISCUSSION

LANDSCAPE AND FOREST COMMUNITY DESCRIPTION

The interplay between latitude and topography of the slope and the associated microclimatic characteristics has resulted in a highly heterogenous forested landscape across the studied area. The Neretva River runs approximately from SE to NW, with distinct differences in light exposure received by different the slopes. Side streams run from the slopes to the river, increasing the diversity of the topographical profile and the resultant tree species communities. Simply, the north and east facing slopes are generally dominated by mesophillous mixed-beech forests, the south and west facing slopes by thermophilic *Quercus* spp. (*Q. cerris* and *C. petraea*). The banks of the Neretva River are natural flooded alluvial floodplain forests dominated by *Alnus* trees, which we believe to be the recently (Vit et al. 2017) described *Alnus rohlenae*. This polyploid tree species is endemic to the Western Balkan peninsula and is now believed to widely replace the more common diploid *A. glutinosa* across the Dinaric Alps (Šmíd et al. 2022). However, genetic testing is needed to confirm the species.

SIGNS OF MANAGEMENT AND FOREST NATURALNESS

On the slopes within the surveyed area, different forest types of varying successional stages were identified. A large proportion of the landscape had signs of historical human management, specifically small-scale land clearing for grazing pastures, and coppicing. We can assume that the collection of woody debris

for fuelwood was commonplace. However, the area has experienced large-scale depopulation, allowing for natural successional processes to occur, including natural regeneration following human disturbance, and the accumulation of deadwood over the last decades. Since cessation of human influence, natural disturbances had clearly occurred in all visited forest sites (i.e. canopy gaps, diverse age and DBH structure). The understory cohort was largely comprised of mixed age and diameter trees of native species. The canopy trees – including some coppiced trees - were also rich in tree-related microhabitats, namely broken branches, trunk and stem-based rot holes, woodpecker cavities (Larrieu et al. 2022). *Lobaria pulmonaria* was identified throughout the area and was present on 15 on the 29 cored trees. Hence most of the sampled forests can be categorised as secondary forests (i.e. forests that regenerated largely through natural processes after significant human and/or natural disturbance of the original forest vegetation at a single point in time or over an extended period, and display a major difference in forest structure and/or canopy species composition with respect to nearby primary forests at similar sites) (Chokkalingam & de Jong 2001).

We also note the presence of small patches of beech and oak devoid of any signs of past human management, on both the north-east (*F. sylvatica*, patches 3, 4, and 9, approximately 7 ha) and south-west (*Quercus* spp., patch 7, approximately 1 ha) facing slopes. These patches fulfilled all criteria stipulated in the EU handbook for old-growth forests, including pit-and-mound microrelief, which was largely absent in the secondary forests (Tab. 1, EC 2023). These patches were surrounded by secondary forests with no distinct borders between the different patches, but rather a natural gradient.

DENDROCHRONOLOGY

Tree cores were collected from 29 trees across nine sites. Out of these, seven were *Quercus* species (*Q. cerris* or *Q. petraea*), and the remaining 22 were *F. sylvatica*. Dendrochronological analyses revealed that age varied from 65 to 255 years, with eight trees exceeding the age of 200 years (Fig. 2). The oldest tree was *Q. petraea*, with the remaining seven over 200 years old being *F. sylvatica* (Fig. 3). Trees older than 200 years are most often absent in managed sites, with beech trees often harvested at 120 years (von Wuehlisch 2008; Piovesan & Biondi 2021). Therefore, the combination of the dendrochronological results and field-based observations suggest that patches 3, 4, 7 and 9 have old-growth forest potential, while patches 1, 2, 5, 6 and 8 are relatively younger.

DAM CONSTRUCTION SITE

During the one hour visit to the dam construction site, we counted over 200 visible tree rings in >10 trees that had been felled. Extracting tree core samples and employing cross-dating methods would be required accurate dating of the trees. These trees were of various species (e.g. *F. sylvatica, Quercus* spp., *Acer pseudoplatanus, Alnus* spp.). Numerous tree-related microhabitats were present (i.e. rot holes, cavities, epiphytes, dead branches). Although it was not possible to ascertain the exact origin of these trees, it appeared that they originated close to where the felled trunks were located (i.e. from the site of construction).

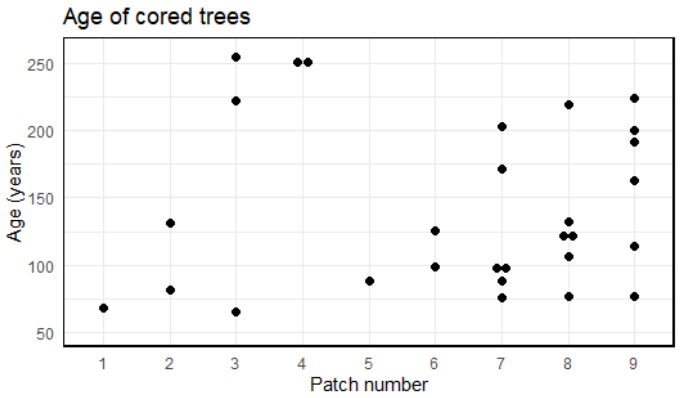

Figure 2. Dotplot displaying the age of trees (y-axis) in each sampled patch (x-axis). The black dots represent each core sample (n = 29).

Slika 2. Točkovni diagram, ki prikazuje starost dreves (os y) v vsakem vzorčenem delu (os x). Črne pike predstavljajo vzorce jedra (n = 29).

Slika 2. Tačkasti dijagram koji prikazuje starost stabala (y-osa) na svakoj uzorkovanoj plohi (x-osa). Crne tačke predstavljaju uzorke jezgra (n = 29).

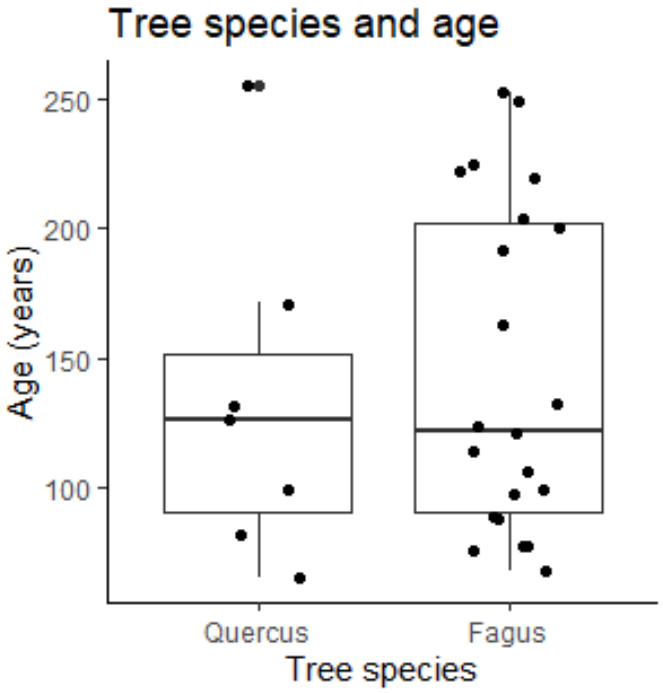

Figure 3. Boxplot displaying the age of trees (x-axis) for *Quercus* and *Fagus* (y-axis). The black dots represent each core sample (n = 29).

Slika 3. Grafikon kvantilov, ki prikazuje starost dreves (os x) za *Quercus* in *Fagus* (os y). Črne pike predstavljajo vzorce jedra (n = 29).

Slika 3. Kutija-dijagram koji prikazuje starost stabala (x-osa) za *Quercus* i *Fagus* (y-osa). Crne tačke predstavljaju uzorke jezgra (n = 29).

GENERAL OVERVIEW

This survey was limited in terms of time and resources, therefore, the findings are a speculative introduction to the presence of old-growth forests in the area. Further investigation is required to confirm the results including, but not limited to, establishing research plots across the landscape to quantify

the volume and diversity of deadwood, regeneration, tree diameter and heights, and extracting more core samples from a wider sample of trees. Regardless of these limitations, this research is a crucial step in assessing the ecological value of the survey area.

The landscape was highly heterogenous, underscoring the ecological value of the Upper Neretva. The diverse tree species composition driven by changes in exposition and complexity of topographical profile likely provides a habitat for a wide range of species. The EU Guidelines for Defining, Mapping, Monitoring, and Strictly Protecting EU Primary and Old-Growth Forests provided an invaluable tool for rapid visual survey of the visited forests using easily identifiable forest structures (EC 2023). Based on these guidelines, it was found that the entire survey area is characterized by a matrix of forest types in different post-management successional stages, including small patches of both beech and oak forest devoid of any indications of past human management which we can therefore categorise as old-growth – increasingly rare in temperate Europe (Sabatini et al. 2018). The main difference between these old-growth patches and neighbouring secondary forests was the absence of coppicing, large volume and variety of standing and lying deadwood, and pit-and-mound microrelief structures – all of which fulfil the criteria outlined by the EU (EC 2023). These characteristics are essential for many old-growth specialists (Zeller et al. 2023). Downed and standing deadwood diversity, for example, increases lichen (Langbehn et al. 2021; Gloor et al. 2024), beetle (Kozák et al. 2021), and fungi (Ferenčík et al. 2022; Majdanova et al. 2023) diversity. Although deadwood volume and diversity are dependent on various factors, such as site conditions and disturbance history, it generally accumulates with time since management activities, hence safeguarding forests with high amounts of deadwood is a key step in biodiversity conservation practices (Bölöni et al. 2017; Bujoczek et al. 2021; Mansuy et al. 2024).

The extent of these old-growth forest patches was nonetheless small (~8 ha), and there were clear signs of historical human management in much of the studied area. The age of the coppiced canopy trees however, suggests that management activities were not intensive nor extensive, and ceased over a century ago, which coincides with the gradual emigration from the area. Hence the forests have largely been abandoned to natural developmental processes. Therefore, after the mortality of the current canopy layer and its replacement with a new cohort of trees, signs of historical human management will be close to absent.

The historical management nonetheless contributed to the mosaic forest structure of the area, which likely heightens the biodiversity of the region through increased habitat heterogeneity. Moreover, there were no sharp contrast borders between old-growth and secondary forests, minimising any detrimental edge effects for forest-dwelling species (Franklin et al. 2021) and allowing for movement of individuals across a large area. Indeed, irrespective of historical management, *Lobaria pulmonaria* was identified throughout the forests, indicating long-term ecological continuity and minimal anthropogenic disturbances during the past decades (Jüriado et al. 2009; Belinchón et al. 2017; Ravera et al. 2023). Furthermore, as the species is a proxy for wider biodiversity, we can assume that its presence is indicative of numerous other threatened species (Nascimbene et al. 2010).

Large beech and oak trees were also present throughout the area, and the dendrochronological analyses revealed that some of the trees dominating the canopy layer exceeded 200 years in age, with several trees reaching 250 years. Under optimal conditions, both oak and beech trees can reach several centuries in age; for example, in old-growth mixed-beech forest sites in Slovakia, trees exceeding 300 and 400 years in age are not uncommon (Mikoláš et al. 2019; Gloor et al. 2024), whilst oak commonly exceeds a similar age (Mölder et al. 2019). However, tree longevity is largely limited by climate and further site conditions (Piovesan & Biondi 2021). Comparably, in managed forests, beech trees are usually felled between 80–120 years (von Wuehlisch 2008). Nonetheless, tree age variation is a key characteristic of late-successional and old-growth forests, which was the case here.

The ecological importance of old trees is paramount. For example, the diversity and abundance of tree-related microhabitats are strongly related to higher tree age and diameter (Ranius et al. 2009; Kozák et al. 2023). We indeed note a high diversity of tree-related microhabitats across the landscape, in particular, trunk and ground rot holes, dead branches, woodpecker cavities, and epiphytes (Larrieu et al. 2022). These features are essential habitats for numerous specialised species (Asbeck et al. 2021). Further, the long-term temporal availability of veteran trees is key for many lichen species (Marmor et al. 2011). In the face of both natural and anthropogenic disturbances, old trees can act as lifeboats for specialised taxa, and their presence can help to sustain populations of species dependent on old-growth forest structures (Hofmeister et al. 2016). Despite their ecological importance, modern forestry practises undervalue the presence of old trees due to their »defects« (i.e. microhabitats), and such trees are hence selected against during thinning practises, leading to a general decline of such trees at the European level over the past century (Bütler et al. 2013). Therefore, to succeed in the protection of forest biodiversity, the conservation of old and large trees is of exceptional importance.

Nonetheless, considering the limited time and financial constraints of this study, only 29 tree cores were taken, which poses a clear limitation on accurate age estimates resulting from small sample size. This uncertainty is amplified by the fact that dendrochronological methods are limited by the quality of core samples. Heart rot and hollow trunks lead to incomplete tree ring series, so the exact age cannot be derived from such samples. Trunk damages are particularly common in old oak trees (Mölder et al. 2019). Therefore, the largest and oldest trees were not selected for coring. Nonetheless, tree size and age do not always correlate; for example, the oldest *F. sylvatica* tree that has been measured was dated to 622 years of age, yet it measures just 12 m in height with a DBH of 65 cm, which is considered small (Piovesan et al. 2019). Slow growth

rates are argued to be a prerequisite for increased longevity in trees (Piovesan et al. 2021). Considering that the limitations of dendrochronology can lead to an underestimation of tree age, we confidently posit that there were numerous trees present across the landscape older than those cored.

Furthermore, the riparian forests located on the banks of the free-flowing Neretva River appear to be dominated by the recently described *Alnus rohlenae*, although genetic tests must confirm these observations, as hybrid species are possible. The Balkan Peninsula was an important European refugium for many taxa – including *A. rohlenae* – during the last glacial maximum which led to the development of numerous endemic taxa via allopatric speciation (Mandák et al. 2016). Šmíd et al. (2022) posit that the Neretva River basin could act as a geographical barrier between *A. rohlenae* and *A. glutinosa* hybrids, highlighting the importance of the Upper Neretva as a potential northern stronghold for this endemic species. *A. rohlenae* (along with *A. glutinosa*) only occupies riparian habitats and areas with soil saturated with groundwater, hence the floodplain forest of the Upper Neretva provides the ideal conditions in which this species can thrive. However, due to the southern location and Mediterranean climate of the Balkan Peninsula, *A. rohlenae* only occurs in non-drying rivers and streams, in sites of higher elevation, and is therefore most often confined to the bottoms of deep canyons. In such locations, the microclimatic conditions appear to be optimal for the tetraploid *A. rohlenae*, however, not for the diploid *A. glutinosa* (Šmíd et al. 2022). The small range of the species and specific habitat requirements means that it is vulnerable to changes in water regime therefore the protection of these species is imperative to maintain tree species diversity in Europe.

Finally, although no quantitative data was taken from the dam construction site at Ulog, we can use the aforementioned knowledge gathered from other sites to confidently support our age predictions. Through counting tree rings, we found trees exceeding 200 years in age have been felled. However, age estimations based on the tree rings visible to the naked eye dramatically underestimates the true age due to periods of suppressed growth in which separate tree rings are inherently difficult to distinguish. These trees also hosted numerous tree-related microhabitats (e.g. cavities, rot holes, broken branches). Hence it appears that HCVF have already been logged, highlighting the importance of rapid protection of the remaining forests of the region.

CONCLUSIONS

This initial rapid survey of the forests of the Upper Neretva River is based upon the EU Guidelines for Defining, Mapping, Monitoring, and Strictly Protecting EU Primary and Old-Growth Forests (EC 2023). It confirms the presence of HCVF and secondary forests – essential for the maintenance of biodiversity – including old-growth forest patches. Although their protection is mandated by the European Union, strict protection is currently not enforced in sites that are not officially categorized as such. As a candidate country for EU integration, Bosnia and Herzegovina has committed to steps to protect biodiversity and reduce deforestation. However, it appears that HCVFs have already been felled in the dam construction site, we therefore call for immediate protection of the remaining forests before these unique ecosystems and their inhabitants are lost.

POVZETEK

Zaradi hitrega izginjanja biotske raznovrstnosti je zaščita ekosistemov, ki gostijo veliko bogastvo ogroženih in specializiranih vrst, nujna. Gozdovi visoke ohranitvene vrednosti – vključno s starodavnimi gozdovi – so kopenski ekosistemi, ki so ključnega pomena za številne okoljske in družbene vrednote, vključno z ohranjanjem ogroženih vrst (Jennings et al. 2003). Kljub temu, da Evropska unija v strategiji EU za biotsko raznovrstnost do leta 2030 zahteva zaščito primarnih in starodavnih gozdov, se njihovo krčenje nadaljuje po vsej celini. Zlasti Balkanski polotok gosti velik delež starodavnih gozdov in številne endemične vrste (Sabatini et al. 2018), vendar so, v povezavi z družbenopolitičnimi spremembami, obsežni projekti sprememb rabe zemljišč običajni po vsej regiji. Zato so hitra prizadevanja za kartiranje in zaščito gozdov visoke ohranitvene vrednosti izjemnega pomena. Namen študije je bil opraviti začetno raziskavo gozdov Gornje Neretve v Bosni in Hercegovini – biotsko raznovrstnega, a ogroženega območja – da bi ugotovili prisotnost morebitnih starodavnih gozdov. Da bi natančno določili območja, kjer bi lahko bili prisotni stari gozdovi, na podlagi heterogene strukture krošnje, smo analizirali satelitske slike. Ob obisku lokacij smo poleg vizualnih pregledov uporabili dendrokronološke metode za oceno starosti dreves ter identifikacijo struktur stare rasti in znakov preteklega človekovega upravljanja (EC 2023).

Ugotovili smo, da so bila mesta zelo heterogena v smislu drevesnih vrst (prevladujejo vrste *Fagus sylvatica* ali *Quercus*), odvisno od orientacije pobočij. Medtem ko je bilo človeško upravljanje vidno po vsej regiji, te dejavnosti niso bile niti razširjene niti intenzivne in so bile v veliki meri sestavljene iz pomlajevanja in ustvarjanja majhnih pašnikov. Dendrokronološko vzorčenje je razkrilo, da je starost krošenj dreves na obiskanih območjih presegla 200 let, pri čemer so mnoga drevesa dosegla starost 250 let, kar kaže na to, da so se človeške dejavnosti prenehale pred več kot stoletjem. Gozdovi so bili pozneje večinoma prepuščeni naravnim sukcesijskim procesom in jih je zdaj mogoče uvrstiti med sekundarne gozdove zaradi velikega obsega in raznolikosti prisotnega mrtvega lesa, prisotnosti indikatorske vrste stare rasti *Lobaria pulmonaria* in velikih dreves s številnimi mikrohabitati, povezanimi z drevesi. Nadalje smo odkrili prisotnost majhnih starodavnih gozdnih zaplat, ki izpolnjujejo merila, ki jih je določila EU (EC 2023), vključno s topografijo jam in gomil. Kljub majhnosti starodavnih zaplat, ni bilo strogih meja med tipi gozdov, ki so se razlikovali v pretekli intenzivnosti gospodarjenja. To je minimiziralo morebitne robne učinke in verjetno omogočilo nemoteno gibanje vrst po pokrajini. Gozdove gornje Neretve zato lahko kategoriziramo kot gozdove z visoko ohranitveno vrednostjo in posledično priporočamo moratorij na sečnjo v regiji, da bi ohranili te ekosisteme, kot je določeno v Zeleni agendi za Zahodni Balkan – ključni komponenti integracije Bosne in Hercegovine v EU.

SAŽETAK

Obzirom na konstantan gubitak biodiverziteta, zaštita ekosistema koji su domaćini velikog broja ugroženih i jedinstvenih vrsta je neophodna. Šume visoke zaštitne vrijednosti - uključujući prašume - su kopneni ekosistemi koji su od ključne važnosti za mnoge ekološke i društvene vrijednosti, uključujući opstanak ugroženih vrsta (Jennings et al. 2003). Uprkos tome što je Evropska unija u Strategiji biodiverziteta EU za 2030. godinu propisala zaštitu primarnih šuma i prašuma, njihov gubitak se nastavlja na području cijelog kontinenta. Balkansko poluostrvo, posebno, domaćin je velikog procenta starih šuma i brojnih endemskih vrsta (Sabatini et al. 2018), ali uz društveno-političke promjene, veliki projekti promjene namjene zemljišta uobičajeni su u cijeloj regiji. Mapiranje i zaštita ovih šuma visoke zaštine vrijednosti trebale bi biti od najveće važnosti. Stoga, cilj ove studije je bio provesti početno istraživanje šuma gornjeg toka rijeke Neretve u Bosni i Hercegovini – bioraznovrsnog, ali ugroženog područja – kako bi se utvrdila prisutnost bilo kakvih starih šuma. Analizirane su satelitske snimke na osnovu heterogenosti strukture krošnje kako bi se izdvojila potencijalna područja starih šuma. Na odabranim lokalitetima korištene su dendrohronološke metode zajedno sa vizuelnim procjenama starosti drveća, da se identifikuju strukture karakteristične za stare šume, kao i pokazatelji predhodnih gazdovanja ovim šumama (EC 2023).

Otkrili smo da su odabrani lokaliteti vrlo heterogeni u pogledu vrsta drveća (dominantne vrste su *Fagus sylvatica* i vrste iz roda *Quercus*), u zavisnosti od ekspozicije. Iako je antropogeni uticaj vidljiv u cijeloj regiji, te aktivnosti nisu bile ni obimne ni intenzivne, već su se uglavnom sastojale od sječe i krčenja šuma u malim razmjerama radi stvaranja pašnjaka. Međutim, dendrohronološko uzorkovanje otkrilo je da je starost krošnji drveća na posjećenim lokalitetima premašila 200 godina, a mnoga stabla dosežu starost od 250 godina, što ukazuje na to da su ljudske aktivnosti, čini se, prestale prije više od jednog vijeka. Šume su nakon toga uglavnom prepuštene prirodnim procesima sukcesije i sada se mogu klasifikovati kao sekundarne šume zbog velike zapremine i prisutnog mrtvog drveta, prisutnosti indikatorske vrste starih šuma *Lobaria pulmonaria* kao i krupnih stabala sa brojnim mikrostaništima. Dalje, otkrili smo prisutnost manjih površina starih šuma, koje ispunjavaju kriterijume koje je postavila EU (EC 2023), uključujući i tzv »pit-and-mound« topografiju. Uprkos njihovoj maloj površini, nedostajale su stroge granice između tipova šuma koje su se razlikovale po intenzitetu gazdovanja u prošlosti, čime su se minimizirali bilo kakvi uticaji jasnih granica i na taj način se vjerovatno omogućilo nesmetano mješanje vrsta po području. Stoga šume gornje Neretve kategorizujemo kao visokovrijedne za očuvanje i preporučujemo moritorijum na sječu šuma u regiji kako bi se očuvali ovi ekosistemi, kako je propisano u Zelenoj agendi za zapadni Balkan – ključnoj komponenti integracije Bosne i Hercegovine u EU.

ACKNOWLEDGEMENTS

I offer my sincere gratitude to Michal Frankovič and Linda Majdanová for assistance in the field, Martin Mikoláš for guidance and support, the dendrochronology team of the Czech University of Life Sciences Prague for the processing of the core samples, Matej Ferenčík for proofreading the final version, the organisers and volunteers of Neretva Science Week for their hard work and dedication, and finally, the residents of Ulog, for their warm welcome to the region.

REFERENCE

Alfaro-Sánchez R, Jump AS, Pino J, Díez-Nogales O, Espelta JM. 2019. Land use legacies drive higher growth, lower wood density and enhanced climatic sensitivity in recently established forests. Agricultural and Forest Meteorology. 276: 107630. https://doi.org/10.1016/j.agrformet.2019.107630

Asbeck T, Großmann J, Paillet Y, Winiger N, Bauhus J. 2021. The use of tree-related microhabitats as forest biodiversity indicators and to guide integrated forest management. Current Forestry Reports. 7(1): 59-68. https://doi.org/10.1007/s40725-020-00132-5

Barredo JI, Brailescu C, Teller A, Sabatini FM, Mauri A, Janouskova K. 2021. Mapping and assessment of primary and old-growth forests in Europe, EUR 30661 EN. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/797591

Belinchón R, Harrison PJ, Mair L, Várkonyi G, Snäll T. 2017. Local epiphyte establishment and future metapopulation dynamics in landscapes with different spatiotemporal properties. Ecology. 98: 741-750. https://doi.org/10.1002/ecy.1686

Bölöni J, Ódor P, Ádám R, Keeton WS, Aszalós R. 2017. Quantity and dynamics of dead wood in managed and unmanaged dry-mesic oak forests in the Hungarian Carpathians. Forest Ecology and Management. 399: 120-131. https://doi.org/10.1016/j.foreco.2017.05.029

Brunialti G, Frati L, Aleffi M, Marignani M, Rosati L, Burrascano S, Ravera S. 2010. Lichens and bryophytes as indicators of old-growth features in Mediterranean forests. Plant Biosystematics. 144: 221-233. https://doi.org/10.1080/11263500903560959

Bujoczek L, Bujoczek M, Zięba S. 2021. How much, why and where? Deadwood in forest ecosystems: The case of Poland. Ecological Indicators. 121: 107027. https://doi.org/10.1016/j.ecolind.2020.107027

Bütler R, Lachat T, Larrieu L, Paillet Y. 2013. Habitat trees: key elements for forest biodiversity. Integrative approaches as an opportunity for the conservation of forest biodiversity. In Kraus D, Krumm F, editors. Integrative approaches as an opportunity for the conservation of forest biodiversity. European Forest Institute. p. 84-91.

Chokkalingam U, De Jong W. 2001. Secondary forest: a working definition and typology. The International Forestry Review. 3(1): 19-26.

Czerepko J, Gawryś R, Szymczyk R, Pisarek W, Janek M, Haidt A, Kowalewska A, Piegdoń A, Stebel A, Kukwa M, et al. 2021. How sensitive are epiphytic and epixylic cryptogams as indicators of forest naturalness? Testing bryophyte and lichen predictive power in stands under different management regimes in the Białowieża forest. Ecological Indicators. 125: 107532. https://doi.org/10.1016/j.ecolind.2021.107532

[EC] European Commission, Directorate-General for Environment. 2023. Commission guidelines for defining, mapping, monitoring and strictly protecting EU primary and old-growth forests. Luxembourg: Publications Office of the European Union; [accessed on 1. 8. 2024]. https://data.europa.eu/doi/10.2779/481811

Di Nuzzo L, Giordani P, Benesperi R, Brunialti G, Fačkovcová Z, Frati L, Nascimbene J, Ravera S, Vallese C, Paoli L, et al. 2022. Microclimatic alteration after logging affects the growth of the endangered lichen *Lobaria pulmonaria*. Plants. 11: 295. https://doi.org/10.3390/plants11030295

Espelta JM, Cruz-Alonso V, Alfaro-Sánchez R, Hampe A, Messier C, Pino J. 2020. Functional diversity enhances tree growth and reduces herbivory damage in secondary broadleaf forests, but does not influence resilience to drought. Journal of Applied Ecology. 57(12): 2362-2372. https://doi.org/10.1111/1365-2664.13728

[FAO] Food and Agriculture Organization of the United Nations. 2024. Forest area (% of land area). FAOSTAT; [accessed on 1. 8. 2024]. https://data.worldbank.org/indicator/AG.LND.FRST.ZS?locations=EU&view=map

Ferenčík M, Svitok M, Mikoláš M, Hofmeister J, Majdanová L, Vostárek O, Kozák D, Bače R, Begović K, Běťák J, et al. 2022. Spatial and temporal extents of natural disturbances differentiate deadwood-inhabiting fungal communities in spruce primary forest ecosystems. Forest Ecology and Management. 517: 120272. https://doi.org/10.1016/j.foreco.2022.120272

Franklin CM, Harper KA, Clarke MJ. 2021. Trends in studies of edge influence on vegetation at human-created and natural forest edges across time and space. Canadian Journal of Forest Research. 51: 274-282. https://doi.org/10.1139/cjfr-2020-0308

Gloor R, Svitok M, Mikoláš M, Hofmeister J, Halda J, Janda P, Sabatini FM, Zemanová L, Buechling A, Kozák D, et al. 2024. Sustaining forest biodiversity: Exploring the effect of long-term natural disturbance dynamics on contemporary lichen communities in primary forest ecosystems. Forest Ecosystems. 11: 100214. https://doi.org/10.1016/j.fecs.2024.100214

Hofmeister J, Hošek J, Malíček J, Palice Z, Syrovátková L, Steinová J, Černajová I. 2016. Large beech (*Fagus sylvatica*) trees as 'lifeboats' for lichen diversity in central European forests. Biodiversity Conservation. 25(6): 1073-1090. https://doi.org/10.1007/s10531-016-1106-x

Holmes RL. 1983. Computer-assisted quality control in tree-ring dating and measurement. Tree-Ring Bulletin. 43: 69-78.

Ioras F, Dautbasic M, Abrudan IV, Gurean D, Lojo A, Trestik T, Ballian D, Bajric M. 2012. Virgin status assessment of Plješevica Forest in Bosnia - Herzegovina. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 37(2): 22-27.

Jennings S, Nussbaum R, Judd N, Evans T. 2003. The high conservation value forest toolkit, Edition 1. Oxford (UK): ProForest.

Jüriado I, Liira J. 2009. Distribution and habitat ecology of the threatened forest lichen *Lobaria pulmonaria* in Estonia. Folia Cryptogamica Estonica. 46: 55-65.

Kozák D, Svitok M, Wiezik M, Mikoláš M, Thorn S, Buechling A, Hofmeister J, Matula R, Trotsiuk V, Bače R, et al. 2021. Historical disturbances determine current taxonomic, functional and phylogenetic diversity of saproxylic beetle communities in temperate primary forests. Ecosystems. 24: 37-55. https://doi.org/10.1007/s10021-020-00502-x

Kozák D, Svitok M, Zemlerová V, Mikoláš M, Lachat T, Larrieu L, Paillet Y, Buechlink A, Bače R, Keeton WS, et al. 2023. Importance of conserving large and old trees to continuity of tree-related microhabitats. Conservation Biology. 37(3): e14066. https://doi.org/10.1111/cobi.14066

Kuussaari M, Bommarco R, Heikkinen RK, Helm A, Krauss J, Lindborg R, Öckinger E, Pärtel M, Pino J, Rodà F, et al. 2009. Extinction debt: a challenge for biodiversity conservation. Trends in Ecology & Evolution. 24(10): 564-571. https://doi.org/10.1016/j.tree.2009.04.011

Langbehn TJ, Hofmeister J, Svitok M, Mikoláš M, Matula R, Halda JP, Svobodová K, Pouska V, Kameniar O, Kozák D, et al. 2021. The impact of natural disturbance dynamics on lichen diversity and composition in primary mountain spruce forests. Journal of Vegetation Science. 32: e13087. https://doi.org/10.1111/jvs.13087

Larrieu L, Courbaud B, Drénou C, Goulard M, Bütler R, Kozák D, Kraus D, Krumm F, Lachat T, Müller J, et al. 2022. Key factors determining the presence of Tree-related Microhabitats: A synthesis of potential factors at site, stand and tree scales, with perspectives for further research. Forest Ecology and Management. 515: 120235. https://doi.org/10.1016/j.foreco.2022.120235

Luyssaert S, Schulze ED, Börner A, Knohl A, Hessenmöller D, Law BE, Ciais P, Grace J. 2008. Old-growth forests as global carbon sinks. Nature. 455: 213-215. https://doi.org/10.1038/nature07276

Majdanová L, Hofmeister J, Pouska V, Mikoláš M, Zíbarová L, Vítková L, Svoboda M, Čada V. 2023. Old-growth forests with long continuity are essential for preserving rare wood-inhabiting fungi. Forest Ecology and Management. 541: 121055. https://doi.org/10.1016/j.foreco.2023.121055

Mandák B, Vít P, Krak K, Trávníček P, Havrdová A, Hadincová V, Zákravský P, Jarolímová V, Bacles CFE, Douda J. 2016. Flow cytometry, microsatellites and niche models reveal the origins and geographical structure of *Alnus glutinosa* populations in Europe. Annals of Botany. 117(1): 107-120. https://doi.org/10.1093/aob/mcv158

Mansuy N, Barredo JI, Migliavacca M, Pilli R, Leverkus AB, Janouskova K, Mubareka S. 2024. Reconciling the different uses and values of deadwood in the European Green Deal. One Earth. 7(9): 1542-1558. https://doi.org/10.1016/j.oneear.2024.08.001

Marmor L, Tõrra T, Randlane T. 2011. Effects of forest continuity and tree age on epiphytic lichen biota in coniferous forests in Estonia. Ecological Indicators. 11: 1270-1276. https://doi.org/10.1016/j.ecolind.2011.01.009

Mikoláš M, Ujházy K, Jasík M, Wiezik M, Gallay I, Polák P, Vysoky J, Čiliak M, Meigs GW, Svoboda M, et al. 2019. Primary forest distribution and representation in a Central European landscape: Results of a large-scale field-based census. Forest Ecology and Management. 449: 117466. https://doi.org/10.1016/j.foreco.2019.117466

Mikoláš M, Piovesan G, Ahlstrom A, Donato DC, Gloor R, Hofmeister J, Keeton WS, Muzs B, Sabatini FM, Svoboda M, et al. 2023. Protect old-growth forests in Europe now. Science. 380(6644): 466. https://doi.org/10.1126/science.adh2303

Mo L, Zohner CM, Reich PB, Liang J, de Miguel S, Nabuurds GJ, Renner SS, van de Hoogen J, Araza A, Herold M, et al. 2023. Integrated global assessment of the natural forest carbon potential. Nature. 624(7990): 92-101. https://doi.org/10.1038/s41586-023-06723-z

Mölder A, Meyer P, Nagel RV. 2019. Integrative management to sustain biodiversity and ecological continuity in Central European temperate oak (*Quercus robur*, *Q. petraea*) forests: An overview. Forest Ecology and Management. 437: 324-339. https://doi.org/10.1016/j.foreco.2019.01.006

Munteanu C, Senf C, Nita MD, Sabatini FM, Oeser J, Seidl R, Kuemmerle T. 2022. Using historical spy satellite photographs and recent remote sensing data to identify high-conservation-value forests. Conservation Biology. 36(2): e13820. https://doi.org/10.1111/cobi.13820

Nascimbene J, Brunialti G, Ravera S, Frati L, Caniglia G. 2010. Testing *Lobaria pulmonaria* (L.) Hoffm. as an indicator of lichen conservation importance of Italian forests. Ecological Indicators. 10(2): 353-360. https://doi.org/10.1016/j.ecolind.2009.06.013

Palmero-Iniesta M, Pino J, Pesquer L, Espelta JM. 2021. Recent forest area increase in Europe: expanding and regenerating forests differ in their regional patterns, drivers and productivity trends. European Journal of Forest Research. 140(4): 793-805. https://doi.org/10.1007/s10342-021-01366-z

Patacca M, Lindner M, Lucas-Borja ME, Cordonnier T, Fidej G, Gardiner B, Hauf Y, Jasinevičius G, Labonne S, Linkevičius E, et al. 2023. Significant increase in natural disturbance impacts on European forests since 1950. Global Change Biology. 29(5): 1359-1376. https://doi.org/10.1111/gcb.16531

Piovesan G, Biondi F, Baliva M, De Vivo G, Marchianò V, Schettino A, Di Filippo A. 2019. Lessons from the wild. Ecology. 100(9): 1-4. https://doi.org/10.1002/ecy.2737

Piovesan G, Biondi F. 2021. On tree longevity. New Phytologist Foundation. 231(4): 1318-1337. https://doi.org/10.1111/nph.17148

Ranius T, Niklasson M, Berg N. 2009. Development of tree hollows in pedunculate oak (*Quercus robur*). Forest Ecology and Management. 257(1): 303-310. https://doi.org/10.1016/j.foreco.2008.09.007

Ravera S, Benesperi R, Bianchi E, Brunialti G, Di Nuzzo L, Frati L, Giordani P, Isocrono D, Nascimbene J, Vallese C, et al. 2023. *Lobaria pulmonaria* (L.) Hoffm.: The multifaceted suitability of the Lung lichen to monitor forest ecosystems. Forests. 14(10): 2113. https://doi.org/10.3390/f14102113

[RCC] Regional Cooperation Council. 2020. Action Plan for the Implementation of the Sofia Declaration on the Green Agenda for the Western Balkans 2021-2030; [accessed on 1. 8. 2024]. https://www.rcc.int/download/docs/Action%20Plan%20ENG%20ver%20I%20(1).pdf/d6b170df3ed1b-06973f02675e474d661.pdf

Sabatini FM, Burrascano S, Keeton WS, Levers C, Lindner M, Pötzschner F, Verkerk PJ, Bauhus J, Buchwald E, Chaskovsky O. 2018. Where are Europe's last primary forests? Diversity and Distributions. 24(10): 1426-1439. https://doi.org/10.1111/ddi.12778

Seidl R, Schelhaas MJ, Rammer W, Verkerk PJ. 2014. Increasing forest disturbances in Europe and their impact on carbon storage. Nature Climate Change. 4(9): 806-810. https://doi.org/10.1038/nclimate2318

Singer G, Eichelmann U, Knook V, Weiss S, Topić V, Ivanić J, Borko S, Zagmajster M. 2023. Neretva Science Week 2022 – shedding light on the biodiversity of the Upper Neretva River valley, Bosnia and Herzegovina. Natura Sloveniae. 25(3): 5-13. https://doi.org/10.14720/ns.25.3.5-13

Šmíd J, Vít P, Douda J, Krak K, Mandák B. 2022. Distribution, hybridisation and morphological variation in *Alnus rohlenae* (Betulaceae) an endemic species of the Balkan Peninsula. European Journal of Forest Research. 141: 641-648. https://doi.org/10.1007/s10342-022-01466-4

Stelstra R. 2023. The continuous challenge of determining the Bosnian Forests. Brussels: EUSTAFOR; [accessed on 1. 8. 2024]. https://eustafor.eu/the-continuous-challenge-of-demining-the-bosnian-forests/

Vit P, Douda J, Krak K, Havrdová A, Mandák B. 2017. Two new polyploid species closely related to *Alnus glutinosa* in Europe and North Africa – An analysis based on morphometry, karyology, flow cytometry and microsatellites. Taxon. 66(3): 567-583. https://doi.org/10.12705/663.4

Von Wuehlisch G. 2008. EUFORGEN Technical Guidelines for genetic conservation and use for European beech (Fagus sylvatica). Rome: Biodiversity International.

Zeller L, Förster A, Keye C, Meyer P, Roschak C, Ammer C. 2023. What does literature tell us about the relationship between forest structural attributes and species richness in temperate forests? - A review. Ecological Indicators. 153: 110383. https://doi.org/10.1016/j.ecolind.2023.110383

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v katerekoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 93–105
»Neretva Science Week 2023«

ZNANSTVENI ČLANEK /
SCIENTIFIC ARTICLE

DOI: 10.14720/ns.21510
Objavljeno na spletu / Published online: 31. 12. 2025

Prejeto / Received: 25. 12. 2024
Sprejeto / Accepted: 29. 12. 2025

Contribution to the knowledge of the butterflies and moths of the upper course of Neretva River, Nevesinjsko polje and the Morine plateau

Branislava DUKIĆ[1*], *Dejan KULIJER*[2], *Thomas ZECHMEISTER*[3]

ABSTRACT

In early June 2023, we studied the Lepidoptera fauna of the upper course of the Neretva River, the valley of the Zalomka River in Nevesinjsko Polje and the Morina plateau between the two. In total, we registered 237 species, 63 butterflies and 174 moths. We found 53 butterfly species in the area of the Upper Neretva River, 37 in Nevesinjsko polje and five on the Morina plateau, along with 156, 40 and 20 moth species, respectively. In this study, we increased the total number of registered Lepidoptera species for the area, from 251 found in the same region during Neretva Science Week 2022, to a total of 414 (93 butterflies and 321 moths). Eight species have the status of Near Threatened and one is categorised as Data Deficient according to IUCN Red List of Threatened Species. Two species are listed as Vulnerable in the Red List of the Federation of Bosnia and Herzegovina and three species are listed on the Annex II of the EU Habitats Directive. Our findings present a much-needed basic knowledge on Lepidoptera of the region, which is important for conservation activities.

IZVLEČEK

Prispevek k poznavanju dnevnih in nočnih metuljev zgornjega toka reke Neretve, Nevesinjskega polja in planote Morine

V začetku junija 2023 smo raziskovali favno metuljev v zgornjem toku reke Neretve, porečju reke Zalomke na Nevesinjskem polju in na planoti Morine med njima. Skupno smo zabeležili 237 vrst, 63 dnevnih in 174 nočnih metuljev. V zgornjem toku reke Neretve smo našli 53 vrst dnevnih metuljev, 37 na Nevesinjskem polju in pet na planoti Morina, medtem ko je bilo nočnih metuljev na the območjih 156, 40 in 20. Skupno število znanih vrst metuljev za to območje smo povečali s prej znanih 251, najdenih tekom Znanstvenega tedna Neretve 2022, na skupno 414 vrst (93 vrst dnevnih in 321 vrst nočnih metuljev). Osem vrst ima status skoraj ogroženih, ena pa je po Rdečem seznamu ogroženih vrst IUCN vrsta z nezadostnimi podatki. Dve vrsti sta na Rdečem seznamu Federacije Bosne in Hercegovine navedeni kot ranljivi, tri vrste pa so navedene v Prilogi II EU Direktive o habitatih. Naši podatki predstavljajo nujno potrebno osnovno znanje o metuljih v regiji, ki je pomembno za varstvene aktivnosti.

[1] Center for Environment, Miše Stupara 5, 78000 Banja Luka, Bosnia and Herzegovina; E-mail: branislava.dukic@czzs.org

[2] National Museum of Bosnia and Herzegovina, Zmaja od Bosne 3, 71000 Sarajevo, Bosnia and Herzegovina; E-mail: dejan.kulijer@gmail.com

[3] Biological Station Lake Neusiedl, Seevorgelände 1, 7142 Illmitz, Austria; E-mail: thomas.zechmeister@bgld.gv.at

* Korespondenčna avtorica / Corresponding author

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

KEY WORDS:
Neretva, Lepidoptera, Bosnia and Herzegovina, protected species

KLJUČNE BESEDE:
Neretva, Lepidoptera, Bosna in Hercegovina, zavarovane vrste

KLJUČNE RIJEČI:
Neretva, Lepidoptera, Bosna i Hercegovina, zavarovane vrste

APSTRAKT

Prilog poznavanju dnevnih i noćnih vrsta leptira gornjeg toka rijeke Neretve, Nevesinjskog polja i visoravni Morine

Početkom juna 2023. godine istraživali smo faunu Lepidoptera u gornjem toku rijeke Neretve, dolini rijeke Zalomke u Nevesinjskom polju i na visoravni Morine koja se nalazi između ova dva područja. Ukupno smo registrovali 237 vrsta, od čega 63 vrste dnevnih i 174 vrste noćnih leptira. Na području rijeke Neretve zabilježene su 53 vrste dnevnih leptira, u Nevesinjskom polju 37, a na Morinskoj visoravni 5 vrsta. Broj vrsta noćnih leptira iznosio je 156, 40 i 20, istim redom. Ovim istraživanjem povećali smo ukupan broj registrovanih vrsta Lepidoptera za ovo područje sa 251, koliko ih je zabilježeno tokom Sedmice Nauke o Neretvi 2022, na ukupno 414 vrsta (93 vrste dnevnih i 321 vrsta noćnih leptira). Osam vrsta ima status skoro ugroženih (Near Threatened), a jedna vrsta status nedostatka podataka (Data Deficient) prema IUCN Crvenoj listi ugroženih vrsta. Dvije vrste nalaze se na Crvenoj listi Federacije Bosne i Hercegovine sa statusom ranjive, dok su tri vrste navedene u Aneksu II Direktive o staništima. Naši nalazi predstavljaju osnovne podatake o fauni Lepidoptera ovog područja, što može biti od velike važnosti za buduće konzervacijske aktivnosti.

INTRODUCTION

Our knowledge on Lepidoptera fauna in Bosnia and Herzegovina is still at an insufficient level compared to the surrounding countries (Plant & Jakšić 2018; Koren & Kulijer 2023). The first extensive study was published in 1904 by the Austrian entomologist Rebel (Rebel 1904). After that, especially in the 70s and 80s of the 20th century, some parts of Bosnia and Herzegovina were systematically investigated (Sijarić 1970, 1983, 1990, 1991; Lelo 2005, 2006, 2008), but the wider area of the Upper Neretva River valley remained unexplored. The first survey of Lepidoptera in the upper course of the Neretva River was carried out during the first Neretva Science Week in 2022 (Dukić & Kunz 2023). The research of the butterfly and moth fauna was repeated in 2023 as part of the second Neretva Science Week, which took place in the period from 2-6 June 2023. The aim was to supplement existing data with new information gathered in the spring, and to expand the research area to include the neighbouring Morine plateau and the valley of the Zalomka river in Nevesinjsko Polje.

MATERIAL AND METHODS

STUDY AREA

The study area is in the southeastern part of Bosnia and Herzegovina and includes the upper part of the Neretva River Valley as well as Morine plateau and part of Nevesinjsko polje.

The Neretva River is the longest river in the Adriatic drainage basin with a total length of about 225 km. In its upper course, it has the characteristics of a mountain river with steep slopes between high mountain massifs. It is a typical karst landscape with well-preserved habitats (Redžić et al. 2008). The Neretva River valley upstream of Ulog is characterized by a remarkable diversity of habitats and vegetation types. These range from riverine forests dominated by willows (*Salix* spp.) and alder (*Alnus rohlenae*), through thermophilous oak forests (*Quercus cerris* and *Q. petraea*) at lower elevations and predominantly south-facing slopes, to mesophillous beech (*Fagus sylvatica*) forests at higher altitudes. In addition, various grassland types exhibiting high species diversity occur throughout the area (Milanović et al. 2025).

The Morine plateau stretches southeast of the Neretva River and northwest from Nevesinjsko polje. It has a surface area of about 47 km^2 and average altitude of 1300 m above sea level. The upper part of the plateau consists mainly of grassy mountain pastures, while the lower part is covered by beech forests on shallower soils.

Nevesinjsko polje is located south of the Neretva River and represents one of the largest karst poljes in Bosnia and Herzegovina (area of 77 km^2). It is positioned in the southeastern part of country at an altitude of around 780 m. All karst poljes in Bosnia and Herzegovina, including the Nevesinjsko polje, represent important areas with high biodiversity and highly specific morphological features and hydrological regime. Nevesinjsko polje is characterized by very diverse types of habitats (Redžić et al. 2008).

Neretva valley, Morine plateau and Nevesinjsko Polje are recognized as potential Natura 2000 areas for Bosnia and Herzegovina (Milanović et al. 2015) with many habitat types, important for butterflies and listed in Annex I of the EU Habitats Directive (EC 1992). In the Neretva valley these include: Alpine rivers and the herbaceous vegetation along their banks (code 3220), Alpine rivers and their ligneous vegetation with *Salix eleganos* (code 3240) and Calcareous rocky slopes with chasmophytic vegetation (code 8210). In the Morine plateau there are Alpine and subalpine calcareous grasslands (code 6170) and in Nevesinjsko Polje Eastern sub-mediterranean dry grasslands (code 62A0) and Lowland hay meadows (code 6510) can be found (Milanović et al. 2015).

In total, five localities were investigated in the area of the Neretva River, two at Morine and three in Nevesinjsko polje (Fig. 1).

DESCRIPTION OF THE SURVEY

The research was performed in early June 2023 (Tab. 1). In total, ten localities were investigated: Ulog, Krupac, Nedavić, Crvanjsko Lake, Cerova, Morine plateau (Svatovsko groblje, Obrnja), Nevesinjsko polje (Humčani, Donje Plužine and Zalomka River) (Tab. 1, Fig. 1).

Different survey methods were used to record butterflies and moths.

Moths were studied at almost all localities, except for localities 5 and 8 (Tab. 1, Fig. 1). We used different light traps, using mercury vapor lamps or actinic UV-lights. The traps were operated from dusk until several hours after sunset, and the surrounding vegetation was regularly inspected to account for species not directly entering the traps.

Several specimens were collected for later identification based on male genitalia and are deposited in the author's collection. Genitalia slides were prepared using a standard procedure: maceration in potassium hydroxide, washing to remove potash, dissecting and cleaning, staining, dehydrating and hardening, and mounting in Canada balsam (Jakšić 1998).

Diurnally active butterfly species were primarily observed and recorded through transect walks and visual encounter surveys during daylight hours. Captured specimens were collected, identified, photographed and released if not needed for later identification. For the collected specimens we used the procedure described above.

During the study, different types of habitats were surveyed with the idea of covering as many different habitats as possible in the short time available. The localities on the slopes near Neretva River are a mosaic of habitats, including species-rich meadows, semi-natural grasslands, and open forest clearings, which provide important areas for both herbaceous and shrub-layer vegetation. In contrast, habitats directly along the river are dominated by riparian forests composed of willow and alder stands, intersected with dynamic gravel bars and periodically inundated riverbanks. We selected very similar habitats in the valley of the Zalomka river in Nevesinjsko polje: meadows, pastures and habitats along the river itself. On the Morine plateau, we included two localities that belong to extensive mountain pastures at higher altitudes.

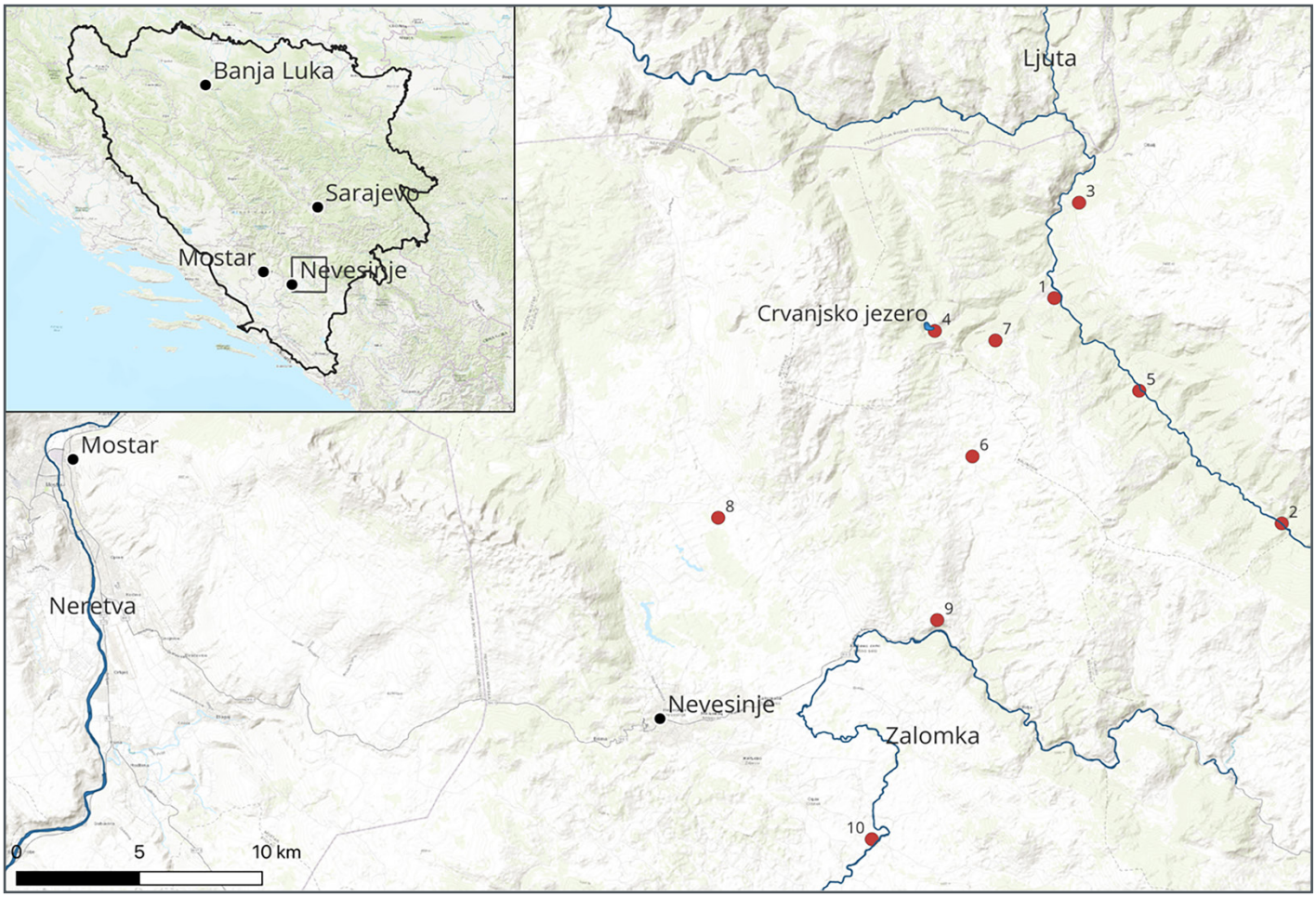

Figure 1. Map of the surveyed localities, numbers correspond to localities given in Tab. 1. The basic map is ESRI World Topographic Map, added with QGIS programme.

Slika 1. Karta s prikazanimi raziskanimi lokalitetami, ki so oštevilčene kot v Tab. 1. Osnovna karta je ESRI World Topographic Map, dostopana s programom QGIS.

Slika 1. Karta sa prikazom istraživanih lokaliteta, gdje brojevi odgovaraju onima u Tab. 1. Mapa u pozadini je preuzeta od ESRI World Topographic Map, pomoću programa QGIS.

Table 1. The list of surveyed localities in the upper course of the Neretva River (1-5), Morine plateau (6-7) and Nevesinjsko Polje (8-10). Coordinates are given in WGS84 latitude and longitude decimal degrees.

Tabela 1. Seznam raziskanih lokalitet na območju gornjega toka reke Neretve (1-5), planote Morine (6-7) in Nevesinjskega polja (8-10). Koordinate so podane v decimalnih stopinjah (WGS84 geografski širina in dolžina).

Tabela 1. Spisak istraženih lokaliteta na području gornjeg toka Neretve (1-5), platoa Morine (6-7) i Nevesinjskog polja (8-10). Koordinate su date u WGS84 koordinatnom sistemu (geografska širina i dužina u decimalnim stepenima).

No	Name of the locality	Habitat type	Elevation (m)	North	East	Date
1	Ulog	extensively used grassland	645	43.40528	18.23304	2. 6. 2023
2	Krupac	extensively used grassland	789	43.32942	18.42574	4. 6. 2023
3	Nedavić	forest clearings, riverbank	590	43.4581	18.32121	4. 6. 2023
4	Crvanjsko Lake	extensively used grassland	1070	43.39001	18.20425	3. 6. 2023
5	Cerova	forest clearings, riverbank	686	43.37887	18.35621	3. 6. 2023
6	Morine, Svatovsko groblje	mountain pastures	1249	43.355033	18.270534	2. 6. 2023
7	Morine, Obrnja	mountain pastures	1169	43.398499	18.282290	2. 6. 2023
8	Nevesinjsko Polje, Humčani	extensively used grassland	840	43.332239	18.14278	6. 6. 2023
9	Nevesinjsko polje, D.Plužine	forest clearings	750	43.293678	18.252595	5. 6. 2023
10	Nevesinjsko Polje, Zalomka River	forest clearings, riverbank	866	43.211517	18.219500	5. 6. 2023

The taxonomy and nomenclature of butterflies follow Wiemers et al. (2018) and the conservation status in Europe is based on Van Swaay et al. (2010). The moth families are listed in taxonomic order according to Kristensen et al. (2007) while the species within each family are listed alphabetically.

RESULTS AND DISCUSSION

During the study in June 2023, 63 species of butterflies were observed (Tab. 2). Considering the data from the previous year (Dukić & Kunz 2023), the total number of butterflies in the wider area of the upper course of the Neretva, Morine and Nevesinjsko polje, increased to 93.

The total number of observed moth species in 2023 for our study was 174. Of these, 156 were found in the Neretva River area. Considering the species observed in the same area in 2022 (Dukić & Kunz 2023), the total number of moth species increased to 303. Tab. 3 also shows findings from the Morina plateau and the Zalomka River valley, which are the first insights into the moth fauna of these areas. The total number of recorded species was 40 for the Zalomka River valley and 20 for the Morine Plateau.

During both Neretva Science Weeks in 2022 (Dukić & Kunz 2023) and 2023, the main focus of research was the upper course of the Neretva River, but Nevesinjsko polje and the Morine plateau were also included in 2023. The number of confirmed species of butterflies in 2022 and 2023 represents 47% of the total number of registered species for Bosnia and Herzegovina, while the number of registered moth species represents 20% of the total number of species known in Bosnia and Herzegovina (Lelo 2004, 2006, 2008, 2016).

For the Morine plateau and Nevesinjsko polje, our data represent the first contribution to the knowledge on Lepidoptera. Despite the fact that only a short time was devoted to visiting these areas (one day and night; Tab. 1), we managed to register 40 butterfly and 50 moth species (Tabs. 2, 3). Although the findings provide some useful insight into the butterfly and moth fauna of the area, the results should be considered as the initial data for more comprehensive future research.

We compared the results of the study performed in the Neretva valley in 2022 (Dukić & Kunz 2023) and observations from 2023. In 2022, a total of seven localities were visited along the upper course of the Neretva in late June/early July (Dukić & Kunz 2023). The same localities were also visited in 2023, except for the Plaža locality, which was devastated during the construction of the Ulog HPP. 55 species of butterflies were recorded in 2022, while 63 species were recorded in 2023 with 25 of those already recorded in 2022. The total number of recorded species thus reached 93. The total number of moth species registered in 2022 was 196 (Dukić & Kunz 2023), while in 2023, 174 species were recorded, 125 of which were new.

The upper course of the Neretva River is proposed as a protected area and could qualify as a potential Natura 2000 site under EU Habitats Directive (Milanović et al. 2015). This designation is supported by the presence of well-preserved riverine, wetland, and semi-natural grassland habitats that sustain a high level of biodiversity, including species of European conservation concern. In this context, we highlight selected species for which basic data on distribution and abundance are presented, illustrating the conservation importance of the area. Notably, recent records confirm the Marsh Fritillary (*Euphydryas aurinia*) and the Eastern Eggar (*Eriogaster catax*), both listed in the Annexes of the directive (EC 1992) The presence of these qualifying species, which are closely associated with traditionally managed grasslands and ecologically intact landscapes, further substantiates the high conservation value of the upper Neretva River and underscores the need for its long-term protection and appropriate management.

Table 2. A list of recorded butterfly species during field survey in 2023. The numbers of localities refer to those in Tab. 1 and Fig. 1. We list the status according to Habitats directive (EC 1992), and according to IUCN Red List of Threatened Species (Van Sway et al. 2010): NT – Near Threatened (IUCN 1996).

Tabela 2. Seznam dnevnih metuljev, ki so bili zabeleženi med terenskim delom v letu 2023. Številke lokalitet so kot v Tab. 1 in na Sl. 1. Navedeni je varstveni status glede na Habitatno direktivo (EC 1992), in glede na IUCN Rdeči seznam ogroženih vrfst (Van Sway et al. 2010): NT – Near Threatened (IUCN 1996).

Tabela 2. Spisak registrovanih vrsta dnevnih leptira tokom istraživanja u 2023. godini. Brojevi lokaliteta odgovaraju onima u Tab. 1 i na Sl. 1. Prikazali smo staus ugroženosti prema Direktivi o staništima (EC 1992) i u skladu sa IUCN Crvenom listom ugroženih vrsta (Van Sway et al. 2010): NT – Near Threatened (IUCN 1996).

No	Family	Species	Locality	Habitats Directive	IUCN Red List
1	Papilionidae	*Iphiclides podalirius* (Linnaeus, 1758)	1,3,5,8,9		
2		*Papilio machaon* Linnaeus, 1758	2,4,8,9,10		
3		*Parnassius mnemosyne* (Linnaeus, 1758)	8,9,10	Annex IV	NT
4		*Zerynthia polyxena* ([Denis & Schiffermüller], 1775)	1,3,8	Annex IV	
5	Hesperiidae	*Spialia orbifer* (Hübner, 1823)	1,2,4,9		
6		*Ochlodes sylvanus* (Esper, 1777)	8		
7		*Carterocephalus palaemon* (Pallas, 1771)	1,2,3,		
8		*Erynnis tages* (Linnaeus, 1758)	3,9		
9		*Pyrgus alveus* (Hübner, 1802)	3,1		
10		*Pyrgus malvae* (Linnaeus, 1758)	3,1		
11		*Pyrgus sidae* (Esper, 1784)	3		
12	Pieridae	*Leptidea sinapis/juvernica*	1,2,3,4,5,8,9,10		
13		*Gonepteryx rhamni* (Linnaeus, 1758)	2,8,9,10		
14		*Colias alfacariensis* Ribbe, 1905	1		
15		*Colias croceus* (Fourcroy, 1785)	1,3,4,9		
16		*Aporia crataegi* (Linnaeus, 1758)	2,3,4,8,10		
17		*Pieris balcana* Lorković, [1969]	3		
18		*Pieris brassicae* (Linnaeus, 1758)	2,4,		
19		*Pieris ergane* (Geyer, 1828)	10		
20		*Pieris napi* (Linnaeus, 1758)	2		
21		*Pieris rapae* (Linnaeus, 1758)	3		
22		*Pontia edusa* (Linnaeus, 1758)	10		
23		*Anthocharis cardamines* (Linnaeus, 1758)	1,3,5,8,9		
24	Riodinidae	*Hamearis lucina* (Linnaeus, 1758)	8,1		
25	Lycaenidae	*Lycaena phlaeas* (Linnaeus, [1760])	2,9		
26		*Lycaena tityrus* (Poda, 1761)	1		
27		*Callophrys rubi* (Linnaeus, 1758)	2		
28		*Pseudophilotes vicrama* (Moore, 1865)	2		NT
29		*Scolitantides orion* (Pallas, 1771)	1,4,6,7		
30		*Glaucopsyche alexis* (Poda, 1761)	2		
31		*Cupido minimus* (Fuessly, 1775)	3		
32		*Plebejus argus* (Linnaeus, 1758)	8,9,10		
33		*Cyaniris semiargus* (Rottemburg, 1775)	8		
34		*Aricia agestis* ([Denis & Schiffermüller], 1775)	8,1		
35		*Aricia artaxerxes* (Fabricius, 1793)	9		
36		*Polyommatus amandus* (Schneider, 1792)	2		
37		*Polyommatus bellargus* (Rottemburg, 1775)	2,4		
38		*Polyommatus dorylas* (Denis & Schiffermüller, 1775)	4		NT

No	Family	Species	Locality	Habitats Directive	IUCN Red List
39		*Polyommatus icarus* (Rottemburg, 1775)	2		
40	Nymphalidae	*Issoria lathonia* (Linnaeus, 1758)	1,2,4,8		
41		*Brenthis hecate* ([Denis & Schiffermüller], 1775)	8		
42		*Brenthis daphne* ([Denis & Schiffermüller], 1775)	10		
43		*Boloria euphrosyne* (Linnaeus, 1758)	8		
44		*Boloria dia* (Linnaeus, 1767)	1,4		
45		*Boloria titania* (Esper, 1793)	2		NT
46		*Vanessa cardui* (Linnaeus, 1758)	8		
47		*Vanessa atalanta* (Linnaeus, 1758)	2,3,9		
48		*Aglais urticae* (Linnaeus, 1758)	2,5,8		
49		*Polygonia c-album* (Linnaeus, 1758)	8		
50		*Nymphalis antiopa* (Linnaeus, 1758)	6		
51		*Euphydryas aurinia* (Rottemburg, 1775)	4,5,6,7,10	Annex II, IV	NT
52		*Melitaea didyma* (Esper, 1778)	2,9		
53		*Melitaea phoebe* (Denis & Schiffermüller) 1775	2,4,5		
54		*Melitaea cinxia* (Linnaeus, 1758)	2,3,10		
55		*Melitaea diamina* (Lang, 1789)	2		
56		*Melitaea athalia* (Rottemburg, 1775)	1,2,4,5,9		
57		*Coenonympha pamphilus* (Linnaeus, 1758)	1,3,5,8,9,10		
58		*Coenonympha arcania* (Linnaeus, [1760])	1,2,3,4,5,8,9,10		
59		*Pararge aegeria* (Linnaeus, 1758)	1,2,		
60		*Lasiommata maera* (Linnaeus, 1758)	8		
61		*Lasiommata megera* (Linnaeus, 1767)	2,8,10		
62		*Erebia medusa* ([Denis & Schiffermüller], 1775)	4,6,7,8,10		
63		*Erebia aethiops* Esper, 1777	6,7		

Table 3. A list of registered moth species during the field survey in 2023. The numbering of localities matches those in Tab. 1 and Fig. 1. We list the status according to Habitats directive (EC 1992).

Tabela 3. Seznam nočnih metuljev, ki so bili zabeleženi med terenskim delom v letu 2023. Številke lokalitet so kot v Tab. 1 in na Sl. 1. Naveden je varstveni status glede na Habitatno direktivo (EC 1992).

Tabela 3. Spisak registrovanih vrsta noćnih leptira tokom istraživanja u 2023. godini. Brojevi lokaliteta odgovaraju onima u Tab. 1 i na Sl. 1. Prikazali smo i status ugruženosti prema Direktivi o staništima (EC 1992).

No	Family	Species list	Locality	Habitats Directive
1	Tineidae	*Euplocamus anthracinalis* (Scopoli, 1763)	2	
2	Plutellidae	*Plutella xylostella* (Linnaeus, 1758)	1,2	
3	Zygaenidae	*Adscita (Adscita) geryon* (Hübner)	2	
4		*Zygaena ephialtes* (Linnaeus, 1767)	1,2,6,9	
5	Cossidae	*Dyspessa ululа* Borkhausen, 1790	2	
6	Tortricidae	*Aethes tesserana* (Denis & Schiffermüller) 1775	1	
7		*Notocelia cynosbatella* (Linnaeus, 1758)	1	
8		*Olethreutes arcuella* (Clerck, 1759)	9	
9		*Ptycholoma lecheana* (Linnaeus 1758)	2	
10		*Syricoris lacunana* (Denis & Schiffermüller) 1775	10	
11	Pterophoridae	*Calyciphora xanthodactyla* (Treitschke, 1833)	2	
12		*Geina didactyla* (Linnaeus, 1758)	1	
13		*Merrifieldia malacodactylus* (Zeller, 1847)	1	

14	Thyrididae	*Thyris fenestrella* (Scopoli 1763)	1	
15	Pyralidae	*Aphomia sociella* (Linnaeus, 1758)	2	
16		*Catastia marginea* (Denis & Schiffermüller) 1775	1	
17		*Megasis prodomella* Duponchel, 1836	7	
18	Crambidae	*Chrysocrambus craterellus* Scopoli, 1763	2	
19		*Cydalima perspectalis* Walker, 1859	1	
20		*Elophila nymphaeata* (Linnaeus 1758)	9	
21		*Eurrhypis pollinalis* (Denis & Schiffermuller, 1775)	1	
22		*Nomophila noctuella* (Denis & Schiffermüller)	2	
23		*Pyrausta cingulata* Linnaeus, 1758	10	
24		*Pyrausta* nigrata Scopoli	1,6	
25		*Pyrausta ostrinalis* Hübner, 1796	1	
26		*Pyrausta purpuralis* Linnaeus, 1758	1	
27		*Scoparia pyralella* Hübner, 1796	1	
28		*Sitochroa verticalis* Linnaeus, 1758	1	
29		*Thisanotia chrysonuchella* Scopoli, 1763	1	
30		*Udea ferrugalis* Hübner, 1796	2	
31	Lasiocampidae	*Eriogaster catax* (Linnaeus, 1758)	1,2,3,4,6,9	Annex II, IV
32		*Eriogaster lanestris* (Linnaeus, 1758)	2,6,10	
33		*Lasiocampa trifolii* (Denis & Schiffermuller, 1775)	1	
34		*Macrothylacia r*ubi (Linnaeus, 1758)	1,2	
35		*Malacosoma castrensis* (Linnaeus, 1758)	2,9	
36		*Malacosoma neustria* (Linnaeus, 1758)	1,6	
37		*Phyllodesma (Phyllodesma) tremulifolia* (Hübner)	1	
38		*Poecilocampa populi* Linnaeus, 1758	1	
39		*Trichiura crataegi* (Linnaeus, 1758)	1	
40	Saturniidae	*Saturnia pavoniella* (Scopoli, 1763)	2	
41		*Saturnia pyri* (Denis & Schiffermuller, 1775)	1,2,10	
42	Sphingidae	*Deilephila porcellus* (Linnaeus, 1758)	1,2,10	
43		*Hyles euphorbiae* (Linnaeus, 1758)	3,10	
44		*Macroglossum stellatarum* (Linnaeus, 1758)	1	
45		*Marumba quercus* (Denis & Schiffermuller, 1775)	10	
46		*Mimas tiliae* Linnaeus, 1758	1	
47		*Smerinthus ocellata* (Linnaeus, 1758)	1,2	
48		*Sphinx ligustri* Linnaeus, 1758	10	
49	Drepanidae	*Watsonalla cultraria* (Fabricius, 1775)	1	
50		*Watsonarctia deserta* (Bartel, 1902)	10	
51	Geometridae	*Agriopis bajaria* (Denis & Schiffermüller) 1775	1	
52		*Alcis repandata* (Linnaeus, 1758)	2	
53		*Alsophila aescularia* (Denis & Schiffermüller) 1775	1	
54		*Aplocera efformata* (Guenée)	2	
55		*Aplocera plagiata* (Linnaeus, 1758)	1	
56		*Campaea margaritaria* (Linnaeus, 1761)	1,2,6,9	
57		*Camptogramma bilineata* (Linnaeus, 1758)	10	
58		*Cataclysme riguata* (Hubner, 1813)	2	
59		*Catarhoe cuculata* (Hufnagel, 1767)	1,2,6,9	

60		*Charissa pullata* (Denis & Schiffermüller) 1775	1,2,6,9
61		*Chiasmia clathrata* (Linnaeus, 1758)	2,4
62		*Chlorissa viridata* (Linnaeus, 1758)	10
63		*Cleorodes lichenaria* (Hufnagel, 1767)	1
64		*Colotois pennaria* (Linnaeus, 1761)	1
65		*Dyscia raunaria* (Freyer, 1851)	1
66		*Ematurga atomaria* (Linnaeus, 1758)	2
67		*Epirrhoe alternata* (Müller, 1764)	1
68		*Epirrhoe hastulata* (Hubner 1790)	1
69		*Erannis defoliaria* (Clerck, 1759)	1,2,9
70		*Eupithecia tantillaria* Boisduval, 1840	1
71		*Heliomata glarearia* (Denis & Schiffermuller, 1775)	1,2,10
72		*Horisme vitalbata* (Denis & Schiffermuller, 1775)	1,2
73		*Hypomecis punctinalis* (Scopoli, 1763)	1,2
74		*Idaea aureolaria* (Denis & Schiffermüller) 1775	4
75		*Idaea aversata* (Linnaeus, 1758)	1,2,6,9
76		*Idaea degeneraria* (Hübner)	2
77		*Idaea filicata* (Hübner, 1799)	1
78		*Idaea trigeminata* (Haworth, 1809)	2
79		*Idia calvaria* (Denis & Schiffermüller) 1775	2
80		*Lomaspilis marginata* (Linnaeus, 1758)	1,2,6,9
81		*Lycia hirtaria* (Clerck, 1759)	1
82		*Mesoleuca albicillata* (Linnaeus, 1758)	1
83		*Odezia atrata* (Linnaeus, 1758)	1
84		*Parocneria detrita* (Esper, 1785)	1
85		*Perconia strigillaria* (Hübner, 1787)	2
86		*Peribatodes rhomboidaria* (Denis & Schiffermuller, 1775)	2,10
87		*Petrophora chlorosata* (Scopoli, 1763)	1
88		*Phigalia pilosaria* (Denis & Schiffermüller) 1775	1
89		*Pseudopanthera macularia* (Linnaeus, 1758)	1,2,9
90		*Scopula incanata* (Linnaeus, 1758)	1,2,6,9
91		*Scopula marginepunctata* (Göze, 1781)	3,2
92		*Scopula ornata* (Scopoli, 1763)	1
93		*Scotopteryx coarctaria* (Denis & Schiffermüller) 1775	1
94		*Selenia lunularia* (Hübner)	1
95		*Siona lineata* (Scopoli, 1763)	2
96		*Thera variata* (Denis & Schiffermüller) 1775	2
97		*Xanthorhoe oxybiata* (Millière, 1872)	1
98	Notodontidae	*Drymonia dodonaea* (Denis & Schiffermüller) 1775	2,7
99		*Pterostoma palpina* (Clerck, 1759)	1
100		*Ptilophora plumigera* (Denis & Schiffermuller, 1775)	2
101	Erebidae	*Amata kruegeri* Ragusa, 1905	1
102		*Amata phegea* (Linnaeus, 1758)	2
103		*Arctia aulica* (Linnaeus, 1758)	1
104		*Arctia villica* (Linnaeus, 1758)	2,10
105		*Calliteara pudibunda* (Linnaeus, 1758)	1,2

106		*Catocala sponsa* (Linnaeus, 1767)	2
107		*Cybosia mesomella* (Linnaeus, 1758)	1,2
108		*Diacrisia sannio* (Linnaeus, 1758)	1
109		*Diaphora luctuosa* (Hübner, 1831)	1,6
110		*Diaphora mendica* (Clerck, 1759)	1,2
111		*Dicallomera fascelina* (Linnaeus, 1758)	1
112		*Eilema complana* (Linnaeus, 1758)	1,9
113		*Eilema depressa* (Esper, 1787)	1
114		*Eilema palliatella* (Scopoli, 1763)	1,2
115		*Eublemma purpurina* (Denis & Schiffermuller, 1775)	10
116		*Euclidia glyphica* (Linnaeus, 1758)	2,6
117		*Euclidia mi* (Clerck, 1759)	1,9
118		*Euproctis chrysorrhoea* (Linnaeus, 1758)	2
119		*Herminia grisealis* (Denis & Schiffermuller, 1775)	2
120		*Lymantria dispar* (Linnaeus, 1758)	2,9
121		*Parascotia fuliginaria* (Linnaeus, 1761)	1
122		*Setina irrorella* (Linnaeus, 1758)	9
123		*Teinoptera olivina* (Herrich-Schäffer, 1852)	1
124		*Tyta luctuosa* (Denis & Schiffermüller) 1775	1,2,9
125		*Wittia sororcula* (Hufnagel, 1767)	1
126	Noctuidae	*Acontia trabealis* (Scopoli, 1763)	1,2,6,9
127		*Acronicta euphorbiae* (Denis & Schiffermüller) 1775	1
128		*Actinotia radiosa* (Esper, 1804)	10
129		*Agrotis cinerea* (Denis & Schiffermuller, 1775)	2
130		*Agrotis exclamationis* (Linnaeus, 1758)	1,2,10
131		*Agrotis ipsilon* (Hufnagel, 1766)	2
132		*Agrotis segetum* (Denis & Schiffermüller) 1775	1
133		*Allophyes oxyacanthae* (Linnaeus, 1758)	1
134		*Anarta trifolii* Hufnagel, 1766	1
135		*Autographa gamma* (Linnaeus, 1758)	1,6
136		*Calophasia lunula* (Hufnagel, 1766)	2
137		*Charanyca apfelbecki* (Rebel, 1901)	2
138		*Charanyca trigrammica* (Hufnagel, 1766)	2
139		*Chersotis multangula* (Hubner, 1803)	1
140		*Chloantha hyperici* (Denis & Schiffermüller) 1775	2
141		*Conisania luteago* (Denis & Schiffermuller, 1775)	1
142		*Cosmia trapezina* (Linnaeus, 1758)	1,6
143		*Diloba caeruleocephala* (Linnaeus, 1758)	1,2,9
144		*Eupsilia transversa* (Hufnagel, 1766)	2
145		*Euxoa nigricans* Linnaeus, 1761	1
146		*Hada plebeja* Linnaeus, 1761	1,6
147		*Hadena (Hadena) filograna* Esper	1,6
148		*Hadena (Hadena) magnolii* Boisduval, 1829	1
149		*Hadena albimacula* (Borkhausen, 1792)	2
150		*Hadena perplexa* (Denis & Schiffermüller) 1775	1
151		*Heliothis viriplaca* (Hufnagel, 1766)	10

152		*Hoplodrina octogenaria* (Goeze, 1781)	1
153		*Lacanobia thalassina* Hufnagel, 1766	1
154		*Lacanobia w-latinum* Hufnagel, 1766	2
155		*Luteohadena luteago* ([Denis & Schiffermüller], 1775)	2
156		*Lygephila pastinum* Treitschke, 1826	1
157		Moma alpium (Osbeck, 1778)	2
158		*Mythimna (Mythimna) vitellina* Hübner, 1808	2
159		*Mythimna albipuncta* (Denis & Schiffermuller, 1775)	1,2
160		*Mythimna ferrago* Fabricius, 1787	1
161		*Noctua comes* Hubner, 1813	9
162		*Noctua fimbriata* (Schreber, 1759)	10
163		*Noctua pronuba* (Linnaeus, 1758)	1,2,10
164		*Ochropleura plecta* Linnaeus, 1761	2
165		*Oligia versicolor* (Borkhausen, 1792)	1
166		*Omia cymbalariae* Hübner, 1809	1
167		*Orthosia miniosa* (Denis & Schiffermuller, 1775)	1
168		*Pachetra sagittigera* (Hufnagel, 1766)	10
169		*Panemeria tenebrata* (Scopoli, 1763)	10
170		*Phlogophora meticulosa* (Linnaeus, 1758)	2
171		*Rusina apfelbecki* (Rebel, 1901)	1
172		*Standfussiana dalmata* Staudinger, 1901	1
173		*Xestia c-nigrum* (Linnaeus, 1758)	2,4
174	Euteliidae	*Eutelia adulatrix* (Hübner, 1813)	1

The *Euphydryas aurinia* (Fig. 2) is a Habitats Directive (Annex II and IV) species and is listed on the Red List of the Federation of Bosnia and Herzegovina. Adult specimens were observed in two localities along the Neretva River (Tab. 1), only two specimens on each site. They have been observed in moist, sheltered meadows above moist alder and willow habitats. This species was also recorded in the Morina plateau and along the Zalomka river, where a larger number of individuals were observed, mostly on a dry grassland. The species is not rare in Bosnia and Herzegovina (Biologer.ba 2025) although its distribution is not known.

Among the newly registered species of moths the records of the *Eriogaster catax* (Fig. 2), which has been reconfirmed for the area of Bosnia and Herzegovina (Rebel 1904) after more than 100 years, are particularly valuable. The species at the caterpillar stage was recorded during unsystematic research at three localities along the Neretva River (Tab. 3). Its presence was also confirmed at Crvanjsko Lake, on the Morina Plateau, and along the Zalomka River. The caterpillars were observed on *Crataegus monogyna* and *Prunus spinosa* plant. The data were gathered from a variety of habitats, including bushes in hedgerows, at forest edges, along dirt roads, in wet and dry meadows and pastures, along streams and in flood zones in riverbeds, all habitats already reported for the species (Chrzanowski et al. 2013; Kadej et al. 2018; Zakšek et al. 2021). All specimens were found on shrubs from 1 to 3 m in height (Kulijer & Dukić, in prep.).

Although the research was carried out as part of the Neretva Science Week in a rather short time, our work significantly contributes to a better knowledge of Lepidoptera species in Bosnia and Herzegovina. Furthermore, such scientific data highlights the value and diversity of this area in terms of biodiversity and can be used as an argument in favour of the conservation of the upper course of the Neretva River.

Figure 2. Two species of the highest conservation concern that were discovered during survey in 2023. Left: the adult Marsh Fritillary (*Euphydrias aurinia*) and right: the caterpillar of the Eastern Eggar (*Eriogaster catax*) (photo: B. Dukić).

Slika 2. Dve vrsti z najvišjim varstvenim statusom, ki sta bili najdeni med raziskavo v letu 2023. Levo: travniški postavnež (*Euphydrias aurinia*) in desno: gosenica hromega volnoritca (*Eriogaster catax*) (foto: B. Dukić).

Slika 2. Dvije vrste od visokog konzervacijskog značaja koje su registrovane tokom istraživanja u 2023. godini. Lijevo: močvarni šarenac (*Euphydrias aurinia*) i desno: gusjenica vunastog leptira (*Eriogaster catax*) (foto: B. Dukić).

POVZETEK

Favna metuljev v Bosni in Hercegovini je slabo raziskana, zlasti v zgornjem toku reke Neretve. Ta študija predstavlja rezultate terenske raziskave, izvedene tekom druge izdaje Znanstvenega tedna Neretve, ki je potekal med 2. in 6. junijem 2023 in je nadaljeval delo iz leta 2022 (Dukić & Kunz 2023). Cilj je bil dopolniti obstoječe podatke s podatki iz pomladne sezone in razširiti območje raziskave na planoto Morine in dolino reke Zalomke na Nevesinjskem polju.

Terensko delo je bilo izvedeno na desetih lokacijah, ki pokrivajo širok spekter habitatov, vključno z rečnimi gozdovi, polnaravnimi travniki, gorskimi pašniki, gozdnimi jasami in kraškimi polji. Dnevni metulji so bili zabeleženi z opazovanjem in transektnimi popisi, medtem ko so bili nočni metulji vzorčeni z uporabo svetlobnih pasti. Skupaj je bilo v letu 2023 zabeleženih 63 vrst dnevnih in 174 vrst nočnih metuljev. Skupaj s podatki iz leta 2022 zdaj poznana fauna širšega območja raziskave obsega 93 vrst dnevnih in 321 vrst nočnih metuljev, kar predstavlja približno 47 % dnevnih in 20 % nočnih metuljev, znanih na območju Bosne in Hercegovine.

Čeprav je bila raziskava na planoti Morine in Nevesinjskem polju zelo kratka, smo tam dokumentirali skupno 40 vrst dnevnih in 50 vrst nočnih metuljev. To so prvi podatki o favni teh območij, ki kažejo visoko biotsko raznovrstnost zgornjega dela reke Neretve, kjer se nahajajo dobro ohranjeni habitati in vrste, ki so varstveno pomembne v Evropi.

Posebej pomembna so potrjena pojavljanja travniškega postavneža (*Euphydryas aurinia*), ki je naveden v Prilogah II in IV Direktive o habitatih, ter hromega volnoritca (*Eriogaster catax*), ki je bil v Bosni in Hercegovini ponovno odkrit po več kot stoletju (Rebel 1904). Naši izsledki potrjujejo visoko varstveno vrednost zgornjega toka reke Neretve in nakazujejo, da raznoliki habitati območja potrebujejo ustrezno dolgoročno varstvo in startegije upravljanja.

SAŽETAK

Fauna leptira (Lepidoptera) u Bosni i Hercegovini i dalje je nedovoljno istražena, naročito u gornjem toku rijeke Neretve. Ova studija predstavlja rezultate istraživanja provedenih tokom Druge sedmice nauke o Neretvi, održane od 2. do 6. juna 2023. godine, nadovezujući se na prethodna istraživanja iz 2022. godine (Dukić & Kunz 2023). Cilj istraživanja bio je dopuniti postojeće podatke nalazima o proljetnoj fauni te proširiti istraživanja na visoravan Morine i dolinu rijeke Zalomke u Nevesinjskom polju.

Terenska istraživanja provedena su na deset lokaliteta koji obuhvataju širok spektar staništa, uključujući riječne šume, poluprirodne travnjake, planinske pašnjake, šumske čistine i kraška polja. Dnevni leptiri bilježeni su vizuelnim opažanjima, dok su noćni leptiri prikupljani pomoću svjetlosnih zamki. Tokom 2023. godine zabilježene su ukupno 63 vrste dnevnih leptira i 174 vrste noćnih leptira. U kombinaciji sa podacima iz 2022. godine, do sada poznata fauna šireg istraživanog područja obuhvata 93 vrste dnevnih leptira i 321 vrstu noćnih leptira, što predstavlja približno 47% faune dnevnih leptira i 20% faune noćnih leptira poznatih u Bosni i Hercegovini.

Iako su visoravan Morine i Nevesinjsko polje istraživani samo kratkotrajno, u tim područjima je zabilježeno 50 vrsta noćnih i 40 vrsta dnevnih leptira, čime je pružen prvi faunistički uvid u ova područja.

Rezultati naglašavaju visoku biološku raznolikost gornjeg toka Neretve, koji karakterišu dobro očuvana staništa i prisustvo vrsta od evropskog konzervacijskog značaja.

Posebno su značajni potvrđeni nalazi močvarnog šarenca (*Euphydryas aurinia*), vrste navedene u Aneksima II i IV Direktive o staništima, kao i vunastog leptira (*Eriogaster catax*), koji je ponovo otkriven u Bosni i Hercegovini nakon više od jednog vijeka (Rebel 1904). Ovi nalazi potvrđuju da je gornji tok rijeke Neretve vrlo važan u konzervacijskom smislu te naglašavaju potrebu za dugoročnom zaštitom i odgovarajućim upravljanjem.

ACKNOWLEDGEMENTS

We are grateful to the organizing team of Neretva Science Week 2023 for inviting us to the event and offering the opportunity to once again study the fauna of Lepidoptera. The authors would like to thank Aleksandra Trajković and Dubravko Dender for help with identification.

REFERENCES

[Biologer.ba] biologer.ba. 2025. Biologer: open biodiversity data platform. Biologer.ba; [accessed 7. 1. 2025]. https://biologer.ba

Chrzanowski A, Kuźmiński R, Łabędzki A, Mazur A, Rutkowski P. 2013. Occurrence of *Eriogaster catax* (Linnaeus, 1758) (Lasiocampidae, Lepidoptera) and the proposed protective actions on the Polish territory. Nauka Przyroda Technologie. 7: 1-7.

Dukić B, Kunz G. 2023. Contribution to the knowledge on butterflies and moths (Insecta: Lepidoptera) of the upper course of the Neretva River, Bosnia and Herzegovina. Natura Sloveniae. 25(3): 137-153. https://doi.org/10.14720/ns.25.3.137-153

[IUCN] World Conservation Monitoring Centre. 1996. *Eriogaster catax*. The IUCN Red List of Threatened Species 1996. e.T8029A12883403; [accessed 25. 12. 2024]. http://dx.doi.org/10.2305/IUCN.UK.1996.RLTS.T8029A12883403.en

Jakšić P. 1998. Male genitalia of butterflies on Balkan Peninsula whit a checklist. Bratislava (SK): František Slamka.

Kadej M., Zając K, Tarnawski D. 2018. Oviposition site selection of a threatened moth *Eriogaster catax* (Lepidoptera: Lasiocampidae) in agricultural landscape—implications for its conservation. Journal of Insect Conservation. 22(1): 29-39. https://doi.org/10.1007/s10841-017-0035-7

Koren T, Kulijer D. 2023. Addition to the knowledge on the moth fauna (Insecta: Lepidoptera) of Bosnia and Herzegovina and Croatia. Natura Sloveniae. 25(1): 37-45. https://doi.org/10.14720/ns.25.1.37-45

Kristensen NP, Scoble MJ, Karsholt O. 2007. Lepidoptera phylogeny and systematics: the state of inventorying moth and butterfly diversity. In: Zhang Z-Q, Shear WA, editors. Linnaeus Tercentenary: Progress in Invertebrate Taxonomy. Zootaxa. 1668: 699-747. https://doi.org/10.11646/zootaxa.1668.1.30

Lelo S. 2004. Revizija Rebelovog popisa leptira Bosne i Hercegovine. Sarajevo: Coron's d.o.o.

Lelo S. 2005. Prilog reviziji Rebelovog popisa leptira (Lepidoptera) Bosne i Hercegovine. Udruženje za inventarizaciju i zaštitu životinja. 1: 69-71.

Lelo S. 2006. Drugi prilog reviziji Rebelovog popisa leptira (Lepidoptera) Bosne i Hercegovine. Udruženje za inventarizaciju i zaštitu životinja. 2: 32-37.

Lelo S. 2008. Dnevni leptiri Bosne i Hercegovine (Lepidoptera: Papilionoidae i Hesperioidae). Sarajevo: Prirodno-Matematički fakultet Univerziteta u Sarajevu.

Lelo S. 2016. Četvrta revizija popisa dnevnih leptira (Lepidoptera: Hesperioidea i Papilionoidea) Bosne i Hercegovine. Udruženje za inventarizaciju i zaštitu životinja. 12: 49-59.

Milanović Đ, Stupar V, Kulijer D, Kotrošan D, Hamzić A. 2015. Natura 2000 u Bosni i Hercegovini: dokle smo stigli?. Glasnik Šumarskog fakulteta Univerziteta u Banjoj Luci. 23: 95-134. https://doi.org/10.7251/GSF1523095M

Milanović Đ, Strgulc Krajšek S, Brujić J, Juraj Čehulić I, Heimer V, Koljanin D, Kravanja M, Rešetnik I, Stupar,V, Schönswetter P, Frajman B. 2025. A contribution to the vascular and bryophyte flora of the upper Neretva and Zalomka River valleys (Bosnia and Herzegovina). Natura Sloveniae. 27(3): 28-65. https://doi.org/10.14720/ns.19952

[EC] European Commission. 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Communities L 206, 22.7.1992. p. 7-50.

Plant CW, Jakšić P. 2018. A provisional checklist and bibliography of the Pyraloidea of the Balkan Peninsula. Atalanta. 49(1-4): 219-263.

Rebel H. 1904. Studien über die Lepidopterenfauna der Balkanländer. II. Teil. Bosnien und Herzegowina. Annalen des Naturhistorischen Museums in Wien 19: 97-377.

Redžić S, Barudanović S, Radević M. 2008. Bosnia and Herzegovina – Land of Diversity, First national report of Bosnia and Herzegovina for the Convention on Biodiversity. Sarajevo: Federal Ministry of Environment and Tourism.

Sijarić R. 1970. Fauna Rhopalocera i Hesperioidea (Lepidoptera) na području prašume Perućice i u kompleksu planina Maglić, Volujak i Zelengora. Glasnik Zemaljskog muzeja Bosne i Hercegovine, Prirodne nauke. Nova serija. 9: 135-178.

Sijarić R. 1983. Sastav i struktura opopulacija Rhopalocera (Lep.) u ekosistemima krša JI Hercegovine i Orjena. Glasnik Zemaljskog Muzeja u Bosni i Hercegovini, Prirodne nauke. Nova serija. 22: 81-93.

Sijarić R. 1990. Promjene u sastavu populacija Rhopalocera (Lepidoptera, Insecta) u okolini Gacka. Glasnik Zemaljskog Muzeja u Bosni i Hercegovini, Prirodne nauke. Nova serija. 29: 73-90.

Sijarić R. 1991. Katalog naučne zbirke Lepidoptera (Insecta) donatora Bore Mihljevića iz Sarajeva. Glasnik Zemaljskog muzeja Bosne i Hercegovine. Prirodne nauke. Nova serija. 30: 169-360.

Van Swaay C, Cuttelod A, Collons S, Maes D, Lopez Munguira M, Šašić M, Settele J, Verovnik R, Verstrael T, Warren M, et al. 2010. European Red List of Butterflies. Luxembourg (LU): Publication Office of the European Union.

Wiemers M, Balletto E, Dincă V, Fric ZF, Lamas G, Lukhtanov V, Munguira ML, Van Swaay C, Vila R, Vliegenthart A, et al. 2018. European Red List of Butterflies. Luxembourg (LU): Publication Office of the European Union.

Zakšek B, Kogovšek N, Rebeušek F, Govedič M. 2021. Larval habitat characteristics of eastern eggar *Eriogaster catax* (Linnaeus, 1758) (Lepidoptera: Lasiocampidae) in Slovenia Natura Sloveniae. 23(2): 49-63. https://doi.org/10.14720/ns.23.2.49-63

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0I nternational License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 106–113
»Neretva Science Week 2023«

ZNANSTVENI ČLANEK /
SCIENTIFIC PAPER

DOI: 10.14720/ns.21576
Objavljeno na spletu / Published online: 15. 12. 2025

Prejeto / Received: 7. 1. 2025
Sprejeto / Accepted: 13. 8. 2025

Occurrence of the softmouth trout *Salmo obtusirostris* in the Upper Neretva River (Bosnia and Herzegovina): a survey based on eDNA analysis

Kurt PINTER[1*†],
Elisabeth HARING,[2,3†]
Moritz WOLF,[1]
Gabriel GRUBER,[1]
Alexandra WANKA[2]

ABSTRACT

The softmouth trout (*Salmo obtusirostris*) is endemic to the Adriatic drainage basin. This study investigated its distribution in the Upper Neretva River and the Ljuta tributary using environmental DNA (eDNA) analysis. We analysed 11 eDNA samples collected over three years (2022–2024), with PCR targeting mitochondrial marker sequences: the cytochrome c oxidase subunit 1 gene (CO1) and the control region (CR). Sanger sequencing of the PCR products confirmed S. obtusirostris haplotypes in eight out of 11 sites, with presence in Glavatičevo, the Ljuta estuary, and the Ljuta River. Generally, the results demonstrate the utility of eDNA analyses in detecting elusive species. Yet, we observed incomplete specificity for *S. obtusirostris* of the PCR primers used. Mixed CO1 haplotypes were detected in several samples, showing double peaks in electropherograms at diagnostic sites, i.e., nucleotides specific for *S. obtusirostris* as well as for *S. trutta*. Our findings imply that *S. obtusirostris* can colonize steep, turbulent habitats. Since haplotype sequencing cannot differentiate between the haplotype derived from pure *S. obtusirostris* or from a hybrid, further investigations are needed that refine detection methods and assess hybridization with members of the *Salmo trutta* complex using a combination of methodological approaches.

IZVLEČEK

Pojavljanje mehkoustne postrvi *Salmo obtusirostris* v zgornji reki Neretvi (Bosna in Hercegovina): študija, temelječa na analizah eDNA

Mehkoustna postrv (*Salmo obtusirostris*) je endemična za porečje Jadranskega morja. V tej študiji smo z analizo okoljske DNA (eDNA) raziskovali njeno razširjenost v zgornjem toku reke Neretve in njenem pritoku Ljuta. Analizirali smo 11 vzorcev eDNA zbranih v treh letih (2022–2024), v katerih smo s PCR iskali zaporedja mitohondrijskih markerjev: gena podenote 1 citokrom c oksidaze (CO1) in kontrolne regije (CR). S Sangerjevim sekvenciranjem PCR produktov smo potrdili haplotipe *S. obtusirostris* na osmih od enajstih lokacij, prisotne v Glavatičevem, ustju Ljute in v reki Ljuti. Rezultati potrjujejo uporabnost analiz eDNA za odkrivanje izmuzljivih vrst. Pri uporabljenih PCR primerjih pa smo opazili tudi nepopolno specifičnost za *S. obtusirostris*. V več vzorcih so bili zaznani mešani haplotipi CO1, ki so kazali dvojne vrhove v elektroferogramih na diagnostičnih mestih, tj. nukleotidih, specifičnih tako za *S. obtusirostris* kot za *S. trutta*. Naše ugotovitve kažejo, da lahko S. obtusirostris naseljuje strme, hitro tekoče predele. S sekvenciranjem haplotipov ne moremo ugotoviti, ali haplotip izvira iz čistega *S. obtusirostris* ali iz hibrida. Za to so potrebne nadaljnje raziskave, s katerimi se bo izboljšalo metode zaznavanja in s kombinacijo pristopov ocenilo hibridizacijo s pripadniki kompleksa *S. trutta*.

[1] BOKU University, Institute of Hydrobiology and Aquatic Ecosystem Management, Gregor-Mendel-Straße 33, 1180 Vienna, Austria

[2] Natural History Museum Vienna, Maria-Theresien-Platz 1010 Vienna, Austria

[3] Department of Evolutionary Biology, University of Vienna, Djerassiplatz 1, 1030 Vienna Austria

* Korespondenčni avtor / Corresponding author;
E-mail: kurt.pinter@boku.ac.at

† Avtorja sta prispevala enakovredno k objavi / The authors have contributed equally to this publication

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

KEY WORDS:

softmouth trout, Neretva River, Ljuta River, PCR-based species detection, environmental DNA, mitochondrial haplotypes, DNA sequencing

KLJUČNE BESEDE:

mehkoustna postrv, reka Neretva, reka Ljuta, odkrivanje vrst na osnovi PCR, okoljska DNA, mitohondrijski haplotipi, sekvenciranje DNA

KLJUČNE RIJEČI:

mekousta pastrmka, rijeka Neretva, rijeka Ljuta, detekcija vrsta zasnovana na PCR-u, DNA iz okoliša, mitohondrijski haplotipovi, sekvenciranje DNA

APSTRAKT

Pojavljivanje mekouste pastrmke *Salmo obtusirostris* u gornjem toku rijeke Neretve (Bosna i Hercegovina): studija zasnovana na eDNA analizama

Mekousna pastrmka (*Salmo obtusirostris*) je endemska vrsta za sliv Jadranskog mora. Ova studija je istraživala njenu rasprostranjenost u gornjem toku rijeke Neretve i pritoci Ljuta koristeći analizu okolišne DNA (eDNA). Analizirali smo 11 uzoraka eDNA prikupljenih tokom tri godine (2022–2024), sa PCR-om usmerenim na sekvence mitohondrijalnih markera: gen podjedinice 1 citohrom c oksidaze (CO1) i kontrolni region (CR). Sangerovo sekvenciranje PCR proizvoda potvrdilo je haplotipove *S. obtusirostris* na osam od 11 lokacija, sa prisustvom u Glavatičevu, estuaru Ljute i rijeci Ljuti. Generalno, rezultati pokazuju korisnost eDNA analiza u otkrivanju neuhvatljivih vrsta. Ipak, primetili smo nepotpunu specifičnost za *S. obtusirostris* za korišćene PCR prajmere. Mešoviti CO1 haplotipovi su otkriveni u nekoliko uzoraka, pokazujući dvostruke pikove u elektroferogramima na dijagnostičkim mestima, tj. nukleotide specifične za *S. obtusirostris* kao i za *S. trutta*. Naši nalazi ukazuju na to da *S. obtusirostris* može kolonizovati strma, turbulentna staništa. Pošto sekvenciranje haplotipa ne može utvrditi da li je haplotip izveden iz čistog *S. obtusirostris* ili iz hibrida, potrebna su dalja istraživanja koja će usavršiti metode detekcije i proceniti hibridizaciju sa članovima *Salmo trutta* kompleksa koristeći kombinaciju metodoloških pristupa.

INTRODUCTION

The softmouth trout, *Salmo obtusirostris* (Heckel, 1852), also known as the Adriatic trout or soft-muzzled trout, is found in river systems within the Adriatic drainage basin, particularly in Bosnia and Herzegovina, Croatia, and Montenegro (Razpet et al. 2007; Mrdak et al. 2012; Glamuzina et al. 2018). This species can be distinguished by its relatively blunt snout, a feature that differentiates it from other trout species. *Salmo obtusirostris* is regarded as closely related to the »*Salmo trutta* complex«, an assemblage comprising several closely related taxa and lineages besides the brown trout, *Salmo trutta* Linnaeus, 1758 (Snoj et al. 2002; Pustovrh et al. 2014; Veličković et al. 2023). The phylogenetic relationship of *S. obtusirostris* with respect to the *S. trutta* complex and the closely related *Salmo ohridanus* Steindachner, 1892 is still unresolved (Pustovrh et al. 2014; Lecaudey et al. 2018; Veličković et al. 2023). *Salmo obtusirostris* thrives in well-oxygenated waters, inhabiting clear, cold, and fast-flowing rivers. Typical habitats where adult specimens can be observed are deeper stream pools (Mrdak et al. 2012). However, its populations have been declining due to habitat degradation, pollution, overfishing, and hybridization with introduced species (Aganović et al. 1966; Muhamedagić et al. 2008; Glamuzina et al. 2018). Consequently, the species is listed as Vulnerable (Ford 2024) on the IUCN Red List of Threatened Species.

During a species assessment conducted in the Upper Neretva River in 2022, environmental DNA (eDNA) samples were taken and analyzed by amplifying short mitochondrial (mt) fragments with subsequent Sanger sequencing (Neuburg et al. 2023). In that study, *S. obtusirostris* was detected in the Glavatičevo region, upstream of Konjic, while approximately 30 km further upstream, in the villages of Nedavić, Ulog, and the headwaters of the Neretva River, we found no evidence of *S. obtusirostris* through eDNA analysis. The objective of the present study was to extend the analyses using newly acquired samples, and to determine the upper distribution limits of haplotypes specific to *S. obtusirostris*. This was achieved by testing eDNA samples from various locations in the Upper Neretva River—particularly in the Ljuta River near its confluence with the Neretva—for the presence of *S. obtusirostris*-specific mitochondrial haplotypes in addition to those associated with the *S. trutta* species complex.

In our previous pilot study (Neuburg et al. 2023), we demonstrated the feasibility of using two short fragments of mitochondrial DNA to differentiate haplotypes of *S. obtusirostris* from those of other species of the *S. trutta* complex. This study extends the analysis to include additional eDNA samples collected in 2023 and 2024, explore the distribution of *S. obtusirostris* and further test primers for their utility to detect this species. Sampling sites were selected in collaboration with the local fisheries manager, who reported that softmouth trout inhabit the Neretva River up to the right bank of the Ljuta estuary and slightly beyond. Oral accounts by fishermen suggest that the uppermost limit of their distribution is the right-bank tributary known as Krupac (Fig. 1), a short spring brook located slightly upstream from the Ljuta River. The Ljuta and Krupac tributaries are traditionally believed to serve as breeding grounds for *S. obtusirostris*. Notably, there are reports that softmouth trout have colonized the lower few kilometers of the Ljuta stream.

MATERIAL AND METHODS

A total of 11 eDNA samples (collected in 2022, 2023, and 2024) were analysed (Tab. 1) using Polymerase Chain Reaction (PCR) and Sanger sequencing of amplicons. This study incorporated three samples (Ner_1, Ner_2, Ner_3) from our earlier survey conducted in 2022 (Neuburg et al. 2023), which were reanalysed in the current PCR experiments, along with three additional water samples (Ner_4, Ner_5, and Lju_1) collected in 2023 from three distinct sites and five further samples obtained in 2024 (Ner_6, Ner_7, Lju_2, Lju_3, Lju_4). The sample sites for 2023 are located in the Neretva River (Fig. 1), around 1.2 km downstream of the confluence with the Ljuta River (Ner_4), directly at the confluence with the Ljuta River (Ner_5), and in the Ljuta River, around 160 m upstream of the river mouth (Lju_1). In 2023, sampling was carried out on 1 June. During the following year, sampling took place in March and in May. On 23 March, during the spawning season of the *S. obtusirostris*, the first sample was taken in the Neretva River, upstream of the confluence with the Ljuta River near Nedavić (Ner_6), which is a repeat of sample »Nedavić« from 2022 (Neuburg et al. 2023). The confluence of the Ljuta River with the Neretva River was also sampled again in 2024 (Ner_7). Sample Lju_2 was collected in the Ljuta River around 400 m from its mouth, Lju_3 was taken around 2 km from the mouth and Lju_4 close to the road bridge over the Ljuta River 3 km upstream of its confluence with the Neretva River. The latter was taken on 12 May 2024.

Sampling was performed in situ by filtering stream water through Spygen VigiDNA filters (0.45 µm pore size) using a peristaltic pump and sterile disposable tubing, processing 30–36 litres per sample. Filters were preserved in 80 mL of Spygen CL1 buffer (Pont et al. 2018) to prevent eDNA degradation. Subsequent analysis of eDNA samples was conducted at the Central Research Laboratories of the Natural History Museum Vienna (NHM). DNA extraction was performed in the NHM's DNA clean room under strict contamination control protocols. All post-extraction work (thermocycling and post-PCR processing) were performed in another laboratory. The DNeasy Blood & Tissue Kit (Qiagen) was used for DNA extraction, following the manufacturer's instructions, with a final elution volume of 60 µl. A negative control extraction without eDNA sample was carried out to detect potential contamination in the extraction reagents. The control extractions were later included in the PCR reactions.

Two marker sequences were employed: (1) a partial region of the mitochondrial cytochrome c oxidase subunit 1 gene (CO1) and (2) a partial region of the mitochondrial control region (CR).

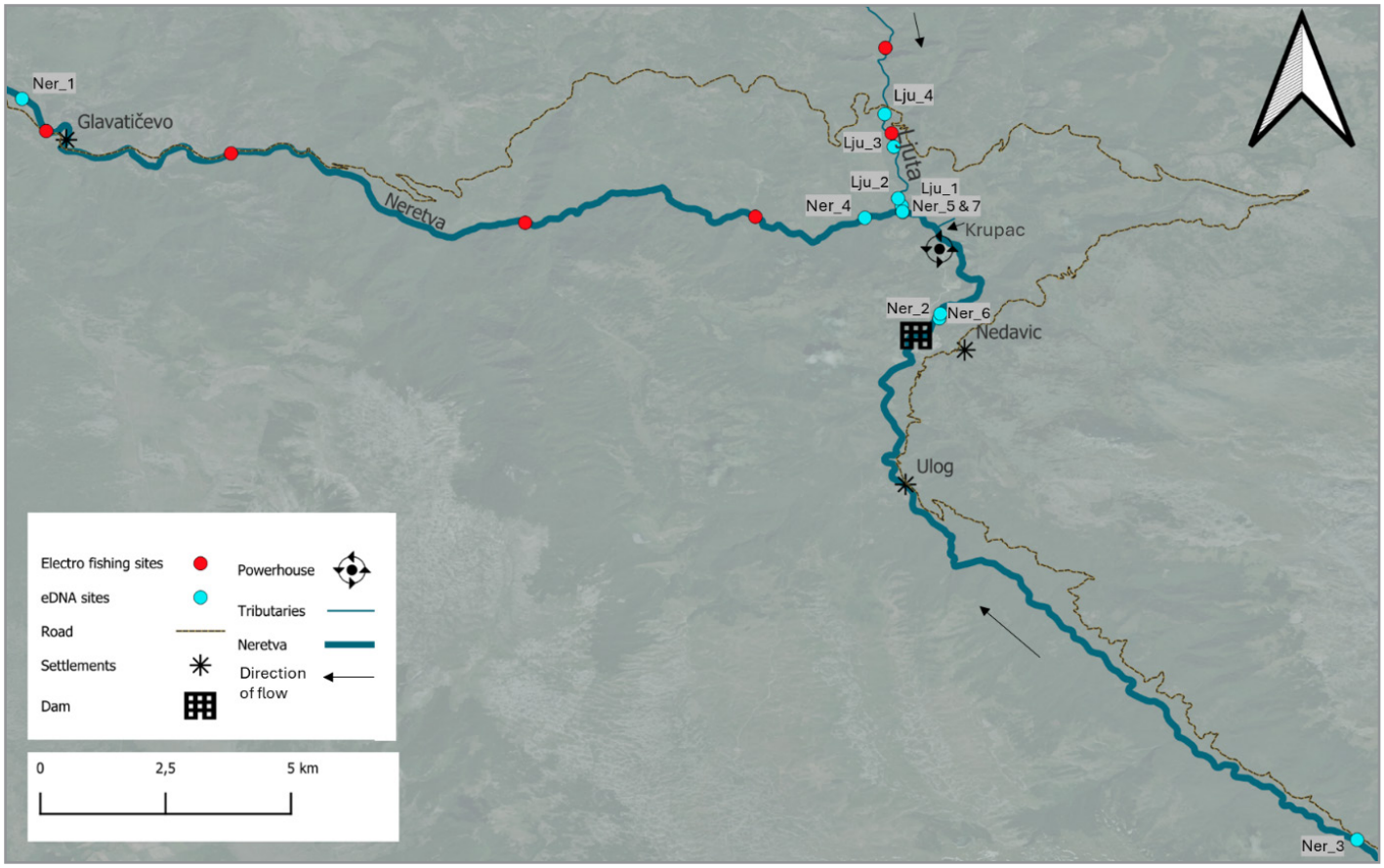

Figure 1. Study area in the Upper Neretva basin with the respective sampling sites in the Neretva River and the Ljuta River, a right bank tributary. For electrofishing sites see Ostojić & Brka (2018).

Slika 1. Območje raziskave v zgornjem porečju Neretve z ustreznimi mesti vzorčenja v reki Neretvi in reki Ljuti, desnem pritoku. Za mesta elektroribolova glej Ostojić & Brka (2018).

Slika 1. Područje istraživanja u slivu gornjeg toka Neretve sa reprezentativnim mjestima uzorkovanja u rijeci Neretvi i rijeci Ljutoj, pritoci na desnoj obali. Lokacije za elektroribolov se odnose na Ostojić & Brka (2018).

Table 1. Overview of the eDNA samples, sampling date and their location in the study area. Ner = Neretva River. Lju = Ljuta River.

Tabela 1. Pregled vzorcev eDNA, datum vzorčenja in njihova lokacija na območju raziskave. Ner = reka Neretva. Lju = reka Ljuta.

Tabela 1. Pregled uzoraka eDNA, datum uzorkovanja i njihova lokacija u području istraživanja. Ner = Rijeka Neretva. Lju = Rijeka Ljuta.

Sample ID	Date	Locality	Latitude	Longitude
Ner_1	1. 7. 2022	»Glavatičevo« in Neuburg et al. (2023)	43°30'42.93" N	18° 5'43.66" E
Ner_2	30. 6. 2022	»Nedavić« in Neuburg et al. (2023)	43°27'28.64" N	18°19'15.62" E
Ner_3	29. 6. 2022	»Confluence« in Neuburg et al. (2023)	43°19'47.22" N	18°25'25.45" E
Ner_4	1. 6. 2023	1.2 km downstream the Ljuta River	43°28'57.62" N	18°18'9.74" E
Ner_5	1. 6. 2023	Confluence Neretva River & Ljuta River	43°29'2.76" N	18°18'43.35" E
Lju_1	1. 6. 2023	160 m upstream the confluence	43°29'8.03" N	18°18'42.53" E
Ner_6	23. 3. 2024	Nedavić	43°27'32.73" N	18°19'16.56" E
Ner_7	23. 3. 2024	Confluence Neretva River & Ljuta River	43°29'3.00" N	18°18'43.01" E
Lju_2	23. 3. 2024	400 m upstream the confluence	43°29'14.81" N	18°18'39.19" E
Lju_3	23. 3. 2024	2 km upstream the confluence	43°30'0.43" N	18°18'35.44" E
Lju_4	12. 5. 2024	3 km upstream the confluence	43°30'29.41" N	18°18'27.30" E

To design primers for these markers, alignments with sequences obtained from the NCBI GenBank database were used (Neuburg et al. 2023). The *S. trutta* species complex includes several closely related nominal species (Pustovrh et al. 2014; Sanz 2018), with p distances below 0.5% in both marker sequences in our dataset. In contrast, *S. obtusirostris* forms a distinct lineage in mitochondrial phylogenetic trees, separated from the *S. trutta* species complex by slightly higher distances (mean distances of 1% and 1.8% for CR and CO1, respectively). Given the close phylogenetic relationship between these species, primers were carefully designed to amplify sequences containing diagnostic sites specific to *S. obtusirostris*. Additionally, the fragments were kept relatively short (<400 bp) to ensure successful amplification of degraded DNA and to preferentially amplify *S. obtusirostris* haplotypes when possible.

For the CO1 marker, nested primers were used to eliminate artefactual bands observed in initial amplifications. After primary amplification with Salm_CO1_1+/Salm_CO1_4- (amplicon length: 263 bp), a reamplification was conducted using either Salm_CO1_3+/Salm_CO1_4- and Salm_CO1_3mod+/Salm_CO1_4- (amplicon length: 210 bp). Both Salm_CO1_3+ and Salm_CO1_4- primers include species-specific bases at their 3´-ends to preferentially amplify *S. obtusirostris* over *S. trutta* and other related species. For the CR marker, primers Salm_CR_5+/Salm_CR_6- were used (amplicon length: 345 bp). In this case, only the reverse primer was designed to be species-specific for *S. obtusirostris*. As this primer pair reliably produced clean amplification without artefactual bands, no nested primers were required. Primer sequences are provided in Tab. 2.

PCR reactions were conducted using the Multiplex PCR Kit (Qiagen, Hilden, Germany) in 25 µl reaction volumes containing 12.5 µl of Multiplex PCR Master Mix, 0.5 µM of each primer, and 1 µl of template DNA. For reamplifications (when nested PCR was carried out), template DNA was transferred by briefly dipping the pipette tip into the original PCR reaction and then into the reamplification tube. The thermocycling conditions were as follows for all reactions: an initial denaturation at 94 °C for 5 minutes, followed by 45 cycles of 94 °C for 30 seconds, an annealing step for 30 seconds, and 72 °C for 30 seconds, with a final extension at 72 °C for 10 minutes. Negative controls were included in all PCRs: control extraction and a PCR reaction without template DNA. PCR products were purified using the QIAGEN PCR Purification Kit and sequenced bidirectionally at Microsynth Austria (Vienna, Austria) using the PCR primers.

Table 2. PCR primers used for the detection of Salmo spp. in eDNA samples. Except for Salm_CO1_3mod+, all primers are from Neuburg et al. (2023). »+« and »–« in primer names indicate forward and reverse primers, respectively.

Tabela 2. PCR primerji, uporabljeni za detekcijo Salmo spp. v vzorcih eDNA. Razen Salm_CO1_3mod+ so vsi primerji iz Neuburg et al. (2023). »+« in »–«v imenih primerjev označujeta direktne oziroma povratne primerje.

Tabela 2. PCR prajmeri korišteni za detekciju Salmo spp. u eDNA uzorcima. Osim Salm_CO1_3mod+, svi prajmeri su iz Neuburg et al. (2023). »+« i »–« u nazivima prajmera označavaju direktne i inverzne prajmere, respektivno.

Marker sequence	Primer name	Sequence (5´-3´)	Annealing temperature
CO1	Salm_CO1_1+	CGTAATTGTTACAGCCCATGCC	60 °C
	Salm_CO1_3+	TTATGATCGGCGGCTTTGGG	60 °C
	Salm_CO1_3mod+	TTATGATCGGCGGCTTTGGGAA	60 °C
	Salm_CO1_4-	CGGAAGCTCCTGCGTGGGCG	60 °C
CR	Salm_CR_5+	GATAATAACCAACTAAGTTGTC	58 °C
	Salm_CR_6-	GGGAACCCTATGCATATAAG	58 °C

RESULTS

Tab. 3 summarizes the results of the PCR experiments conducted with the two marker sequences. PCR products were successfully obtained and sequenced for all samples, except for two of which only CO1 could be amplified (Ner_3, Ner_6). Haplotypes of *S. obtusirostris* were detected in all samples, except for three (Ner_2, Ner_3, Ner_6).

Table 3. Results of the PCR tests with three primer sets.

Tabela 3. Rezultati PCR testov s tremi kompleti primerjev.

Tabela 3. Rezultati PCR testova sa tri seta prajmera.

Sample ID	CR Salm_CR_5+/ Salm_CR_6-	CO1 Salm_CO1_3+/ Salm_CO1_4-	CO1 CO1_3mod+/ Salm_CO1_4-
Ner_1	*obtusirostris*	*obtusirostris*	*obtusirostris*
Ner_2	*trutta*	*trutta*	*trutta*
Ner_3	—	*trutta*	*trutta*
Ner_4	*obtusirostris*	*obtusirostris*	*obtusirostris* / *trutta*
Ner_5	*obtusirostris*	*obtusirostris*	*obtusirostris* / *trutta*
Ner_6	—	*trutta*	*trutta*
Ner_7	*obtusirostris*	*obtusirostris*	*obtusirostris* / *trutta*
Lju_1	*obtusirostris*	*obtusirostris*	*obtusirostris* / *trutta*
Lju_2	*obtusirostris*	*obtusirostris* / *trutta*	*obtusirostris* / *trutta*
Lju_3	*obtusirostris*	*obtusirostris* / *trutta*	*obtusirostris* / *trutta*
Lju_4	*obtusirostris*	*obtusirostris*	*obtusirostris* / *trutta*

An intriguing observation was made regarding the CO1 primer pairs. With primers Salm_CO1_3+/Salm_CO1_4-, despite the presence of mismatches for *S. trutta* at the 3´-ends of both primers, mixed sequences characterized by double peaks at the diagnostic sites were detected in two samples (Lju_2 and Lju_3). For the primer pair Salm_CO1_3mod+/Salm_CO1_4-, where only the reverse primer exhibited a mismatch, mixed sequences were identified in 7 out of 11 samples (Tab. 3). Only one sample (Ner_1 from Glavatičevo) yielded pure *S. obtusirostris* haplotypes with all three markers.

In three samples (Ner_2, Ner_3, Ner_6) exclusively *S. trutta* was detected. While in Ner_3 and Ner_6, the *S. trutta* haplotype was obtained only with the CO1 marker, no PCR product was obtained with the CR primer pair, which is not surprising as the reverse CR primer was designed to be species-specific for *S. obtusirostris*. However, in sample Ner_2, haplotypes attributed to the *S. trutta* species complex were identified not only by the two CO1 primer pairs but even with the CR primer pair.

DISCUSSION

As we obtained sequences of *S. obtusirostris* and/or *S. trutta* respectively from all samples, detection of eDNA of these species appeared easy to accomplish. Yet, the primers used proved to be not entirely species-specific. Although we had designed primers using diagnostic sites (match/mismatch at the 3´-ends) for specificity, unintended co-amplification of the non-target species occurred repeatedly. However, none of the PCRs amplified sequences from species other than *S. obtusirostris* or the *S. trutta* complex. Overall, the CR primers demonstrated higher specificity for *S. obtusirostris*, as no mixed haplotypes (characterized by double peaks at the diagnostic sites) were observed for this marker. Nonetheless, even the CR primer pair amplified *S. trutta* in one sample (Ner_2). Notably, in this sample, the other two primer sets also exclusively detected *S. trutta*, strongly supporting that *S. obtusirostris* was absent at this site. The lack of perfect species specificity for all primer sets may not solely be attributed to primer binding characteristics. It is likely also influenced by varying relative abundances of haplotypes within the water body, which could affect the outcome of PCR amplification.

The detection of *S. obtusirostris* haplotypes in 7 out of 10 samples in the upper part of the investigation area suggests a considerable distribution of *S. obtusirostris* in the Upper Neretva River, particularly around the Ljuta River, and within the Ljuta River itself. Conversely, the absence of *S. obtusirostris* haplotypes in samples collected in the Neretva River upstream of the confluence with the Ljuta tributary (Ner_3, Ner_6) in 2024 suggests that the species is currently absent from those areas. This also confirms the result of the Nedavić sample site from 2022 (Ner_2) by Neuburg et al. (2023).

The detection of *S. obtusirostris* in the Glavatičevo area (Ner_1; see also Neuburg et al. 2023) and at the Ljuta estuary, approximately 25 km upstream, indicates that the species may inhabit the entire river section between these sites. However, this interpretation must be made cautiously. It is important to emphasize that the eDNA method detects haplotypes present in the river rather than fish. Since the extent of hybridization between *S. obtusirostris* and the *S. trutta* complex in this area is unknown, it remains unclear whether the detected haplotypes originated from pure *S. obtusirostris* individuals or from hybrids.

The probability that some of the detected haplotypes derive from hybrids cannot be excluded, although it is most likely low. While cases of hybridization between *S. trutta* and *S. obtusirostris* have been documented in the Neretva catchment and Jadro River (Razpet et al. 2007; Sušnik et al. 2007), the extent of natural hybridization is generally considered to be limited (Razpet et al. 2007). In other systems, such as the Zeta River in Montenegro, no evidence of hybridization has been found despite the sympatric occurrence of *S. obtusirostris* and *S. trutta* (Mrdak et al. 2012). When discussing the origin of hybrids in the Neretva River, reports suggesting that fish farms have released hybrids into the wild should be given close consideration. The assumption of stocked hybrids is repeatedly expressed by local fisheries representatives (pers. comm. Hrabren Kapić) and echoes in

angling magazines (e.g. BistroBiH 2025). Stocking measures in the Neretva reportedly extended upstream only as far as the confluence with the Ladanica River upstream of Glavatičevo. Upstream of this point, no stocking has been practiced, which reduces the likelihood of artificially introduced hybrids.

Previous ichthyological surveys recorded the presence of *S. obtusirostris* in the tributaries of Neretva, including the Ljuta River (Muhamedagić et al. 2008). Fisheries managers also support the presence of *S. obtusirostris* along the 25 km stretch between Glavatičevo and the Ljuta estuary and in the Ljuta River itself (pers. comm. Hrabren Kapić). Our eDNA results are in line with these observations albeit, as mentioned above, we do not know whether and to which proportion we detected hybrids. The occurrence of *S. obtusirostris* in the Ljuta River would indicate the species' ability to inhabit steep and turbulent watercourses (Fig. 2). This means that it may also colonize habitats that are not inhabited by the grayling to which it is often compared in terms of the ecological niche it occupies (Mrdak et al. 2012).

Figure 2. Ljuta River downstream from the road bridge, close to the sampling site Lju_4. © Arthur de Bruin & Dick Harrewijn, 2023.

Slika 2. Reka Ljuta dolvodno od cestnega mostu, blizu mesta vzorčenja Lju_4. © Arthur de Bruin in Dick Harrewijn, 2023.

Slika 2. Rijeka Ljuta nizvodno od mosta, blizu mjesta uzorkovanja Lju_4. © Arthur de Bruin i Dick Harrewijn, 2023.

In contrast, electrofishing surveys conducted in 2011 and 2018, which examined four sampling sites along this stretch of the Neretva River (see Fig. 1), and two additional sites in the lower course of the Ljuta River, did not detect *S. obtusirostris* (Ostojić & Brka 2018). Yet, this outcome may also reflect the challenges of proving the occurrence with electrofishing techniques only. Difficulties may stem from the species' low abundance (Muhamedagić et al. 2008), elusive behaviour, or preference for hidden habitats such as deep pools which can also be found in the Ljuta River.

FUTURE PERSPECTIVES

Summing up, a logical next step would be a systematic assessment of the trout populations, focusing on both *S. obtusirostris* and *S. trutta* through a combination of morphological (electrofishing) and genetic analyses (eDNA and analysis of individual fish). Additionally, it would be valuable to further optimize the employment of mt marker sequences (CR, CO1) using a qPCR approach: With a target-specific probe differentiation of the two species the detection methodology could be refined. This could be the method of choice for broad surveys of the distribution of *S. obtusirostris* haplotypes. However, catching fish remains the sole viable method for obtaining morphological assessments of fish (hybrid or pure species) and/or for further genetic analyses of individual specimens (e.g., mt haplotypes, nuclear markers).

POVZETEK

V tej študiji smo raziskovali pojavljanje in razširjenost mehkouste postrvi (*Salmo obtusirostris*) v zgornjem toku reke Neretve in njenem pritoku, reki Ljuti (Bosna in Hercegovina). Vrsta je endemična za jadransko povodje in uvrščena na Rdeči seznam IUCN kot ranljiva. Z analizo okoljske DNA (eDNA) v kombinaciji s PCR amplifikacijo mitohondrijskih markerjev (CO1, CR) in naknadnim Sangerjevim sekvenciranjem smo pregledali 11 vzorcev vode, zbranih med letoma 2022 in 2024.

Naši rezultati so potrdili haplotipe *S. obtusirostris* na osmih od 11 vzorčnih mestih, to je v Glavatičevu, v ustju reke Ljute in v reki Ljuti. Rezultati nakazujejo, da ta vrsta morda naseljuje celoten, približno 25 km dolg, odsek reke med Glavatičevim in ustjem reke Ljute, in da je sposobna naseliti tudi strma in hitro tekoča območja, kakršna so v reki Ljuti. Haplotipi *S. obtusirostris* niso bili odkriti nad sotočjem Ljute (lokacije Ner_2, Ner_3, Ner_6), kar potrjuje prejšnja opazovanja, da je tu zgornja meja razširjenosti vrste v reki Neretvi.

Pomembna je ugotovitev, da uporabljeni primerji niso bili povsem specifični za vrsto. Medtem ko je par primerjev CR pokazal sorazmerno visoko specifičnost, so se v amplifikacijah na podlagi CO1 večkrat pojavili mešani haplotipi (*S. obtusirostris* / *S. trutta*). To kaže, da v tem sistemu na odkrivanje s pomočjo eDNA lahko vplivata tako specifičnost primerjev kot tudi relativna pogostost haplotipov v vodi. Nadalje, preko zaznavanja haplotipov ni mogoče določiti, ali ti izvirajo iz čistih osebkov *S. obtusirostris* ali iz hibridov s kompleksom *S. trutta*. Previdnost pri interpretaciji izhaja iz prejšnjih poročanj o hibridizaciji v porečju Neretve (Razpet et al. 2007; Sušnik et al. 2007) kot tudi sumov vnosov iz ribogojnic.

Kljub temu se naši izsledki ujemajo s poročanji lokalnih ribiških upraviteljev, da je *S. obtusirostris* prisotna vzdolž tega odseka reke Neretve in v pritoku Ljuta. Dejstvo, da vrsta ni bila odkrita z električnim ribolovom (Ostojić & Brka 2018), je lahko posledica omejitev metode zaradi majhne številčnosti vrste, njenega neopaznega vedenja in skrivanja v habitatih, kot so globoki tolmuni.

SAŽETAK

U ovoj studiji istražili smo prisustvo i rasprostranjenost mekousne pastrmke (*Salmo obtusirostris*) gornjeg toka rijeke Neretve i njene pritoke, rijeke Ljute (Bosna i Hercegovina), endemske vrste sliva Jadranskog mora koja je navedena kao »ranjiva« na Crvenoj listi IUCN-a. Korištenjem analize ekološke DNA (eDNA) u kombinaciji sa PCR amplifikacijom mitohondrijskih markera (CO1, CR) i naknadnim Sanger sekvenciranjem, ispitali smo 11 uzoraka vode prikupljenih između 2022. i 2024. godine.

Naši rezultati otkrili su haplotipove *S. obtusirostris* na 8 od 11 mjesta uzorkovanja, potvrđujući njenu prisutnost u Glavatičevu, na ušću Ljute i unutar rijeke Ljute. Nalazi sugerišu da vrsta može nastanjivati cijeli riječni dio između Glavatičeva i ušća Ljute, na udaljenosti od oko 25 km, i da je također sposobna da kolonizuje strma i turbulentna staništa poput onih na rijeci Ljuti. Međutim, uzvodno od ušća Ljute (lokacije Ner_2, Ner_3, Ner_6) nisu otkriveni haplotipovi *S. obtusirostris*, što podržava prethodna zapažanja da je gornja granica rasprostranjenosti vrste u rijeci Neretvi već dostignuta u ovom regionu.

Važan metodološki uvid je da korišteni prajmeri nisu bili u potpunosti specifični za vrstu. Dok je par CR prajmera pokazao relativno visoku specifičnost, mješoviti haplotipovi (*S. obtusirostris* / *S. trutta*) pojavljivali su se više puta u amplifikacijama temeljenim na CO1. Ovo ukazuje na to da na detekciju zasnovanu na eDNA u ovom sistemu može uticati i specifičnost prajmera i relativna količina haplotipova u vodi. Štaviše, sama detekcija haplotipova ne može utvrditi da li sekvence potiču od čistih jedinki *S. obtusirostris* ili od hibrida sa kompleksom *S. trutta*. Prethodni izvještaji o hibridizaciji u slivu Neretve (Razpet et al. 2007; Sušnik et al. 2007) i sumnje na uvođenje ribnjaka naglašavaju potrebu za oprezom u interpretaciji.

Uprkos ovim nesigurnostima, naši nalazi su u skladu sa usmenim izvještajima lokalnih ribočuvara koji ukazuju na prisutnost *S. obtusirostris* duž ovog riječnog dijela i u pritoci Ljuta. Odsustvo detekcija u istraživanjima elektroribolova (Ostojić & Brka 2018) može odražavati metodološka ograničenja zbog niske brojnosti vrste, neuhvatljivog ponašanja i sklonosti ka skrivenim staništima poput dubokih dijelova rijeke.

ACKNOWLEDGEMENTS

First, we would like to express our gratitude to two unknown reviewers for their conscientious review of our publication. We thank RiverWatch for their invaluable work, which represents the basis of this research. We are especially grateful to Hrabren Kapić, a dedicated fisheries manager of the Neretva River, for his support and collaboration during our stay. Our appreciation extends to the Bosnian farmer who guided us to the Ljuta estuary. Finally, we thank Arthur de Bruin and Dick Harrewijn for their companionship, contributions, and exceptional video work, which showcases the breathtaking beauty of the Balkans to a wider audience.

REFERENCES

Aganović M, Vuković T, Kapetanović N. 1966. Ihtiofauna jablaničke vodene akumulacije. Ribarstvo. 21: 92-95.

[BistroBiH] Bistro Bosno i Hercegovino! 2025. Endemske i autohtone vrste rijeke Neretve pred izumiranjem. Bistro Bosno i Hercegovino!; [accessed 7. 5. 2025]. http://www.bistrobih.ba/nova/2011/01/31/endemske-i-autohtone-vrste-rijeke-neretve-pred-izumiranjem/

Ford M. 2024. *Salmo obtusirostris*. The IUCN Red List of Threatened Species. [accessed 1. 1. 2025]; 2024: e. T19862A137328571. https://dx.doi.org/10.2305/IUCN.UK.2024-2.RLTS.T19862A137328571.en

Glamuzina B, Stanić-Koštroman S, Matić-Skoko S, Glamuzina L, Muhamedagić S, Rozić I, Weiss S, Pavličević J. 2018. Recent status and life history traits of endangered soft-mouth trout, *Salmo obtusirostris* in the river Neretva catchment (Bosnia and Herzegovina) as a consequence of river alteration. Journal of Applied Ichthyology. 34(5): 1160-1168. https://doi.org/10.1111/jai.13780

Lecaudey LA, Schliewen UK, Osinov AG, Taylor EB, Bernatchez L, Weiss S. 2018. Inferring phylogenetic structure, hybridization and divergence times within Salmoninae (Teleostei: Salmonidae) using RAD-sequencing. Molecular phylogenetics and evolution. 124: 82-99. https://doi.org/10.1016/j.ympev.2018.02.022

Muhamedagić S, Gjoen HM, Vegra M. 2008. Salmonids of the Neretva River basin-present state and suggested sustainable selection programme to protect and strengthen salmonid populations. In: Proceedings of the symposium on Interactions between social, economic and ecological objectives of inland commercial and recreational fisheries and aquaculture. Antalya, Turkey, 21-24 May 2008. Food and Agriculture Organization. p. 224-275.

Mrdak D, Nikolić V, Tošić A, Simonović P. 2012. Molecular and ecological features of the soft-muzzled trout *Salmo obtusirostris* (Heckel, 1852) in the Zeta River, Montenegro. Biologia. 67: 222-233. https://doi.org/10.2478/s11756-011-0150-y

Neuburg J, Friedrich T, Haring E, Höfler S, Maric A, Marić S, Popp S, Simonović P, Snoj A, Sušnik B, et al. 2023. The ichthyofauna of the upper Neretva River. Natura Sloveniae. 25(3): 155-180. https://doi.org/10.14720/ns.25.3.155-180

Ostojić I, Brka M. 2018. Revizija ribarske osnove za dio ribolovnog područja – Ribolovna zona Konjic. Mostar, Sarajevo (BIH): Sveučilište u Mostaru, Agronomski i prehrambeno-tehnološki fakultet, Univerzitet u Sarajevu, Poljoprivredno-prehrambeni fakultet.

Pont D, Rocle M, Valentini A, Civade R, Jean P, Maire A, Roset N, Schabuss M, Zornig H, Dejean T. 2018. Environmental DNA reveals quantitative patterns of fish biodiversity in large rivers despite its downstream transportation. Scientific Reports. 8: 10361. https://doi.org/10.1038/s41598-018-28424-8

Pustovrh G, Snoj A, Bajec S. 2014. Molecular phylogeny of Salmo of the western Balkans, based upon multiple nuclear loci. Genetics Selection Evolution. 46: 7. https://doi.org/10.1186/1297-9686-46-7

Razpet A, Sušnik S, Jug T, Snoj A. 2007 Genetic variation among trout in the River Neretva basin, Bosnia and Herzegovina. Journal of Fish Biology. 70 (Suppl. A): 94-110. https://doi.org/10.1111/j.1095-8649.2007.01392.x

Sanz N. 2018. Phylogeographic history of brown trout: a review. In: Lobón-Cerviá J, Sanz N, editors. Brown trout: biology, ecology and management. Hoboken (NJ): John Wiley & Sons. p. 15-63.

Snoj A, Melkič E, Sušnik S, Muhamedagić S, Dovč P. 2002. DNA phylogeny supports revised classification of *Salmothymus obtusirostris*. Biological Journal of the Linnean Society. 77(3): 399-411. https://doi.org/10.1046/j.1095-8312.2002.00130.x

Sušnik S, Weiss S, Odak T, Delling B, Treer T, Snoj A. 2007. Reticulate evolution: ancient introgression of the Adriatic brown trout mtDNA in softmouth trout *Salmo obtusirostris* (Teleostei: Salmonidae). Biological Journal of the Linnaean Society. 90(1): 139-152. https://doi.org/10.1111/j.1095-8312.2007.00717.x

Veličković T, Snoj A, Simić V, Šanda R, Vukić J, Barcytė D, Stanković D, Marić S. 2023. A new perspective on the molecular dating of the brown trout complex with an extended phylogeographic information on the species in Serbia. Contributions to Zoology. 92(4): 362-389. https://doi.org/10.1163/18759866-bja10046

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 114–122
»Neretva Science Week 2023«

KRATKA ZNANSTVENA VEST /
SHORT COMMUNICATION

DOI: 10.14720/ns.20096
Objavljeno na spletu / Published online: 22. 12. 2025

Prejeto / Received: 1. 11. 2024
Sprejeto / Accepted: 17. 6. 2025

Contribution to the knowledge of spiders (Araneae) of the upper course of the Neretva River in Bosnia and Herzegovina

Žan KURALT[1*],
Neža PAJEK ARAMBAŠIČ,[2]
Rok KOSTANJŠEK[3]

[1] Genialis d.o.o., Vojkova cesta 63, SI-1000 Ljubljana, Slovenia

[2] Faculty of Computer and Information Science, University of Ljubljana, Večna pot 113, SI-1000 Ljubljana, Slovenia

[3] Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, SI-1000 Ljubljana, Slovenia

* Korespondenčni avtor / Corresponding author;
E-mail: zan.kuralt@gmail.com

KEY WORDS:
biodiversity, faunal survey, species inventory, spiders, Bosnia and Herzegovina

KLJUČNE BESEDE:
biodiverziteta, naravovarstvo, favnistična raziskava, inventarizacija vrst, pajki, Bosna in Hercegovina

KLJUČNE RIJEČI:
biodiverzitet, očuvanje prirode, istraživanje faune, inventarizacija vrsta, pauci, Bosna i Hercegovina

ABSTRACT

The upper course of the Neretva River, located in the rugged landscapes of Bosnia and Herzegovina (BiH), hosts a unique and largely unexplored ecosystem with significant biodiversity. This study aims to document the spider (Araneae) species inhabiting this region, including the Neretva's wider catchment area, Nevesinjsko polje, and the Vranjača cave. Using various sampling methods, we identified 84 spider species from 72 genera and 22 families, with 50 (60%) species reported in BiH for the first time. Notable findings include the abundant *Piratula knorri* (Scopoli, 1763) (Lycosidae), and cave-dwelling species such as a region endemic *Parastalita stygia* (Joseph, 1882) (Dysderidae) and *Lepthyphantes leprosus* (Ohlert, 1865) (Linyphiidae). Our results emphasise the importance of this understudied region for spider biodiversity and underscore the need for ongoing research to enhance faunistic knowledge and inform conservation efforts in BiH.

IZVLEČEK

Prispevek k poznavanju pajkov (Araneae) zgornjega toka reke Neretve v Bosni in Hercegovini

Zgornji tok reke Neretve, ki leži v razgibani pokrajini Bosne in Hercegovine (BiH), je edinstven in v veliki meri neraziskan ekosistem z visoko biotsko raznovrstnostjo. Namen prispevka je dokumentirati vrste pajkov (Araneae), ki naseljujejo to območje, vključno s širšim porečjem Neretve in Nevesinjskim poljem ter jamo Vranjača. Z različnimi metodami vzorčenja smo ujeli 84 vrst pajkov iz 72 rodov in 22 družin, pri čemer je bilo 50 (60 %) vrst prvič zabeleženih v BiH. Med zanimivejšimi najdbami gre omeniti vrsto *Piratula knorri* (Scopoli, 1763) (Lycosidae), ki je bila najštevilčnejša vrsta v obrežnem delu Neretve, in redke vrste, ki živijo v jamah, kot sta *Parastalita stygia* (Joseph, 1882) (Dysderidae) in *Lepthyphantes leprosus* (Ohlert, 1865) (Linyphiidae). Naši rezultati potrjujejo biotsko raznovrstnost pajkov v regiji in potrebo po nadaljnjih favnističnih raziskavah v BiH.

APSTRAKT

Doprinos poznavanju pauka (Araneae) gornjeg toka rijeke Neretve u Bosni i Hercegovini

Gornji tok rijeke Neretve, smešten u neravnim pejzažima Bosne i Hercegovine (BiH), domaćin je jedinstvenih i uglavnom neistraženih ekosistema sa bogatim biodiverzitetom. Cilj ove studije je da dokumentuju vrste pauka (Araneae) koje naseljavaju ovaj region, uključujući šire područje sliva Neretve, Nevesinjsko polje i pećinu Vranjaču. Koristeći različite metode uzorkovanja, identifikovali smo 84 vrste pauka iz 72 roda i 22 porodice, od kojih je 50 (60 %) vrsta prvi put prijavljeno u BiH. Značajni nalazi uključuju brojnu populaciju vrste *Piratula knorri* (Scopoli, 1763) (Lycosidae), kao i vrste koje žive u pećinama, kao što su endemske vrste: *Parastalita stygia* (Joseph, 1882) (Dysderidae) i *Lepthyphantes leprosus* (Ohlert, 1865) (Linyphiidae). Naši rezultati naglašavaju značaj ovog nedovoljno proučavanog regiona za biodiverzitet pauka i podvlače potrebu za kontinuiranim istraživanjima kako bi se unapredilo znanje o fauni i naglasili napori za očuvanje prirode u BiH.

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

INTRODUCTION

The upper course of the Neretva River in Bosnia and Herzegovina (BiH) harbors one of Europe's most ecologically diverse yet understudied ecosystems. The region's varied topography and microclimates support rich biological diversity, but its spider fauna remains poorly documented (EEA 2010).

Spiders (Araneae), serving as both predators and prey, play an important role in maintaining ecological balance in the ecosystem (Cardoso et al. 2011; Foelix 2011). Despite their crucial role in food web dynamics and ecosystem integrity (Wise 1995), there is a significant lack of data on the diversity and distribution of spider species in this area. An initial overview of the spider fauna of the former Yugoslavia, including Bosnia and Herzegovina, was provided by Nikolić & Polenec (1981), offering an early foundation for regional studies. Komnenov (2009) further advanced this work in BiH with the first contemporary checklist for the country. Later publications reported new or even endemic species in the region (Wunderlich 2011; Logunov 2015; Bauer et al. 2020; Stanković & Ćurčić 2020) and expanded knowledge on subterranean species (Naumova et al. 2016). New species were added to the checklist as a result of revisions by group specialists (Bosmans 2009; Huber et al. 2021; Huber 2022; Castelluci et al. 2024).

Addressing this knowledge gap, our study maps the distribution of spider species along various points in the upper course of the Neretva River. Specimens were collected during the Neretva Science Week 2023, a field-based research expedition focused on biodiversity documentation in underexplored regions of Bosnia and Herzegovina. We documented numerous species – some recorded in this region for the first time – including in the wider Neretva catchment area, Nevesinjsko Polje, and the Vranjača Cave. These findings add to the limited knowledge of Bosnia and Herzegovina's araneofauna and offer the basis for further explorations of spider biodiversity patterns in the Balkan Peninsula. We aimed to highlight the importance of continued biodiversity research in underexplored regions like the upper Neretva River. A deeper understanding of these ecosystems is vital for their conservation and the sustainable management of natural resources in BiH and beyond (Russi 2013; MFTER 2016).

MATERIAL AND METHODS

Specimens were collected during the Neretva Science Week 2023 (2–7 June 2023), an interdisciplinary biodiversity survey organized in the Upper Neretva region. Sampling was conducted by a team of araneologists and volunteers across 17 localities using various field techniques, including selective collection with forceps or an aspirator (Fig. 1), round sweep nets, leaf litter sifters, and pitfall traps. The specimens were preserved in 70% ethanol. The collected material was identified using several determination keys (Roberts 1995; Oger 2023; Nentwig et al. 2024). Extraction, identification, preparation, and observation were carried out on site using light stereomicroscopes in an improvised lab in Ulog village and at the Department of Biology, Biotechnical Faculty, University of Ljubljana.

Figure 1. Collecting spiders using an aspirator in one of the gravel bars along the upper part of the Neretva River (photo: Neža Pajek Arambašič).

Slika 1. Selektivno vzorčenje pajkov z aspiratorjem na enem od prodišč zgornjega toka reke Neretve (foto: Neža Pajek Arambašič).

Slika 1. Selektivno uzorkovanje pauka aspiratorom na jednom od šljunkovitih sprudova gornjeg toka rijeke Neretve (foto: Neža Pajek Arambašič).

RESULTS

During the Neretva Science Week 2023, we collected 84 spider species from 72 genera and 22 families (Tab. 2). For each species, we provide data on the collecting site, geographic latitude and longitude (WGS84), altitude in metres above sea level (a.s.l), date of collection, sampling method, and material provider (Legit). As the authors of this article, we conducted all species identifications (Tab. 1).

To support future research on the spider fauna of Bosnia and Herzegovina, we provide photographic documentation of the pedipalps and epigynes of selected specimens listed in Tab. 1. This material includes newly recorded species found at multiple localities – likely widespread but previously overlooked – such as *Mangora acalypha*, *Drassyllus villicus*, *Microneta viaria*, *Pardosa alacris*, *Pardosa prativaga*, *Piratula knorri*, *Phrurolithus festivus*, *Metellina mengei*, and *Euryopis flavomaculata* (Figs. 2a–r). It also features rarely recorded species associated with cave habitats, *Lepthyphantes leprosus* (Figs. 2s–2t) (Nentwig et al. 2024), and the Dinaric endemic cave species *Parastalita stygia* (Fig. 2u).

DISCUSSION

The spider fauna of BiH is poorly known as the national spider checklist comprises only 182 species (Nentwig et al. 2024; WSC 2024). Based on the diverse climate, terrain, and habitat types, one would expect this number to be up to 10 times higher. As seen in Fig. 3, checklists of neighboring countries Croatia, Serbia, and Montenegro comprise 771, 773, and 287 species, respectively, and are, like the Bosnian, far from complete. Altogether we identified 84 species from 72 genera and 22 families.

Table 1. Localities where spiders were collected. Sampling methods' abbreviations are: A – aspirator, F – forceps, LLS – leaf litter sifter, MT – moth trap, P – photo voucher, RSN – round sweep net.

Tabela 1. Lokacije vzorčenja pajkov. Kratice metod vzorčenja so: A – aspirator, F – pinceta, LLS – sejanje listne stelje, MT - past za nočne metulje, P - fotovaučer, RSN – okrogla lovilna vreča.

Tabela 1. Lokacije uzorkovanja pauka. Skraćenice metoda uzorkovanja su: A – aspirator, F – pinceta, LLS – sito za lišće, MT – klopka za moljce, P – foto vaučer, RSN – okrugla mreža za hvatanje.

Locality ID	Description of the Locality	Lat. Long.	Altitude m a.s.l.	Date	Sampling methods	Legit
NSW01	meadow; Ulog; Ulog; Kalinovik; Upper Neretva	43.416792°N 18.311152°E	651 m	2. 6. 2023 7. 6. 2023	F, A	N. Pajek Arambašič, Ž. Kuralt, A. Požrl
NSW02	river bank and riparian vegetation; Ulog; Ulog; Kalinovik; Upper Neretva	43.415693°N 18.314688°E	656 m	2. 6. 2023	F, A	N. Pajek Arambašič, Ž. Kuralt
NSW03	riparian forest; Neretva; Cerova; Kalinovik; Upper Neretva	43.37662°N 18.357438°E	692 m	3. 6. 2023	F, A	N. Pajek Arambašič, Ž. Kuralt
NSW04	forest; Jablanići; Ulog; Kalinovik; Upper Neretva	43.403599°N 18.333226°E	672 m	3. 6. 2023	LLS	N. Pajek Arambašič, Ž. Kuralt
NSW06	wet meadow; Kladopoljsko jezero; Obalj; Kalinovik; Upper Neretva	43.4169175°N 18.4265456°E	1388 m	2. 6. 2023	P	N. Pajek Arambašič, Ž. Kuralt
NSW07	wet meadow; Ulog; Ulog; Kalinovik; Upper Neretva	43.417381°N 18.310999°E	644 m	4. 6. 2023	RSN	N. Pajek Arambašič, Ž. Kuralt
NSW08	gravel bar; Nedavić; Nedavić; Kalinovik; Upper Neretva	43.460237°N 18.321882°E	607 m	4. 6. 2023	F, A	M. Zagmajster, E. Premate, A. Požrl, L. Trebše, T. Kepic
NSW09	meadow; Biograd; Nevesinje; Nevesinje; Nevesinjsko polje	43.1856583°N 18.1206417°E	835 m	5. 6. 2023	F, A, RSN	N. Pajek Arambašič, Ž. Kuralt
NSW10	cave; Vranjača; Biograd; Nevesinje; Nevesinjsko polje	43.1862556°N 18.1152972°E	820 m	5. 6. 2023	F, A	N. Pajek Arambašič, Ž. Kuralt
NSW11	river bank and riparian vegetation; Strujevina; Nevesinje; Nevesinje; Nevesinjsko polje	43.20111°N 18.13361°E	857 m	5. 6. 2023	F, A	N. Pajek Arambašič, Ž. Kuralt
NSW12	bog; Sopilja; Nevesinje; Nevesinje; Nevesinjsko polje	43.3013083°N 18.1175361°E	841 m	5. 6. 2023	F, A, RSN	N. Pajek Arambašič, Ž. Kuralt
NSW13	forest; Obrnja; Ulog; Kalinovik; Upper Neretva	43.3906139°N 18.2767056°E	1210 m	5. 6. 2023	F, A, LLS	N. Pajek Arambašič, Ž. Kuralt
NSW14	meadow; Budisavlje; Grabovica; Nevesinje; Nevesinjsko polje	43.219947°N 18.228212°E	855 m	5. 6. 2023	MT	N. Pajek Arambašič, Ž. Kuralt
NSW15	cave; Čašica ; Tmuše; Kalinovik; Upper Neretva	43.441546°N 18.326585°E	1072 m	5. 6. 2023	F, A	N. Pajek Arambašič, Ž. Kuralt
NSW16	gravel bar; Trešnjevica; Ulog; Kalinovik; Upper Neretva	43.44222°N 18.3067°E	634 m	6. 6. 2023	F, A	N. Pajek Arambašič, Ž. Kuralt
NSW17	meadow; Jezero; Ulog; Kalinovik; Upper Neretva	43.41734°N 18.28943°E	820 m	6. 6. 2023	F, A	A. Požrl

Table 2. Species list of the examined spiders. New records for the fauna of Bosnia and Herzegovina are marked with an asterisk. For abbreviations of localities, see Tab. 1. Numbers next to gender symbols refer to the number of collected individuals.

Tabela 2. Seznam zabeleženih vrst pajkov. Prve najdbe za Bosno in Hercegovino so označene z zvezdico. Natančen opis lokalitet je v Tab. 1. V oklepajih je navedeno število in spol ujetih in določenih pajkov.

Tabela 2. Lista vrsta istraživanih pauka. Novi nalazi za Bosnu i Hercegovinu označeni su zvjezdicom. Detaljan opis lokaliteta dat je u Tab. 1. Brojevi pored simbola pola odnose se na broj sakupljenih jedinki.

No.	Family / Species	Localities
	AGELENIDAE	
1	**Eratigena agrestis* (Walckenaer, 1802)	NSW09 (1 ♀)
2	**Histopona torpida* (C. L. Koch, 1837)	NSW02 (1 ♀, 1 ♂)
	AMAUROBIIDAE	
3	**Amaurobius jugorum* L. Koch, 1868	NSW04 (1 ♀)
	ANYPHAENIDAE	
4	*Anyphaena accentuata* (Walckenaer, 1802)	NSW02 (2 ♀, 2 ♂), NSW03 (1 ♂), NSW16 (1 ♀)
	ARANEIDAE	
5	*Aculepeira ceropegia* (Walckenaer, 1802)	NSW12 (1 ♂)
6	**Araneus triguttatus* (Fabricius, 1775)	NSW01 (1 ♂)
7	**Cyclosa conica* (Pallas, 1772)	NSW09 (1 ♀)
8	**Mangora acalypha* (Walckenaer, 1802)	NSW07 (1 ♀, 3 ♂), NSW09 (2 ♀, 1 ♂), NSW12 (1 ♀)
9	*Nuctenea umbratica* (Clerck, 1757)	NSW01 (1 juv)
10	*Zilla diodia* (Walckenaer, 1802)	NSW09 (1 ♀)
	CLUBIONIDAE	
11	**Clubiona similis* L. Koch, 1867	NSW02 (2 ♀)
	DICTYNIDAE	
12	**Brigittea civica* (Lucas, 1848)	NSW12 (2 ♀)
13	**Brigittea latens* (Fabricius, 1775)	NSW07 (1 ♀)
14	*Dictyna uncinata* Thorell, 1856	NSW07 (1 ♀)
	DYSDERIDAE	
15	**Harpactea lepida* (C. L. Koch, 1838)	NSW13 (1 ♂)
16	*Parastalita stygia* (Joseph, 1882)	NSW10 (1 ♂)
	GNAPHOSIDAE	
17	**Callilepis nocturna* (Linnaeus, 1758)	NSW09 (1 ♀)
18	**Callilepis schuszteri* (Herman, 1879)	NSW02 (1 ♀)
19	*Drassodes lapidosus* (Walckenaer, 1802)	NSW01 (1 ♂), NSW02 (2 ♀, 2 ♂), NSW09 (2 ♂)
20	**Drassyllus villicus* (Thorell, 1875)	NSW02 (1 ♀, 1 ♂), NSW03 (1 ♀, 1 ♂), NSW04 (2 ♀)
21	**Haplodrassus signifer* (C. L. Koch, 1839)	NSW02 (1 ♀)
	LINYPHIIDAE	
22	**Agyneta rurestris* (C. L. Koch, 1836)	NSW11 (1 ♀)
23	**Crosbyarachne silvestris* (Georgescu, 1973)	NSW13 (1 ♀)
24	*Diplocephalus cristatus* (Blackwall, 1833)	NSW10 (1 ♀)
25	*Frontinellina frutetorum* (C. L. Koch, 1835)	NSW01 (1 ♀)
26	*Lepthyphantes leprosus* (Ohlert, 1865)	NSW10 (1 ♀, 1 ♂), NSW13 (3 ♀)
27	**Microneta viaria* (Blackwall, 1841)	NSW03 (1 ♀), NSW13 (3 ♀)

No.	Family / Species	Localities
28	**Midia midas* (Simon, 1884)	NSW13 (1 ♀)
29	**Oedothorax agrestis* (Blackwall, 1853)	NSW03 (4 ♀)
30	**Oedothorax apicatus* (Blackwall, 1850)	NSW02 (1 ♀)
31	*Porrhomma convexum* (Westring, 1851)	NSW10 (2 ♀, 1 ♂)
32	**Sauron rayi* (Simon, 1882)	NSW04 (1 ♀)
33	*Tenuiphantes flavipes* (Blackwall, 1854)	NSW02 (1 ♀), NSW03 (5 ♀), NSW13 (1 ♀)
34	**Trichoncus affinis* Kulczyński, 1894	NSW02 (1 ♀)
35	**Trichopterna cito* (O. Pickard-Cambridge, 1873)	NSW10 (1 ♀)
36	**Walckenaeria monoceros* (Wider, 1834)	NSW13 (1 ♀)
	LYCOSIDAE	
37	**Alopecosa pulverulenta* (Clerck, 1757)	NSW09 (2 ♀)
38	**Arctosa leopardus* (Sundevall, 1833)	NSW11 (1 ♀)
39	*Arctosa maculata* (Hahn, 1822)	NSW02 (1 ♂)
40	**Pardosa agrestis* (Westring, 1861)	NSW07 (1 ♀)
41	**Pardosa alacris* (C. L. Koch, 1833)	NSW03 (1 ♀), NSW09 (3 ♀, 2 ♂)
42	*Pardosa amentata* (Clerck, 1757)	NSW03 (2 ♀), NSW07 (1 ♀)
43	*Pardosa hortensis* (Thorell, 1872)	NSW02 (5 ♀), NSW04 (1 ♀), NSW07 (1 ♀, 2 ♂), NSW09 (5 ♀)
44	*Pardosa lugubris* (Walckenaer, 1802)	NSW02 (2 ♀), NSW03 (3 ♀, 2 ♂), NSW04 (4 ♀), NSW09 (3 ♀, 2 ♂)
45	*Pardosa morosa* (L. Koch, 1870)	NSW02 (3 ♀), NSW03 (2 ♀)
46	**Pardosa prativaga* (L. Koch, 1870)	NSW11 (1 ♀), NSW12 (1 ♀)
47	**Pardosa proxima* (C. L. Koch, 1847)	NSW11 (1 ♀)
48	**Pardosa atomaria* (C. L. Koch, 1847)	NSW12 (2 ♂)
49	**Pirata piraticus* (Clerck, 1757)	NSW12 (2 ♀)
50	**Piratula knorri* (Scopoli, 1763)	NSW02 (1 ♀, 2 ♂), NSW03 (5 ♀, 7 ♂), NSW08 (1 ♀)
51	**Trochosa ruricola* (De Geer, 1778)	NSW01 (1 ♀)
	NESTICIDAE	
52	*Nesticus cellulanus* (Clerck, 1757)	NSW02 (1 ♀)
	OXYOPIDAE	
53	**Oxyopes heterophthalmus* (Latreille, 1804)	NSW12 (1 ♂)
	PHILODROMIDAE	
54	*Philodromus aureolus* (Clerck, 1757)	NSW01 (1 ♂)
55	**Philodromus margaritus* (Clerck, 1757)	NSW11 (1 ♂)
	PHRUROLITHIDAE	
56	**Phrurolithus festivus* (C. L. Koch, 1835)	NSW02 (1 ♀), NSW04 (1 ♂)
57	**Phrurolithus minimus* C. L. Koch, 1839	NSW02 (1 ♀, 2 ♂)
	PISAURIDAE	
58	*Pisaura mirabilis* (Clerck, 1757)	NSW07 (1 ♀, 1 ♂), NSW09 (1 ♂), NSW12 (1 ♀)
	SALTICIDAE	
59	**Attulus rupicola* (C. L. Koch, 1837)	NSW02 (4 ♀)
60	**Carrhotus xanthogramma* (Latreille, 1819)	NSW03 (1 ♂)
61	**Chalocoscirtus infimus* (Simon, 1868)	NSW09 (3 ♂)

No.	Family / Species	Localities
62	**Euophrys frontalis* (Walckenaer, 1802)	NSW09 (1 ♂)
63	*Evarcha arcuata* (Clerck, 1757)	NSW09 (1 ♀, 3 ♂), NSW12 (2 ♂)
64	*Evarcha falcata* (Clerck, 1757)	NSW09 (1 ♂)
66	**Heliophanus dubius* C. L. Koch, 1835	NSW09 (1 ♀)
66	*Heliophanus flavipes* (Hahn, 1832)	NSW09 (2 ♂)
67	**Heliophanus patagiatus* Thorell, 1875	NSW01 (1 ♂)
68	**Neon reticulatus* (Blackwall, 1853)	NSW03 (1 ♀)
69	*Philaeus chrysops* (Poda, 1761)	NSW06 (1 ♂), NSW09 (1 ♀, 1 ♂)
	SPARASSIDAE	
70	*Micrommata virescens* (Clerck, 1757)	NSW05 (1 ♀), NSW12 (1 ♂)
	TETRAGNATHIDAE	
71	*Meta menardi* (Latreille, 1804)	NSW10 (1 ♀)
72	**Metellina mengei* (Blackwall, 1869)	NSW03 1 ♂), NSW07 (1 ♀)
73	*Metellina merianae* (Scopoli, 1763)	NSW02 (1 ♀, 1 ♂), NSW03 (2 ♀)
74	*Tetragnatha extensa* (Linnaeus, 1758)	NSW07 (1 ♂)
	THERIDIIDAE	
75	**Crustulina guttata* (Wider, 1834)	NSW04 (1 ♀)
76	**Euryopis flavomaculata* (C. L. Koch, 1836)	NSW02 (1 ♀, 2 ♂), NSW03 (1 ♂), NSW04 (2 ♀)
	THOMISIDAE	
77	**Diaea livens* Simon, 1876	NSW07 (1 ♂)
78	*Misumena vatia* (Clerck, 1757)	NSW17 (1 ♀)
79	*Ozyptila praticola* (C. L. Koch, 1837)	NSW03 (2 ♂)
80	**Pistius truncatus* (Pallas, 1772)	NSW07 (1 ♂)
81	*Synema globosum* (Fabricius, 1775)	NSW07 (7 ♀)
82	*Thomisus onustus* Walckenaer, 1805	NSW09 (1 ♂)
83	*Tmarus piger* (Walckenaer, 1802)	NSW07 (1 ♀)
84	*Xysticus kochi* Thorell, 1872	NSW01 (1 ♀), NSW07 (4 ♀, 2 ♂), NSW09 (1 ♂), NSW12 (1 ♂)

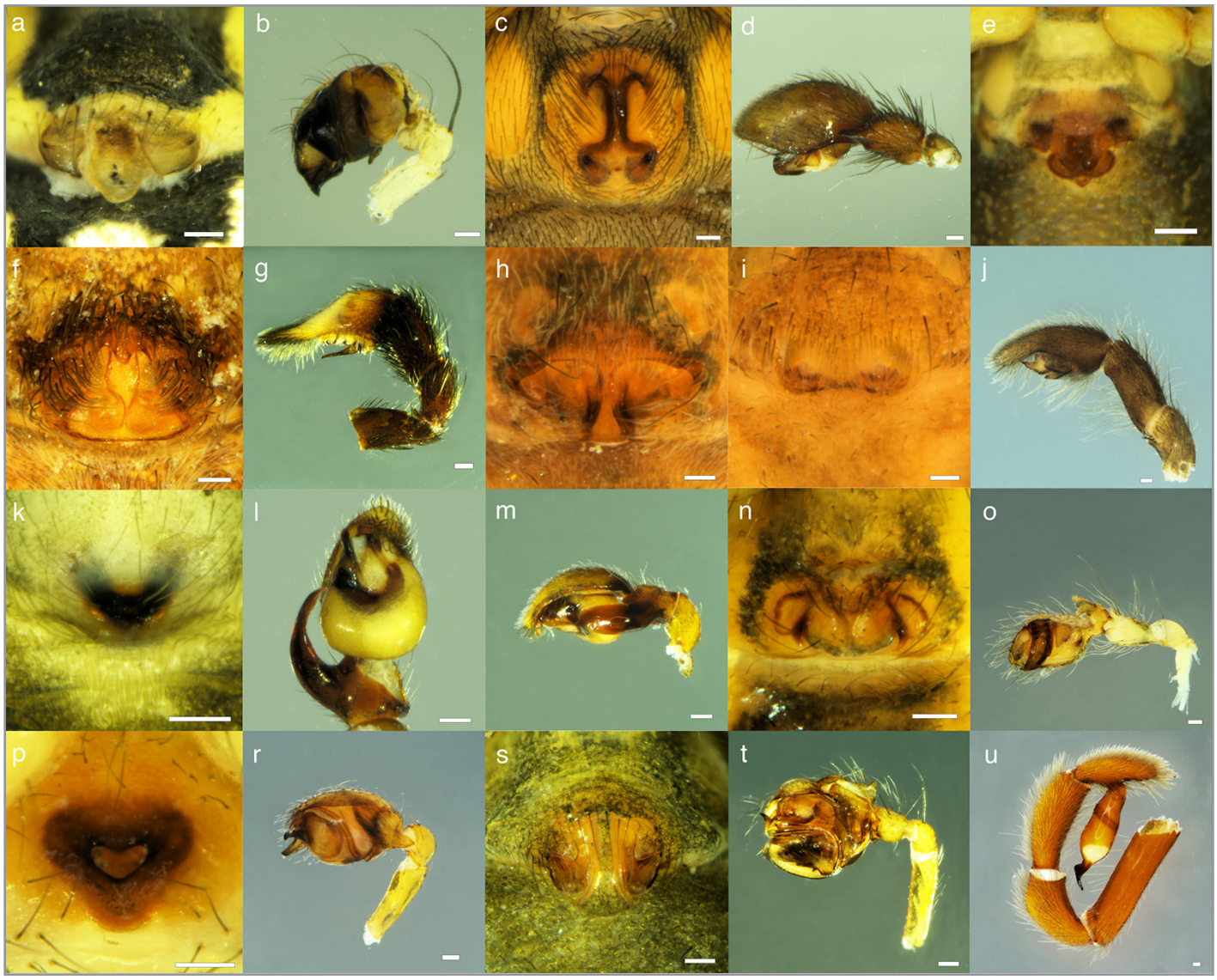

Figure 2. Ventral views of epiginae and lateral views of right pedipalps of selected species. *Mangora acalypha* epigyne (a) and pedipalp (b), *Drassyllus villicus* epigyne (c) and pedipalp (d), *Microneta viaria* epigyne (e), *Pardosa alacris* epigyne (f) and pedipalp (g), *Pardosa prativaga* epigyne (h), *Piratula knorri* epigyne (i) and pedipalp (j), *Phrurolitus festivus* epigyne (k) and pedipalp – ventral view (l), and pedipalp – lateral view (m), *Metellina mengei* epigyne (n) and pedipalp (o), *Euryops flavomaculata* epigyne (p) and pedipalp (r), *Lephtyphantes leprosus* epigyne (s) and pedipalp (t), and *Parastalita stygia* pedipalp (u). (Scale bars represent 100 µm).

Slika 2. Ventralni pogledi na epigine in lateralni pogledi na desne pedipalpe izbranih vrst. *Mangora acalypha* epigina (a) in pedipalp (b), *Drassyllus villicus* epigina (c) in pedipalp (d), *Microneta viaria* epigina (e), *Pardosa alacris* epigina (f) in pedipalp (g), *Pardosa prativaga* epigina (h), *Piratula knorri* epigina (i) in pedipalp (j), *Phrurolithus festivus* epigina (k) in pedipalp – ventralni pogled (l), ter pedipalp – lateralni pogled (m), *Metellina mengei* epigina (n) in pedipalp (o), *Euryopis flavomaculata* epigina (p) in pedipalp (r), *Lepthyphantes leprosus* epigina (s) in pedipalp (t) ter *Parastalita stygia* pedipalp (u). (Merila predstavljajo 100 µm).

Slika 2. Ventralni prikazi epigina i bočni prikazi desnih pedipalpa odabranih vrsta. *Mangora acalypha* epigina (a) i pedipalp (b), *Drassyllus villicus* epigina (c) i pedipalp (d), *Microneta viaria* epigina (e), *Pardosa alacris* epigina (f) i pedipalp (g), *Pardosa prativaga* epigina (h), *Piratula knorri* epigina (i) i pedipalp (j), *Phrurolithus festivus* epigina (k), pedipalp – ventralni prikaz (l) I pedipalp – bočni prikaz (m), *Metellina mengei* epigina (n) i pedipalp (o), *Euryopis flavomaculata* epigina (p) i pedipalp (r), *Lepthyphantes leprosus* epigina (s) i pedipalp (t) i *Parastalita stygia* pedipalp (u). (Skala predstavlja 100 µm).

Of these, 56 were collected in the Upper Neretva, and 37 in the Nevesinjsko polje and Vranjača cave. 50 (60%) of the identified spider species are new additions to araneofauna of BiH, which confirms the knowledge gap in the country and supports further faunistic research in the region.

Piratula knorri (Scopoli, 1763) (Figs. 2i, j) was among the more frequently encountered species along the Neretva River. This wandering spider from the Lycosidae (wolf spider) family is strongly associated with riparian habitats, where it exploits surface tension to run across water and may even dive to pursue prey. Its dependence on freshwater ecosystems makes it sensitive to habitat disturbance, which is reflected in its inclusion on the Red List of Slovenian spiders (Polenec 1992). Highlighting its presence in our survey underscores the ecological value and conservation relevance of intact riverine habitats in the region.

The visit to Vranjača cave proved to be very fruitful since, among others, we managed to collect *Leptyphantes leprosus* (Ohlert, 1865) (Figs. 2s, t), which is rarely found in natural habitats according to the Spiders of Europe portal (Nentwig et al. 2024). Moreover, we also collected *Parastalita stygia* (Joseph, 1882) (Fig. 2u), an eyeless Dysderid spider, endemic to the Dinaric region, in the cave.

These results are noteworthy, especially considering the short sampling period and unfavourable weather with daily showers. Spiders also differ in their annual cycles, meaning we missed spider species that reach adulthood in either early spring or late summer/early autumn. Long-term sampling throughout the year would yield even higher alpha diversity and uncover even more rare (possibly endangered) species.

The majority of species documented in this study represent taxa that are commonly found across Central and Southeastern Europe and are therefore expected to occur in Bosnia and Herzegovina. Their presence aligns well with these species' known distribution patterns and habitat preferences, particularly in temperate forest and grassland ecosystems typical of the region. While the assemblage reflects a largely expected faunal composition, the findings provide valuable baseline data for future biodiversity assessments and monitoring efforts.

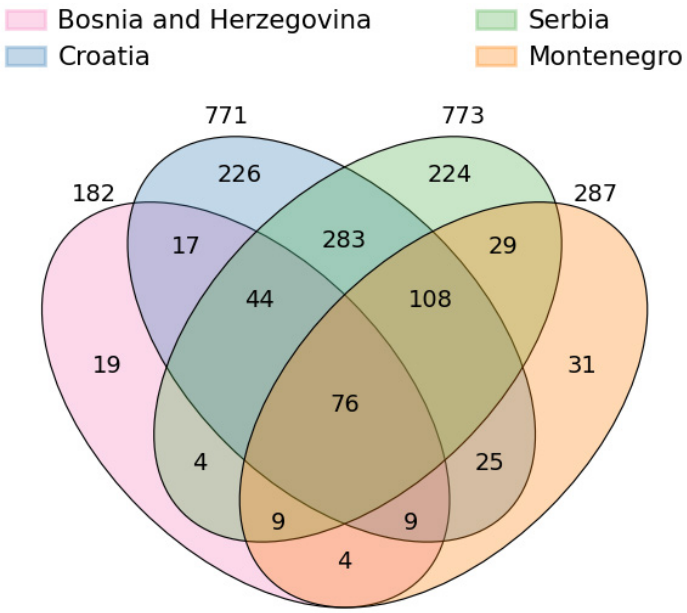

Figure 3. Venn diagram depicting comparison of spider species between Bosnia and Herzegovina and neighbouring countries according to Nentwig et al. (2024).

Slika 3. Vennov diagram števila vrst pajkov v Bosni in Hercegovini in v sosednjih državah po Nentwig et al. (2024).

Slika 3. Vennov dijagram broja vrsta pauka u Bosni i Hercegovini i susjednim zemljama prema Nentwigu et al. (2024).

POVZETEK

V okviru projekta Neretva Science Week 2023 smo raziskovali pajke ozemlja zgornjega toka reke Neretve in širše okolice, vključno z Nevesinjskim poljem in jamo Vranjača v Bosni in Hercegovini. Vzorčili smo na sedemnajstih lokacijah (Tab. 1), in ulovili ter določili 84 vrst pajkov, ki pripadajo 72 rodovom in 22 družinam pri čemer je bilo kar 60 odstotkov prvič zabeleženih v Bosni in Hercegovini (Tab. 2). Tako visok delež novih vrst za državo kaže na pomanjkljivo poznavanje favne pajkov v BiH in izpostavlja pomen tovrstnih raziskav na tem razmeroma neraziskanem območju. Primerjava s favno pajkov sosednjih držav kaže precejšnjo diskrepanco, saj imata Hrvaška in Srbija po več kot 770 zabeleženih vrst, medtem ko je število doslej zabeleženih vrst v Bosni in Hercegovini le 182 (Sl. 3), kar je glede na raznolikost habitata in podnebnih razmer presenetljivo nizko. Z dolgoročnimi raziskavami bi bi zagotovo zaznali večje število vrst, predvsem tistih, ki odraslost dosežejo v zgodnji pomladi ali pozno poleti in jeseni. Tovrstne raziskave bi prispevale k bolj podrobnemu vpogledu v vrstno sestavo in pestrost območja ter podprle bodoče naravovarstvene pobude in trajnostno upravljanje naravnih virov v Bosni in Hercegovini.

SAŽETAK

U okviru projekta Sedmica nauke Neretva 2023, istraživali smo pauke iz gornjeg toka rijeke Neretve i šireg okolnog područja, uključujući Nevesinjsko polje i pećinu Vranjaču u Bosni i Hercegovini. Uzorkovali smo na 17 lokacija (Tab. 1), te uhvatili i identifikovali 84 vrste pauka koje pripadaju 72 roda i 22 porodice, od kojih je 60 % prvi put zabilježeno u Bosni i Hercegovini (Tab. 2). Tako visok udio vrsta koje su nove u zemlji ukazuje na nedostatak znanja o fauni pauka u BiH i naglašava važnost takvih istraživanja u ovom relativno neistraženom području. Poređenje sa faunom pauka susjednih zemalja pokazuje značajnu razliku, jer Hrvatska i Srbija imaju po više od 770 zabilježenih vrsta, dok je broj do sada zabilježenih vrsta u Bosni i Hercegovini samo 182 (Sl. 3), što je iznenađujuće malo obzirom na raznolikost staništa i klimatskih uslova. Dugoročna istraživanja bi sigurno otkrila veći broj vrsta, posebno onih koje dostižu odraslu dob u rano proljeće ili kasno ljeto i jesen. Takva istraživanja bi doprinijela detaljnijem uvidu u sastav vrsta i raznolikost područja te podržala buduće inicijative za očuvanje prirode i održivo upravljanje prirodnim resursima u Bosni i Hercegovini.

ACKNOWLEDGMENTS

We would like to express our sincere gratitude to Manuela Habe and the members of the Speleo group including Maja Zagmajster, Ester Premate, Tinkara Kepic, Annasibila Požrl and Liza Trebše, for their invaluable assistance in collecting specimens from the field. We also wish to thank the organizers of the research expedition for their outstanding coordination and logistical support. Their dedication to facilitating biodiversity research in the Upper Neretva region was instrumental to the success of this project. The microscopic part of research was supported by the Slovenian Research Agency (ARRS) funding to »Infrastructural Center Microscopy of Biological Samples« (MRIC UL, I0-0022-0481-08), at Biotechnical Faculty, University of Ljubljana, Slovenia.

REFERENCES

Bauer T, Lemke M, Pantini P. 2020. *Xysticus brevidentatus* new to Bosnia and Herzegovina (Araneae: Thomisidae), with remarks on the habitat and distribution. Arachnologische Mitteilungen. 60(1): 34-37. https://doi.org/10.30963/aramit6007

Bosmans R. 2009. Revision of the genus *Zodarion* Walckenaer, 1833, part III. South East Europe and Turkey (Araneae: Zodariidae). Contributions to Natural History. 12(1): 211-295. https://doi.org/10.5169/seals-786968

Cardoso P, Pekár S, Jocqué R, Coddington JA. 2011. Global patterns of guild composition and functional diversity of spiders. PLoS One. 6(6): e21710. https://doi.org/10.1371/journal.pone.0021710

Castellucci F, Luchetti A, Scharff N. 2024. Enigmatic and extravagant genitalia in the spider genus *Mastigusa* (Araneae, Cybaeidae)–a taxonomic revision. Invertebrate Systematics. 38(3): IS23047. https://doi.org/10.1071/IS23047

[EEA] European Environment Agency. (2010). Europe's ecological backbone: Recognizing the true value of our mountains. EEA Report No 6/2010.

Foelix RF. 2011. Biology of Spiders (3rd edition). Oxford (UK): Oxford University Press.

Huber BA. 2022. Revisions of *Holocnemus* and *Crossopriza*: the spotted-leg clade of Smeringopinae (Araneae, Pholcidae). European Journal of Taxonomy. 795(1): 1-241. https://doi.org/10.5852/ejt.2022.795.1663

Huber BA, Pavlek M, Komnenov M. 2021. Revision of the spider genus *Stygopholcus* (Araneae, Pholcidae), endemic to the Balkan Peninsula. European Journal of Taxonomy. 752(1): 1-60. https://doi.org/10.5852/ejt.2021.752.1391

Komnenov M. 2009. Checklist of spiders (Araneae) of Bosnia and Herzegovina. Uzizaž i Biospeld. 5: 51-69.

Logunov DV. 2015. Taxonomic-faunistic notes on the jumping spiders of the Mediterranean (Aranei: Salticidae). Arthropoda selecta. 24(1): 33-85. https://doi.org/10.15298/arthsel.24.1.03

[MFTER] Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina. Strategy and action plan for protection of biological diversity in Bosnia and Herzegovina (2015-2020). Sarajevo: Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina; [accessed 30. 1. 2025]. https://www.cbd.int/doc/world/ba/ba-nbsap-v2-en.pdf

Naumova MV, Lazarov SP, Petrov BP, Deltshev CD. 2016. New faunistic data on the cave-dwelling spiders in the Balkan Peninsula (Araneae). Ecologica Montenegrina. 7: 425-438. https://doi.org/10.37828/em.2016.7.17

Nentwig W, Blick T, Bosmans R, Gloor D, Hänggi A, Kropf C. 2024. Spiders of Europe. Version 10.2024. Bern: Natural History Museum Bern; [accessed 25. 10. 2024]. https://doi.org/10.24436/1

Nikolić F, Polenec A. 1981. Catalogus faunae Jugoslaviae, III/4. Ljubljana: Consilium academiarum scientarum rei publicae socialisticae foederativae Jugoslaviae.

Oger P. 2023. Les araignées de Belgique et de France; [accessed 7. 6. 2023]. http://arachno.piwigo.com/

Polenec, A., 1992. Rdeči seznam ogroženih pajkov (Aranea) Slovenije. Varstvo narave. 17: 173-176.

Roberts MJ. 1995. Collins Field Guide. Spiders of Britain & Northern Europe. London (GB): HarperCollins Publishers Ltd.

Russi D, ten Brink P, Farmer A, Badura T, Coates D, Förster J, Kumar R, Davidson N. 2013. The economics of ecosystems and biodiversity for water and wetlands. London and Brussels: IEEP; Gland: Ramsar Secretariat.

Stanković M, Ćurčić M. 2020. New species in the arachnofauna of Bosnia and Herzegovina from the protected habitat of Gromiželj, Velino selo. Arhiv za tehničke nauke 22(1): 67-78. https://doi.org/10.7251/afts.2020.1222.067S

Wise DH. 1995. Spiders in ecological webs. Cambridge (UK): Cambridge University Press.

[WSC] World Spider Catalog. 2024. World Spider Catalog. Version 25.5. Bern: Natural History Museum Bern; [accessed 25. 10. 2024]. https://doi.org/10.24436/2

Wunderlich J. 2011. On extant West-Palearctic (mainly Southern European) spiders (Araneae) of various families, with new descriptions. Beiträge zur Araneologie. 6: 158-338.

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v katerem koli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 123–127
»Neretva Science Week 2023«

KRATKA ZNANSTVENA VEST /
SHORT COMMUNICATION

DOI: 10.14720/ns.19816
Objavljeno na spletu / Published online: 14. 11. 2025

Prejeto / Received: 17. 9. 2024
Sprejeto / Accepted: 9. 2. 2025

Additional notes on aquatic Coleoptera of the Upper Neretva River catchment and Zalomka River

Michaela BROJER

2nd Zoological Department (Entomology),
Natural History Museum Vienna, Burgring 7,
1010 Vienna, Austria;
Email: michaela.brojer@nhm.at

KEY WORDS:
water beetles, *Hydraena bosnica*, *Prionocyphon serricornis*, intermittent river

KLJUČNE BESEDE:
vodni hrošči, *Hydraena bosnica*, *Prionocyphon serricornis*, presihajoča reka

KLJUČNE RIJEČI:
vodeni tvrdokrilci, *Hydraena bosnica*, *Prionocyphon serricornis*, povremeni tok

ABSTRACT

As a follow-up to the investigation of the water beetle fauna of the upper course of the Neretva River in 2022, during the second »Neretva Science Week« in June 2023, additional tributaries were sampled and the presence of the endemic Bosnian species *Hydraena bosnica* has been confirmed (male specimens were collected). Additionally, three springs located at the slopes of the Neretva Valley were examined. Zalomka River exhibited an entirely different water beetle assemblage in comparison to that of the Neretva River and its tributaries, resulting from its intermittent character.

IZVLEČEK

Dodatne informacije o vodnih hroščih povodja gornje Neretve in reke Zalomke

Kot nadaljevanje raziskovanja favne vodnih hroščev zgornjega toka reke Neretve v letu 2022 smo na drugem »Tednu znanosti Neretva« junija 2023 vzorčili dodatne pritoke. Potrdili smo prisotnost bosanske endemične vrste *Hydraena bosnica* (moški osebki). Poleg tega smo povzorčili tri izvire na obronkih doline Neretve. Reka Zalomka ima popolnoma drugačno združbo vodnih hroščev kot Neretva s pritoki, kar je posledica njenega presihajočega značaja.

APSTRAKT

Dodatne informacije o vodenim tvrdokrilcima sliva gornje Neretve i rijeke Zalomke

Kao nastavak istraživanja faune vodenih insekata gornjeg toka rijeke Neretve započetog 2022. godine, istraživanje je nastavljeno tokom Druge sedmice nauke (jun 2023. godine). Prikupljani su uzorci sa novih lokaliteta i potvrđeno je prisustvo bosanskohercegovačke endemske vrste *Hydraena bosnica* (muški primjerci). Uz to, prikupljeni su uzorci sa još tri izvora sa padina iznad rijeke Neretve. Rijeka Zalomka ima potpuno drugačiju zajednicu vodenih insekata od rijeke Neretve i njenih pritoka, što je rezultat njenog povremenog toka.

INTRODUCTION

With 55 species belonging to 11 families collected in summer 2022 it was already shown that the upper course of the Neretva River exhibits a species-rich water beetle assemblage, including Balkan endemics and rarely collected species – most probably resulting from the presence of different kinds of habitats present along the naturally flowing river (Brojer 2023).

During the 2023 edition of Science Week (see acknowledgment) additional localities were sampled for further investigation of biodiversity in this area. This paper presents the results of a follow-up water beetle survey after the one carried out during the Neretva Science Week in 2022.

MATERIAL AND METHODS

During the second Science Week in June 2023 five different tributaries in the upper course of the Neretva River (Jezernica, Tuniski Potok, Međeđak, Krupac, small tributary to Krupac stream), some additional springs, special habitats on the slopes of the Neretva Valley, and two localities along the Zalomka River, an intermittent karstic river in Nevesinjsko Polje, were examined (Tab. 1). Samples were collected by the author following the same procedure as described in Brojer (2023) – qualitative sampling at different habitats by using a hand net (mesh width 500 µm). Additional material was provided by other participants of the Science Week (Tab. 1).

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

Table 1. Sampling localities at Neretva tributaries (trib.), Neretva Valley (NV) and Zalomka River (Z), including their codes, GPS coordinates in WGS 84 system (latitude/longitude), altitude, sampling dates, and the names of collectors (Leg.): Thea Schwingshackl (TS), Jan Martini (JM), Anna Katharina Lau (AKL), Michaela Brojer (MB).

Tabela 1. Lokacije vzorčenja na pritokih Neretve (trib.), v dolini Neretve (NV) in na reki Zalomki (Z), vključno s kodami lokacij, GPS koordinatami v WGS84 koordinatnem sistemu (dolžina/širina), nadmorskimi višinami, datumi vzorčenja in imeni legatorjev (Leg.): Thea Schwingshackl (TS), Jan Martini (JM), Anna Katharina Lau (AKL), Michaela Brojer (MB).

Tabela 1. Lokacije prikupljenih uzoraka na pritokama Neretve (trib.), u dolini Neretve (NV) i na rijeci Zalomki (Z), uključujući lokacijske kodove, GPS koordinate u WGS84 koordinatnom sistemu (dužina/širina), nadmorske visine, datume uzorkovanja i imena legatora (Leg.): Thea Schwingshackl (TS), Jan Martini (JM), Anna Katharina Lau (AKL), Michaela Brojer (MB).

Locality name	Locality code	Lat/Long	Altitude (m)	Date of sampling	Leg.
Jezernica (trib.)	Jez	43.41376/18.28550	750	4. 6. 2023	MB
Tuniski Potok (trib.)	Tun	43.37112/18.3756	770	3./6. 6. 2023	JM/MB
Međeđak (trib.)	Među	43.34271/18.35990	1060	6. 6. 2023	AKL & JM
Krupac (trib.)	Kru	43.33092/18.42894	805	6. 6. 2023	MB
Krupac trib. (trib.)	tKru	43.33584/18.43431	880	5. 6. 2023	JM
Spring 1 (NV)	Spr1	43.37372/18.40079	1290	6. 6. 2023	MB
Spring 2 (NV)	Spr2	43.37538/18.40227	1350	6. 6. 2023	MB
Spring 3 (NV)	Spr3	43.37685/18.40156	1350	5./6. 6. 2023	TS/MB
Old tree (NV)	Ot	43.36918/18.39174	1070	6. 6. 2023	MB & TS
Meander (Z)	Zal1	43.18739/18.15707	825	5. 6. 2023	MB
Sink hole (Z)	Zal2	43.18265/18.12494	675	5. 6. 2023	MB

RESULTS AND DISCUSSION

Within the tributaries of the upper course of Neretva at three out of five localities (Međeđak (Fig. 1), Krupac, and a small tributary to Krupac stream) (Tab. 2) male specimens of *Hydraena bosnica* Apfelbeck, 1909 (Fig. 2) were collected. Thus, the presence of this Bosnian and Herzegovinian endemic species, only known from the south-eastern part of the country (Mičetić Stanković & Jäch 2012), has been confirmed for this area, especially in small streams of the Neretva Valley. In 2022 only female specimens were collected and therefore could not be determined to species level without any doubt (Brojer 2023). Additional species found at these localities are already reported from the samples of the previous year.

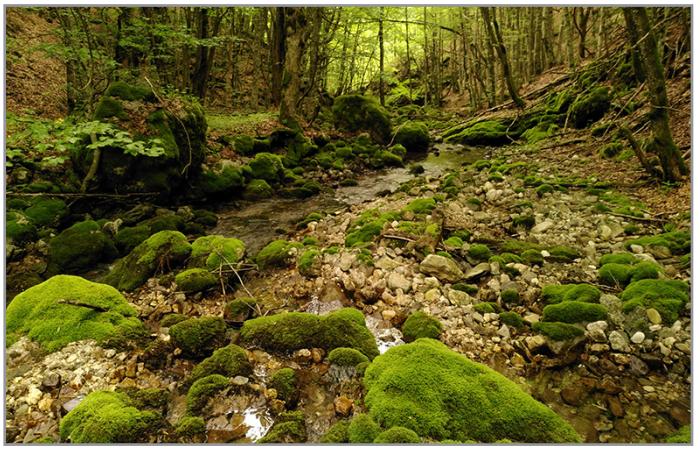

Figure 1. Međeđak stream. Photo: Gabriel Singer.

Slika1. Potok Međeđak. Foto: Gabriel Singer.

Slika 1. Potok Međeđak. Foto: Gabriel Singer.

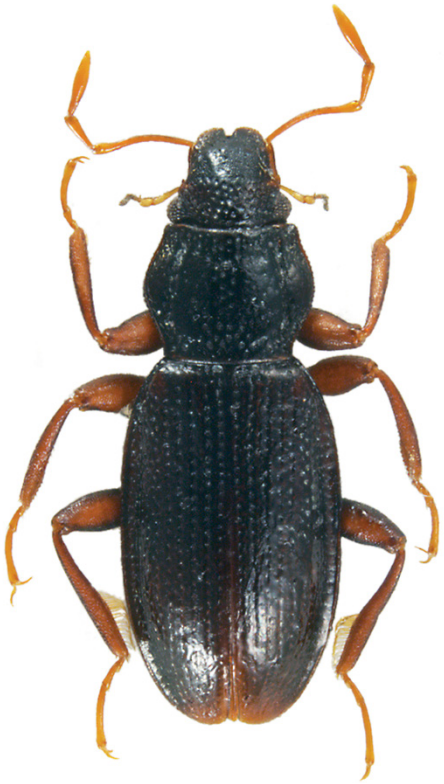

Figure 2. Habitus photograph of a male specimen of *Hydraena bosnica*. Photo: Michaela Brojer.

Slika2. Fotografija habitusa samca *Hydraena bosnica*. Foto: Michaela Brojer.

Slika 2. Fotografija muške jedinke *Hydraena bosnica*. Foto: Michaela Brojer.

With the larvae of *Eubria palustris* (Germar, 1818), the examination of three springs led to the finding of an additional water beetle family, Psephenidae, not previously registered during Science Week 2022. Another noteworthy finding is the rather rarely collected species *Prionocyphon serricornis* (Müller, 1821) (Scirtidae) with larvae requiring highly specialized phytotelmatic habitats such as water-filled cavities in hollow deciduous trees and stumps (Klausnitzer 2009).

At Zalomka River, an intermittent karstic river, the most striking result of the survey is the dominance of water beetles indicated as rheotolerant or even stagnobiont and the total absence of rheobiont or rheophilic species (such as Elmidae and Hydraenidae) (Hebauer 1986, 1994; Pakulnicka & Nowakowski 2012). Most specimens were collected at a calm area at the edge of a large meander (Fig. 3), where a remnant pool very likely forms during the dry phase of the river. No beetle specimen was collected directly in the river channel. Overall, Zalomka River shows a completely different species assemblage (Tab. 2) compared to the sampling localities at the tributaries to Neretva. This reflects the intermittent character of this river, resulting in a very different species assemblage in comparison to that of the Upper Neretva River (Brojer 2023). A similar water beetle assemblage was reported from Rimanić stream in Montenegro (Pavićević & Pešić 2012).

Figure 3. Meander at Zalomka River (Zal1). Photo: Michaela Brojer.
Slika3. Meander reke Zalomke (Zal1). Foto: Michaela Brojer.
Slika 3. Meandar rijeke Zalomka (Zal1). Foto: Michaela Brojer.

Table 2. Species of aquatic Coleoptera at Neretva tributaries, Neretva Valley and Zalomka River (L = Larva).
Tabela 2. Vrste vodnih hroščev v pritokih Neretve, v dolini Neretve in v Zalomki.
Tabela 2. Vrste vodenih tvrdokrilaca u pritokama rijeke Neretve, u dolini Neretve i u Zalomki.

Species	Neretva tributaries					Neretva Valley				Zalomka River	
	Jez	Tun	Med	Kru	tKru	Spr1	Spr2	Spr3	Ot	Zal1	Zal2
DYTISCIDAE											
Agabus guttatus (Paykull, 1798)										●	
Hydroporus cf. *lucasi* Reiche in Marseul, 1866 (♀)										●	
Hydroporus foveolatus (Heer, 1840)										●	
Laccophilus hyalinus (De Geer, 1774)											●
Scarodytes halensis (Fabricius, 1787)											●
HYDRAENIDAE											
Hydraena bosnica Apfelbeck, 1909			●	●	●						
Hydraena morio Kiesenwetter, 1849		●	●	●	●						
Hydraena nigrita Germar, 1824	●										
Hydraena subintegra Ganglbauer, 1901			●	●	●						
HELOPHORIDAE											
Helophorus sp. 1										●	●
Helophorus sp. 2										●	●
Helophorus sp. 3										●	
Helophorus sp. 4										●	

Species	Neretva tributaries					Neretva Valley				Zalomka River	
	Jez	Tun	Međ	Kru	tKru	Spr1	Spr2	Spr3	Ot	Zal1	Zal2
HYDROPHILIDAE											
Anacaena lutestens (Stephens, 1829)										●	
Helochares lividus (Forster, 1771)											●
Hydrobius fuscipes (Linnaeus, 1758)										●	●
SCIRTIDAE											
Elodes sp. (L)					●			●			
Hydrocyphon sp. (L)					●						
Prionocyphon serricornis (Müller, 1821) (L)									●		
ELMIDAE											
Elmis bosnica (Zaitzev, 1908)			●								
Elmis rioloides (Müller, 1806)			●								
Esolus angustatus (Müller, 1821)	●		●	●							
PSEPHENIDAE											
Eubria palustris (Germar, 1818) (L)								●			

POVZETEK

V drugem »Tednu znanosti na Neretvi« v juniju 2023 je bilo pregledanih pet različnih pritokov v zgornjem toku reke Neretve (Jezernica, Tuniški potok, Međeđak, Krupac, manjši pritok potoka Krupac) ter dodatno izviri in posebni habitati na pobočjih doline Neretve in dveh lokacijah ob reki Zalomki, presihajoči kraški reki na Nevesinjskem polju. Pri Međeđaku, Krupcu in manjšem pritoku potoka Krupac smo z najdenimi moškimi osebki potrdili prisotnost *Hydraena bosnica* Apfelbeck, 1909, bosansko-hercegovske endemične vrste, ki je za to območje znana le v jugovzhodnem delu države.

Ostale najdene vrste so bile za to območje potrjene že tekom Tedna znanosti 2022. Pri reki Zalomki je najbolj presenetljiv rezultat prevlada reotolerantnih ali celo stagnobiontnih vodnih hroščev, in popolna odsotnost reobiontnih ali reofilnih vrst (kot so Elmidae in Hydraenidae). Največ primerkov je bilo zbranih na območju umirjenega toka na robu velikega meandra, ki v sušni fazi najverjetneje tvori tolmun. Na splošno reka Zalomka kaže popolnoma drugačno združbo vrst v primerjavi z zgornjim tokom Neretve in njenih pritokov, kar lahko pojasnimo s presihajočim značajem te reke.

V izvirih smo našli dodatno družino vodnih hroščev, Psephenidae, ki ni bila zaznana med Tednom znanosti 2022. Druga omembe vredna najdba je redko nabrana vrsta *Prionocyphon serricornis* (Müller, 1821) (Scirtidae). Ličinke te vrste potrebujejo zelo specializirane fitotelmatske habitate, kot so z vodo napolnjene votline v votlih listavcih in štorih.

SAŽETAK

Tokom druge »Sedmice nauke na Neretvi« u junu 2023. godine istraženo je pet različitih pritoka gornjeg toka rijeke Neretve (Jezernica, Tuniški potok, Međeđak, Krupac i manja pritoka potoka Krupac), kao i izvori i posebna staništa na padinama doline Neretve i dva lokaliteta uz rijeku Zalomku, kraške ponirnice u Nevesinjskom polju. Na Međeđaku, Krupcu i manjoj pritoci potoka Krupac potvrđeno je prisustvo muških jedinki *Hydraena bosnica* Apfelbeck, 1909, bosanskohercegovačke endemske vrste, koja je za ovo područje poznata samo u jugoistočnom dijelu zemlje.

Ostale pronađene vrste već su potvrđene za ovo područje tokom Sedmice nauke 2022. U rijeci Zalomci, iznenađujući rezultat je dominacija vodenih tvrdokrilaca poznatih kao reotolerantne ili čak stagnobiontske, te potpuno odsustvo reobiontskih ili reofilnih vrsta (kao što su Elmidae i Hydraenidae). Najveći broj primjeraka sakupljen je u području mirnog toka na rubu velikog meandra, koji najvjerovatnije izgleda kao bazen u sušnoj fazi. Generalno, rijeka Zalomka pokazuje potpuno drugačiji sastav vrsta u odnosu na gornji tok Neretve i njenih pritoka, što se može objasniti povremenim tokom ove rijeke.

Istraživanje izvora dovelo nas je do otkrića nove porodice vodenih insekata, Psephenidae, koja nije potvrđena tokom Sedmice nauke 2022. Još jedan nalaz vrijedan pažnje je rijetko uzorkovana vrsta *Prionocyphon serricornis* (Müller, 1821) (Scirtidae), čije larve zahtijevaju veoma specifična fitotelmatska staništa, kao što su šupljine ispunjene vodom u dupljama listopadnih stabala i panjeva.

ACKNOWLEDGEMENTS

Financial support for this work was provided by Riverwatch (www.riverwatch.eu) and EuroNatur (www.euronatur.org). The Neretva Science Week is part of the Scientists for Balkan Rivers project within the Save the Blue Heart of Europe campaign (www.balkanrivers.net) that is financially supported by MAVA Foundation and the Manfred-Hermsen Stiftung (www.m-h-s.org). Specimens were collected under permit number (04/2-19-2-293/23) kindly issued by the Federal Ministry of Environment and Tourism (Federation of Bosnia and Herzegovina) and permit number (07/1.30/625-385/23) by the Ministry of Culture and Education (Republic of Srpska). Additionally, the author wants to thank Jan Martini, Anna Katharina Lau and Thea Schwingshackl (all of them University of Innsbruck) for providing specimens of aquatic Coleoptera from their samples and Helena Shaverdo (Natural History Museum Vienna) for the determination of Dytiscidae.

REFERENCES

Brojer M. 2023. Contribution to the knowledge of water beetles sensu lato (Coleoptera) from the upper course of Neretva River in Bosnia and Herzegovina. Natura Sloveniae 25(3): 43-60. https://doi.org/10.14720/ns.25.3.43-60

Hebauer F. 1986. Käfer als Bioindikatoren – dargestellt am Ökosystem Bergbach. Laufener Seminarbeiträge 7/83: 55-65.

Hebauer F. 1994. Entwurf einer Entomosoziologie aquatischer Coleoptera in Mitteleuropa (Insecta, Coleoptera, Hydradephaga, Hydrophiloidea, Dryopoidea). Lauterbornia. 19: 43-57.

Klausnitzer B. 2009. Insecta: Coleoptera: Scirtidae. Heidelberg: Spektrum Akademischer Verlag. (Süßwasserfauna von Mitteleuropa; vol. 20/17). https://doi.org/10.1007/978-3-8274-2187-6

Mičetić Stanković V, Jäch MA. 2012. Description of a new species of the »Haenydra« lineage (Coleoptera: Hydraenidae) from the Republic of Macedonia. Zootaxa. 3503: 82-88. https://doi.org/10.11646/zootaxa.3503.1.6

Pakulnicka J, Nowakowski J. 2012. The effect of hydrological connectivity on water beetles fauna in water bodies within the floodplain of a lowland river (Neman river, Belarus). Oceanological and Hydrobiological Studies 41/2: 7-17. https://doi.org/10.2478/s13545-012-0012-4

Pavićević A, Pešić V. 2012. Water beetle distribution along a perennial distance gradient in an intermittent stream from the Mediterranean part of Montenegro. Archives of Biological Sciences. 64(1): 345-351. https://doi.org/10.2298/ABS1201345P

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 128–139
»Neretva Science Week 2023«

KRATKA ZNANSTVENA VEST /
SHORT COMMUNICATION

DOI: 10.14720/ns.21748
Objavljeno na spletu / Published online: 23. 12. 2025

Prejeto / Received: 29. 1. 2025
Sprejeto / Accepted: 13. 7. 2025

Plecoptera and Trichoptera species in the Upper Neretva Catchment (Bosnia and Herzegovina) – new data from 2023 supplement the high diversity recorded a year before

Pia TEUFL,
*Wolfram GRAF**

BOKU, University of Natural Resources and Life Sciences, Vienna, Institute of Hydrobiology and Aquatic Ecosystem Management (IHG), Working Group Rheophylax, Gregor Mendel Strasse 33, A-1180 Vienna, Austria

* Korespondenčni avtor / Corresponding author;
E-mail: wolfram.graf@boku.ac.at

ABSTRACT

The Balkan Peninsula is considered to be a biodiversity hotspot, hosting a particularly high number of endemic species. Despite increased faunistic research in recent decades many areas remain poorly investigated, particularly regarding the aquatic entomofauna. The order Plecoptera, for instance, is strongly associated with cold, well-oxygenated mountain rivers and is known for its high sensitivity to environmental change. Consequently, stoneflies serve as valuable bioindicators in environmental monitoring. Similarly, the order Trichoptera includes many species with high habitat specificity, which are vulnerable to habitat degradation. A comprehensive understanding of the region's species inventory is essential, not only to deepen the knowledge about the distribution and habitat preferences of endemic and rare species, but also to assess what is at stake in case of significant environmental changes, such as those caused by hydropower development. To address these gaps in our knowledge, faunistic surveys focusing on Plecoptera and Trichoptera were conducted in 2022 and 2023 along the upper reaches of the Neretva River and its tributaries Krupac, Ljuta, and Jezernica as well as smaller, unnamed brooks within the catchment. Here we report the results from 2023 and compare them to the data published in 2022; both surveys conducted as part of the Neretva Science Week. We aim to contribute to the broader understanding of species diversity, distribution, and abundance of Plecoptera and Trichoptera in this area.

IZVLEČEK

Vrste redov Plecoptera in Trichoptera v zgornjem porečju reke Neretve (Bosna in Hercegovina) – novi podatki iz leta 2023 dopolnjujejo že leto prej zaznano visoko diverziteto

Balkanski polotok velja za žarišče biotske raznovrstnosti z izjemnim številom endemičnih vrst. Kljub povečanim raziskavam favne v zadnjih desetletjih so mnoga območja še vedno slabo raziskana, zlasti kar zadeva vodne žuželke. Red Plecoptera je na primer močno povezan s hladnimi, dobro oksigeniranimi gorskimi rekami in je znan po svoji visoki občutljivosti na okoljske spremembe. Posledično so vrbnice dragoceni bioindikatorji pri spremljanju okolja. Podobno red Trichoptera vključuje številne vrste z visoko specifičnostjo habitata, ki so posledično ranljive za degradacijo habitata. Celovit popis vrst v regiji je bistven za razumevanje razširjenosti in habitatnih preferenc endemičnih in redkih vrst, kot tudi za oceno, kaj je na kocki v primeru pomembnih okoljskih sprememb, kot so tiste, ki jih povzroča razvoj hidroelektrarn. Da bi odpravili te vrzeli v znanju, so bile v letih 2022 in 2023 izvedene raziskave favne, osredotočene na vrbnice in mladoletnice vzdolž zgornjega toka reke Neretve in njenih pritokov Krupac, Ljuta in Jezernica, pa tudi manjših, neimenovanih potokov znotraj porečja. Tukaj poročamo o rezultatih iz leta 2023 in jih primerjamo z že objavljenimi podatki iz leta 2022, pri čemer sta obe raziskavi del Tednov znanosti Neretve. S tem želimo prispevati k širšemu razumevanju vrstne raznolikosti, razširjenosti in številčnosti vrbnic in mladoletnic na tem območju.

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

KEY WORDS:
Neretva, biodiversity, caddisflies, stoneflies, hydropower

KLJUČNE BESEDE:
Neretva, biotska raznovrstnost, vrbnice, mladoletnice, hidroenergija

KLJUČNE RIJEČI:
Neretva, biodiverzitet, dlakorilci, kamenjarke, hidroenergija

APSTRAKT

Vrste redova Plecoptera i Trichoptera u gornjem slivu rijeke Neretve (Bosna i Hercegovina): novi podaci iz 2023. godine dopunjuju visok diverzitet zabilježen već prethodne godine

Balkansko poluostrvo se smatra žarištem biodiverziteta, domaćinom posebno velikog broja endemskih vrsta. Uprkos povećanim istraživanjima faune u poslednjim decenijama, mnoga područja su i dalje slabo istražena, posebno kada je u pitanju vodena entomofauna. Red Plecoptera, na primer, snažno je povezan sa hladnim, dobro oksigeniranim planinskim rijekama i poznat je po svojoj visokoj osetljivosti na promene u okruženju. Shodno tome, kamenjarke služe kao vredni bioindikatori u praćenju životne sredine. Slično tome, red Trichoptera uključuje mnoge vrste sa visokom specifičnošću staništa, koje su posljedično ranjive na degradaciju staništa. Sveobuhvatno razumjevanje inventara vrsta u regionu je neophodno, ne samo da bi se produbilo znanje o rasprostranjenosti i preferencijama staništa endemskih i retkih vrsta, već i da bi se procenilo šta je u pitanju u slučaju značajnih promena u okruženju, kao što su one izazvane izgradnjom hidroenergije. Da bi se popunili ovi nedostaci u znanju, faunistička istraživanja usmerena na Plecoptera i Trichoptera sprovedena su 2022. i 2023. godine duž gornjeg toka rijeke Neretve i njenih pritoka Krupac, Ljuta i Jezernica, kao i manjih, neimenovanih potoka unutar sliva. Ovde izveštavamo o rezultatima iz 2023. godine i upoređujemo ih sa već objavljenim podacima iz 2022. godine, pri čemu su oba istraživanja dio Sedmice nauke na Neretvi. Ovim ciljamo da doprinesemo širem razumjevanju raznolikosti vrsta, rasprostranjenosti i brojnosti kamenjarki (Plecoptera) i dlakokrilaca (Trichoptera) u ovom području.

INTRODUCTION

Rivers play a crucial role for ecosystems and people existing in their vicinity. In addition to providing the basis for all life – water – they perform a variety of other ecosystem services (Barnes & Mann 1993; Dudgeon et al. 2006; Arthington et al. 2010). Besides their economic value, natural river ecosystems function as a habitat for a broad variety of organisms, ranging from single-celled organisms and macrophytes to fish and macroinvertebrates (Pellaud 2007; Richardson 2019). However, these sensitive ecosystems are currently severely threatened by human interferences and climate change (Dudgeon et al. 2006; Vörösmarty et al. 2010; Schinegger et al. 2012; Grizzetti et al. 2017). Global warming alone has a major impact on rivers and their biota (Hauer et al. 1997; Hering et al. 2009; Strayer & Dudgeon 2010), while anthropogenic pressures are manifold and include hydropower generation, flood protection by regulating river flow or the influence of agriculture (Schinegger et al. 2012). Although the destruction of riverine ecosystems across much of Europe has been extensively observed, studied and quantified under the framework of the European Water Framework Directive (EC 2000), the Balkan Peninsula with its pristine lotic systems has recently emerged as a focal point for potential hydropower exploitation. This region has acted as a crucial refugial territory during the Last Glacial Period (Kühne et al. 2017) and is known for a particularly rich faunal inventory (Kryštufek & Reed 2004; Graf et al. 2018; Psonis et al. 2018) including an outstandingly high number of endemic species (Previšić et al. 2014; Graf et al. 2023). The distribution of these organisms is restricted to specific geographical areas, so they are particularly vulnerable to habitat degradation. The alteration of morphological and hydrological characteristics caused by hydropower construction could result in substantial reduction of overall diversity and, in the case of endemic species, the potential risk of extinction. The Neretva is one of many river systems currently considered for the construction of hydroelectric power plants (Pešić et al. 2019; Vučković et al. 2021), which could put the faunal inventory of the river and its many tributaries at risk (Skoulikidis et al. 2022; Graf et al. 2023). During the Neretva Science Week 2023 we reassessed the diversity of Trichoptera and Plecoptera species in the Neretva Catchment, refining the findings from the previous sampling campaign conducted in 2022 (Graf et al. 2023). Both groups include many endemic species on the one hand, and species which are dependent on well-oxygenated streams with high current velocities on the other hand. This makes them valuable indicator organisms for environmental degradation. The aim of this short communication is to present the species lists of the 2023 sampling campaign and compare it to the one conducted the year before (Graf et al. 2023) to give insight into the species richness of the Neretva River and its tributaries.

MATERIAL AND METHODS

In 2023, we reinvestigated the Plecoptera and Trichoptera fauna in the Upper Neretva Catchment through a thorough assessment of various habitats in the Neretva River, its tributaries Krupac, Ljuta, and Jezernica, as well as some smaller brooks. Sampling sites were largely consistent with those sampled in 2022 (Graf et al. 2023), with only slight spatial deviations at some of the sites. However, additionally to the five sites mentioned in Graf et al. (2023), we also sampled some new locations in the area.

The field work was conducted between 1. to 5. 6. 2023, a month earlier in the season than the sampling campaign conducted in 2022, which took place between 28.6. to 1.7. 2022 (Graf et al. 2023). Fig. 1 provides an overview of the sampling sites visited in 2023. The sites largely corresponded to the ones sampled in 2022, but include a few additional sites. For the coordinates of the sites sampled in 2022 see Graf et al. (2023).

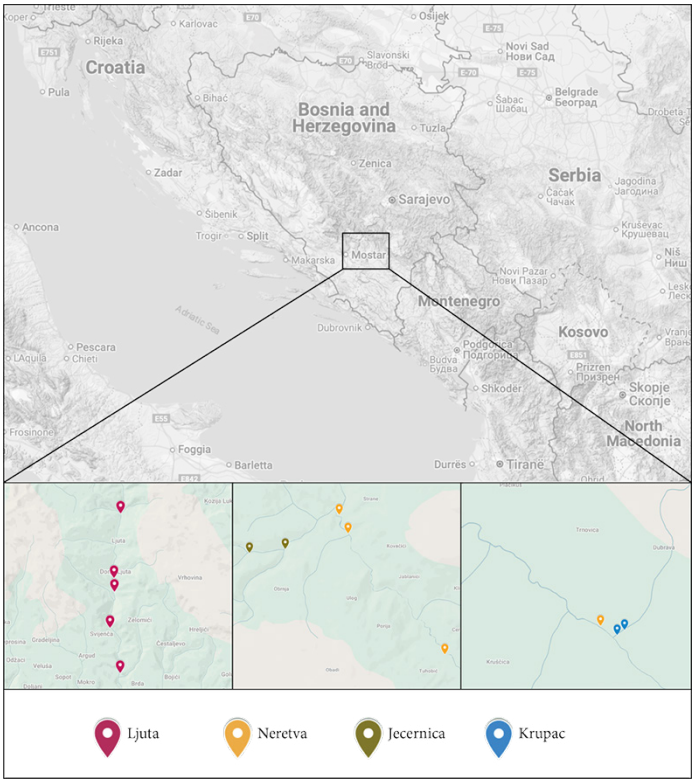

Figure 1. Overview of the sites sampled for Plecoptera and Trichoptera in 2023 in the Upper Neretva River Catchment.

Slika 1. Pregled vzorčnih mest, kjer so bile leta 2023 vzorčene vrbnice in mladoletnice v zgornjem porečju reke Neretve.

Slika 1. Pregled lokaliteta uzorkovanja na kojima su Plecoptera i Trichoptera uzorkovani 2023. godine u slivu gornjeg toka rijeke Neretve.

During the day, a sweeping net was used to capture adult organisms, while larval stages were collected from the streams using a sieve. Additionally, light traps were set up during the night at Neretva and Krupac. Detailed information on sampling methods is given in Tab. S1. Identification of Trichoptera was carried out using standard taxonomic keys, primarily Malicky (2004). Due to the fragmented nature of Plecoptera identification literature, sources were selected on the basis of the family, genus, or species in question (e.g. Kaćanski and Zwick 1970; Kaćanski 1979; Ikonomov 1983; Murányi et al. 2016).

The classification of species as »Balkan endemics« and »rheobionts« was based on ecological and biogeographic information compiled from current literature (Graf 2008, 2009; Stanić-Koštroman et al. 2012; Previšić et al. 2014; Neu et al. 2018) and species traits available in the freshwaterecology.info database (Schmidt-Kloiber & Hering 2015).

RESULTS

In total, 82 species were collected during the two sampling campaigns in 2022 (Graf et al. 2023) and 2023. 55% of the species were only detected in 2022, 16% were newly recorded in 2023. 29% of the species were found in both years (Fig. 2, Tab. 1).

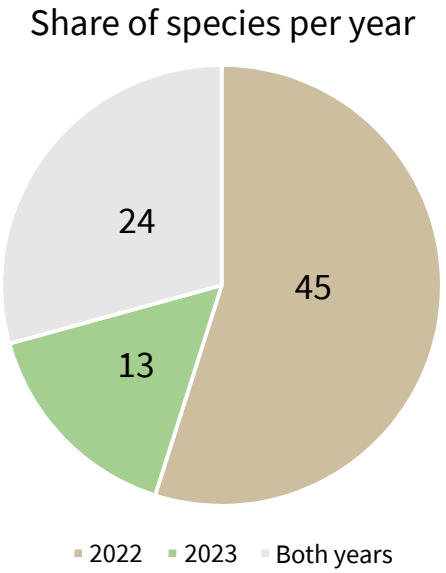

Figure 2. Proportion of Plecoptera and Trichoptera species recorded in the Upper Neretva River Catchment in 2022, 2023 or in both years.

Slika 2. Delež vrst vrbnic in mladoletnic, zabeleženih v zgornjem porečju reke Neretve samo v letu 2022, samo v letu 2023 ali v obeh letih.

Slika 2. Udio vrsta Plecoptera i Trichoptera zabilježenih u slivu gornjeg toka rijeke Neretve samo u 2022. godini, samo u 2023. godini ili u obje godine.

In total, 65 Trichoptera and 17 Plecoptera species were documented. With 78%, the proportion of rheobiontic taxa was extraordinarily high. 27 species endemic to the Balkan peninsula were collected, which equals 33% of all collected species (Fig. 3).

Tab. 1 provides an overview of the species collected in 2022 (Graf et al. 2023) and 2023.

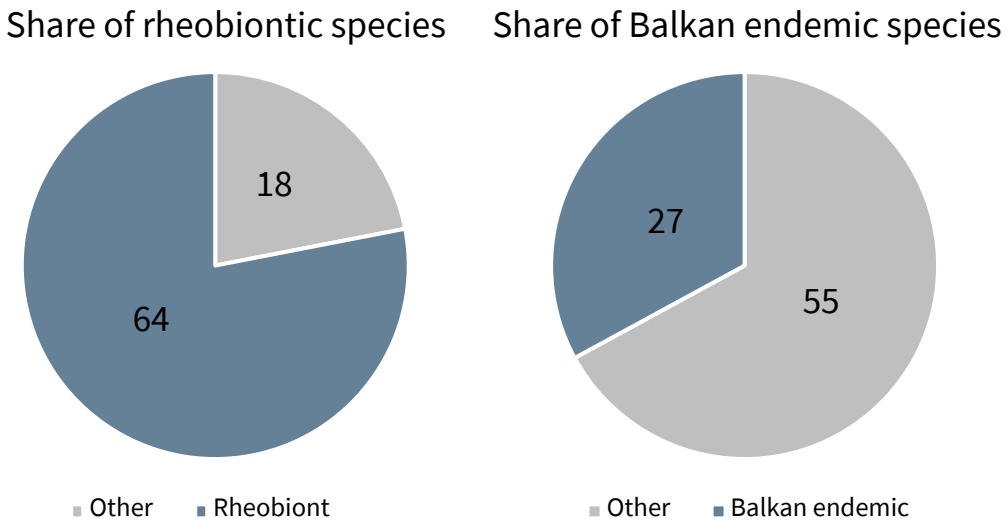

Figure 3. Proportion of rheobiontic species and species endemic to the Balkan.

Slika 3. Delež reobiontskih vrst in vrst, endemičnih za Balkan.

Slika 3. Udio reobiontskih i endemskih vrsta za Balkan.

Table 1. Plecoptera and Trichoptera species collected in the Upper Neretva River Catchment in 2022 (Graf et al. 2023) and 2023. Abbreviations: RB = Rheobiont species, BE = Balkan endemic. Color codes: brown = collected in 2022, green = collected in 2023, grey = collected in both years.

Tabela 1. Vrste vrbnic in mladoletnic, zbrane v zgornjem porečju reke Neretve v letih 2022 (Graf et al. 2023) in 2023. Okrajšave: RB = vrsta reobiontov, BE = balkanski endemit. Barvne kode: rjava = zbrano leta 2022, zelena = zbrano leta 2023, siva = zbrano v obeh letih.

Tabela 1. Vrste Plecoptera i Trichoptera prikupljenih u slivu gornjeg toka rijeke Neretve 2022. (Graf et al. 2023.) i 2023. godine. Skraćenice: RB = Reobiontna vrsta, BE = Balkanski endem. Kodovi boja: smeđa = prikupljeno 2022. godine, zelena = prikupljeno 2023. godine, siva = prikupljeno u obje godine.

Order	Family	Species	2022	2023	RB	BE
Trichoptera	Rhyacophilidae	*Rhyacophila armeniaca* Guérin, 1834	×		×	×
Trichoptera	Rhyacophilidae	*Rhyacophila balcanica* Radovanovic, 1953	×		×	×
Trichoptera	Rhyacophilidae	*Rhyacophila fasciata viteceki* Valladoid & Kucinic, 2020	×		×	×
Trichoptera	Rhyacophilidae	*Rhyacophila loxias* Schmid, 1970	×	×	×	×
Trichoptera	Rhyacophilidae	*Rhyacophila morettina* Botosaneanu, 1980	×		×	×
Trichoptera	Rhyacophilidae	*Rhyacophila nubila* Zetterstedt, 1840	×	×	×	
Trichoptera	Rhyacophilidae	*Rhyacophila polonica* McLachlan, 1879	×	×	×	
Trichoptera	Rhyacophilidae	*Rhyacophila tristis* Pictet, 1834	×	×	×	
Trichoptera	Glossosomatidae	*Glossosoma bifidum* McLachlan, 1879	×		×	
Trichoptera	Glossosomatidae	*Glossosoma boltini* Curtis, 1834	×		×	
Trichoptera	Glossosomatidae	*Glossosoma discophorum* Klapálek, 1902	×		×	×
Trichoptera	Glossosomatidae	*Glossosoma conformis* Neboiss, 1963	×		×	
Trichoptera	Glossosomatidae	*Agapetus ochripes* Curtis, 1834	×		×	
Trichoptera	Glossosomatidae	*Synagapetus iridipennis* McLachlan, 1879	×	×	×	
Trichoptera	Glossosomatidae	*Synagapetus slavorum* Botosaneanu, 1960	×	×	×	×
Trichoptera	Hydroptilidae	*Hydroptila tineoides* Dalman, 1819	×			
Trichoptera	Hydroptilidae	*Allotrichia pallicornis* Eaton, 1873	×		×	
Trichoptera	Hydroptilidae	*Ithytrichia lamellaris* Eaton, 1873	×		×	
Trichoptera	Philopotamidae	*Wormaldia pulla* McLachlan, 1878	×		×	
Trichoptera	Philopotamidae	*Wormaldia subnigra* McLachlan, 1865	×		×	×
Trichoptera	Philopotamidae	*Wormaldia bosniaca* Botosaneanu, 1960		×		×
Trichoptera	Philopotamidae	*Philopotamus montanus* Donovan, 1813		×		
Trichoptera	Polycentropodidae	*Polycentropus flavomaculatus* Pictet, 1834	×		×	

Order	Family	Species	2022	2023	RB	BE
Trichoptera	Polycentropodidae	*Polycentropus ierapetra dirfis* Malicky, 1974	×		×	×
Trichoptera	Polycentropodidae	*Polycentropus ierapetra slovenicus* Malicky, 1998	×		×	×
Trichoptera	Polycentropodidae	*Polycentropus excisus* Klapálek, 1894	×		×	
Trichoptera	Polycentropodidae	*Polycentropus schmidi* Novak & Botosaneanu, 1965	×		×	
Trichoptera	Psychomyiidae	*Psychomyia klapaleki* Malicky, 1995	×		×	×
Trichoptera	Psychomyiidae	*Psychomyia pusilla* Fabricius, 1781	×		×	
Trichoptera	Psychomyiidae	*Tinodes braueri* McLachlan, 1878	×		×	×
Trichoptera	Psychomyiidae	*Tinodes rostocki* McLachlan, 1878	×		×	
Trichoptera	Psychomyiidae	*Tinodes unicolor* Pictet, 1834	×		×	
Trichoptera	Psychomyiidae	*Tinodes waeneri* Linnaeus, 1758	×			
Trichoptera	Hydropsychidae	*Diplectrona atra* McLachlan, 1878	×	×	×	×
Trichoptera	Hydropsychidae	*Hydropsyche incognita* Pitsch, 1993	×		×	
Trichoptera	Hydropsychidae	*Hydropsyche instabilis* Curtis, 1834	×		×	
Trichoptera	Hydropsychidae	*Hydropsyche mostarensis* Klapálek, 1898	×		×	×
Trichoptera	Hydropsychidae	*Hydropsyche dinarica* Marinkovic-Gospodnetic, 1979		×		
Trichoptera	Brachycentridae	*Brachycentrus montanus* Klapálek, 1892	×	×	×	
Trichoptera	Brachycentridae	*Micrasema minimum* McLachlan, 1876	×		×	
Trichoptera	Brachycentridae	*Micrasema sericeum* Klapálek, 1902	×		×	×
Trichoptera	Thremmatidae	*Thremma anomalum* McLachlan, 1876	×		×	×
Trichoptera	Goeridae	*Goera pilosa* Fabricius, 1775	×		×	
Trichoptera	Goeridae	*Silo piceus* Brauer, 1857	×	×	×	
Trichoptera	Lepidostomatidae	*Crunoecia* sp.	×		×	
Trichoptera	Lepidostomatidae	*Lepidostoma basale* Kolenati, 1848	×		×	
Trichoptera	Limnephilidae	*Drusus schmidi* Botosaneanu, 1960	×	×	×	×
Trichoptera	Limnephilidae	*Drusus radovanovici* Marinkovic-Gospodnetic, 1971		×		×
Trichoptera	Limnephilidae	*Ecclisopteryx keroveci* Previsic, Graf & Vitecek, 2014	×	×	×	×
Trichoptera	Limnephilidae	*Limnephilus lunatus* Curtis, 1834	×			
Trichoptera	Limnephilidae	*Limnephilus vittatus* Fabricius, 1798	×			
Trichoptera	Limnephilidae	*Micropterna sequax* McLachlan, 1875	×		×	
Trichoptera	Limnephilidae	*Potamophylax luctuosus* Piller & Mitterbacher, 1783		×		
Trichoptera	Limnephilidae	*Potamophylax pallidus* Klapálek, 1899	×		×	×
Trichoptera	Limnephilidae	*Stenophylax mitis* McLachlan, 1875	×	×	×	
Trichoptera	Sericostomatidae	*Oecismus monedula* Hagen, 1859	×		×	
Trichoptera	Sericostomatidae	*Sericostoma flavicorne* Schneider, 1845	×		×	
Trichoptera	Odontoceridae	*Odontocerum albicorne* Scopoli, 1763	×	×	×	
Trichoptera	Beraeidae	*Beraea pullata* Curtis, 1834		×		
Trichoptera	Beraeidae	*Beraeamyia schmidi* Botosaneanu, 1960	×	×	×	×
Trichoptera	Beraeidae	*Ernodes articularis* Pictet, 1834	×		×	
Trichoptera	Leptoceridae	*Adicella filicornis* Pictet, 1834	×		×	
Trichoptera	Leptoceridae	*Oecetis testacea* Curtis, 1834	×			
Trichoptera	Leptoceridae	*Athripsodes albifrons* Linnaeus, 1758	×		×	
Trichoptera	Leptoceridae	*Ceraclea dissimilis* Stephens, 1836	×		×	
Plecoptera	Chloroperlidae	*Chloroperla tripunctata* Scopoli, 1763	×	×	×	
Plecoptera	Perlodidae	*Isoperla bosnica* Aubert, 1964	×	×	×	×
Plecoptera	Perlodidae	*Isoperla tripartita* gr. (nov. sp.?)	×	×	×	×

Order	Family	Species	2022	2023	RB	BE
Plecoptera	Perlidae	*Dinocras megacephala* Klapálek, 1907	×	×	×	
Plecoptera	Perlidae	*Perla marginata* Panzer, 1799	×	×	×	
Plecoptera	Taeniopterygidae	*Brachyptera seticornis* Klapálek, 1902		×		
Plecoptera	Taeniopterygidae	*Brachyptera tristis* Klapálek, 1901	×	×	×	×
Plecoptera	Taeniopterygidae	*Brachyptera beali* Navás, 1923		×		×
Plecoptera	Nemouridae	*Amphinemura sulcicollis* Stephens, 1836	×	×	×	
Plecoptera	Nemouridae	*Amphinemura triangularis*		×		
Plecoptera	Nemouridae	*Protonemura auberti* Illies, 1954	×	×	×	
Plecoptera	Nemouridae	*Protonemura intricata* Ris, 1902	×	×	×	
Plecoptera	Nemouridae	*Nemoura cinerea* Retzius, 1783		×		
Plecoptera	Nemouridae	*Nemoura minima* Aubert, 1946		×		
Plecoptera	Nemouridae	*Nemurella pictetii* Klapálek, 1900		×		
Plecoptera	Leuctridae	*Leuctra inermis* Kempny, 1899	×	×	×	
Plecoptera	Leuctridae	*Leuctra hippopoides* Kempny, 1899		×		×

DISCUSSION

As outlined by Weiss et al. (2018), multiple hydropower projects are currently proposed or under construction along the Neretva River and its tributaries, including small-scale hydroelectric plants in ecologically valuable headwater areas. These projects threaten to disrupt the longitudinal connectivity and restrict dynamic flow regimes of rivers, which are crucial for sustaining their ecological integrity and biotic diversity. Impoundments and altered flow dynamics are not only expected to reduce habitat heterogeneity and quality, but also decrease the availability of habitats with high current velocities, which are critical for sustaining rheophilic aquatic biota (Poff et al. 1997; Grill et al. 2019).

The high proportion of rheobiontic Plecoptera and Trichoptera species in the Upper Neretva Catchment underscores the potential negative impact of planned hydropower developments on macroinvertebrate communities and species diversity. Notably, the presence of *Drusus radovanovici*, a micro-endemic species known only from a few spring habitats in Bosnia and Herzegovina underscores the vulnerability of such taxa to habitat degradation due to their extremely limited distribution range (Kučinić et al. 2008, 2011). Furthermore, the fact that over one-third of the recorded species are endemic to the Balkan Peninsula highlights the importance of conserving these sensitive aquatic habitats. Despite the increased scientific attention that the area has received in recent years (e.g. Ikonomov 1983; Murányi 2007; Popijač & Sivec 2009; Oláh & Kovács 2013, 2014; Petrović et al. 2014; Previšić et al. 2014; Bilalli et al. 2023; Graf et al. 2023; Teufl & Graf 2024) our understanding of the faunal inventory remains incomplete. For instance, the larvae of *Drusus schmidi* and *Beraeamyia schmidi* were collected, which have not yet been described.

As illustrated in Tab. 1, only about one-third of the species were found in both years, even though similar habitats were sampled and many sites were assessed during both campaigns. Differences in species composition and abundance are largely attributable to variations in sampling success with the light traps, which were installed in different habitats. Flight activities of caddisflies are significantly influenced by air temperature (Waringer 1991; Houghton 2004; Diken 2008; Nowinszky et al. 2014), so the abiotic conditions during sampling play a crucial role in the outcome. During the 2022 campaign, a remarkably high number of individuals were captured (Graf et al. 2023) with 40.000 specimens collected in a single night. Out of these, one-third were identified as *Syngapetus slavorum* and *Agapetus ochripes*. In contrast, these two species were entirely absent in May 2023, as low nighttime temperatures during the sampling period led to conspicuously low caddisfly densities in the light traps. Despite these subpar conditions, high species diversity was recorded, which would probably be even higher if activities of terrestrial stages of aquatic insects would have been supported by warmer nights, as was the case in 2022.

Bosnia and Herzegovina and especially the Neretva region is well known as a biodiversity hotspot, and several studies have contributed to the closing of knowledge gaps regarding the macroinvertebrate inventory of the area (e.g. Klapálek, 1899; Stanić-Koštroman 2009; Stanić-Koštroman et al. 2015; Graf et al. 2023). However, the mentioned aspects highlight the importance of continuous and repeated sampling campaigns, as long-time monitoring strategies with seasonally varying collecting trips are crucial to gain a comprehensive understanding of the faunal inventory. In most cases, larval stages are not properly described to identify the organisms at the species level, necessitating the need for collecting the adult stages as well. The fact that different groups and species have specific emergence periods must be considered when planning biodiversity surveys. For instance, the complete lack of data from the summer and autumn represents a significant gap, as the specimens collected during these seasons would contribute substantially to the documented species richness. While a joint sampling campaign conducted in a short time frame offers an advantage in terms of organization, it also provides valuable opportunities for public engagement and media visibility. Such coordinated efforts can help to communicate the

ecological significance of pristine areas and raise awareness about the need for their protection. However, from a scientific perspective, these campaigns inherently only capture a partial snapshot of biodiversity, which underscores the need for repeated and temporally distributed surveys to document the full species richness.

POVZETEK

Prispevek predstavlja posodobljene favnistične podatke o favni vrbnic (Plecoptera) in mladoletnic (Trichoptera) v porečju zgornje Neretve (Bosna in Hercegovina), ki temeljijo na terenskem delu, opravljenem med Znanstvenim tednom Neretva v letih 2022 in 2023. Skupno je bilo zabeleženih 82 vrst, in sicer 65 vrst Trichoptera in 17 vrst Plecoptera. Delež reobiontskih vrst je bil izjemno visok (78 %). 27 vrst (33 %) je bilo endemičnih za Balkanski polotok, kar potrjuje izjemen ekološki pomen tega območja. Vrstna sestava združb, popisanih v zaporednih letih, se razlikuje, predvsem zaradi različnih sezon vzorčenja in različne uspešnosti lova. Rezultati potrjujejo, da je za celovito poznavanje favne nujen kontinuiran sezonski monitoring, brez katerega ne zaznamo številnih larvalnih stopenj in adultnih oblik ki imajo izrazita obdobja izletanja iz vode. Ob umeščanju hidroelektrarn v regiji je treba ohranjati nedotaknjena povirna območja, od katerih je odvisna visoko specializirana in občutljiva združba vodnih žuželk.

SAŽETAK

Ovaj rad predstavlja ažurirane faunističke podatke o fauni kamenarki (Plecoptera) i tulara (Trichoptera) iz sliva Gornje Neretve (Bosna i Hercegovina), na osnovu terenskog istraživanja provedenog tokom Sedmice nauke na Neretvi 2023. godine. Ukupno su zabilježene 82 vrste tokom dvije uzastopne kampanje uzorkovanja u 2022. i 2023. godini, uključujući 65 vrsta Trichoptera i 17 vrsta Plecoptera. Udio reobiontskih vrsta bio je izuzetno visok (78 %), a 27 vrsta (33 %) bile su endemične za Balkansko poluostrvo, što potvrđuje izuzetnu ekološku vrijednost ovog područja. Razlike u sastavu vrsta između godina uglavnom su pripisane sezonskom dinamikom i varijabilnom uspjehu hvatanja. Rezultati naglašavaju važnost kontinuiranog i sezonski raspoređenog monitoringa kako bi se postiglo sveobuhvatno razumijevanje faunističke raznolikosti, jer mnogi larvalni stadijumi ostaju neopisani, a brojni taksoni pokazuju različite periode emergencije. U svjetlu tekućeg razvoja hidroenergetskih projekata u regiji, ovi nalazi ukazuju na neophodnost očuvanja netaknutih izvorišnih staništa koja podržavaju visoko specijalizovane i osjetljive zajednice vodenih insekata.

ACKNOWLEDGMENTS

Thanks to Christoph Novotny for an inspired field trip and the intense sampling effort during the Neretva Science Week 2023. We also thank Gabriel Singer and his team for the collection of additional material.

REFERENCES

Arthington AH, Naiman RJ, McClain ME, Nilsson C. 2010. Preserving the biodiversity and ecological services of rivers: new challenges and research opportunities. Freshwater Biology. 55: 1-16. https://doi.org/10.1111/j.1365-2427.2009.02340.x

Barnes R, Mann K, editors. 1993. Fundamentals of aquatic ecology. London (UK): Blackwell Scientific Publications.

Bilalli A, Ibrahimi H, Musliu M, Grapci-Kotori L, Slavevska-Stamenković V, Hinić J, Geci D, Sivec I. 2023. New records and distribution data of stoneflies (Insecta: Plecoptera) from the Western Balkans. Natura Croatica. 32: 555-570. https://doi.org/10.20302/NC.2023.32.37

Diken G. 2008. Light-trapping of caddisflies (Insecta: Trichoptera) from Eğirdir Lake in the southern Turkey. Journal of FisheriesSciences.com. 2: 653-661. https://doi.org/10.3153/jfscom.2008030

Dudgeon D, Arthington AH, Gessner MO, Kawabata Z, Knowler DJ, Lévêque C, Naiman RJ, Prieur-Richard A, Soto D, Stiassny MLJ, Sullivan CA. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews. 81: 163-182. https://doi.org/10.1017/S1464793105006950

[EC] European Commission. 2000. Water Framework Directive (2000/60/EC). Official Journal of the European Union. 327: 1-73.

Graf W, editor. 2008. Distribution and Ecological Preferences of European Freshwater Organisms, Volume 1: Trichoptera. Sofia, Moscow: Pensoft.

Graf W, editor. 2009. Distribution and Ecological Preferences of European Freshwater Organisms, Volume 2: Plecoptera. Sofia, Moscow: Pensoft.

Graf W, Bauernfeind E, Ivković M, Kolcsár L-P. 2023. Aquatic insects (Ephemeroptera, Plecoptera, Trichoptera and Diptera: Tipuloidea) from the upper Neretva in Bosnia-Herzegovina. Natura Sloveniae. 25(3): 29-42. https://doi.org/10.14720/ns.25.3.29-42

Graf W, Grabowski M, Hess M, Heckes U, Rabitsch W, Vitecek S. 2018. Contribution to the knowledge of aquatic invertebrate Fauna of the Vjosa in Albania. Acta ZooBot Austria. 155: 135.153.

Grill G, Lehner B, Thieme M, Geenen B, Tickner D, Antonelli F, Babu S, Borrelli P, Cheng L, Crochetiere H, et al. 2019. Mapping the world's free-flowing rivers. Nature. 569: 215-221. https://doi.org/10.1038/s41586-019-1111-9

Grizzetti B, Pistocchi A, Liquete C, Udias A, Bouraoui F, Van De Bund W. 2017. Human pressures and ecological status of European rivers. Scientific Reports. 7: 205. https://doi.org/10.1038/s41598-017-00324-3

Hauer FR, Baron JS, Campbell DH, Fausch KD, Hostetler SW, Leavesley GH, Leavitt PR, Mcknight DM, Stanford JA. 1997. Assessment of climate change and freshwater ecosystems of the Rocky Mountains, USA and Canada. Hydrological Processes. 11: 903-924. https://doi.org/10.1002/(SICI)1099-1085(19970630)11:8<903::AID-HYP511>3.0.CO;2-7

Hering D, Schmidt-Kloiber A, Murphy J, Lücke S, Zamora-Muñoz C, López-Rodríguez MJ, Huber T, Graf W. 2009. Potential impact of climate change on aquatic insects: A sensitivity analysis for European caddisflies (Trichoptera) based on distribution patterns and ecological preferences. Aquatic Sciences. 71: 3-14. https://doi.org/10.1007/s00027-009-9159-5

Houghton DC. 2004. Biodiversity of Minnesota Caddisflies (Insecta: Trichoptera): Delineation and Characterization of Regions. Environmental Monitoring and Assessment. 95: 153-181. https://doi.org/10.1023/B:EMAS.0000029890.07995.90

Ikonomov P. 1983. Nouvelles espèces de Plécoptères (Insecta, Plecoptera) de Macédoine. III. Fragmenta Balcanica. 11: 175-183.

Kaćanski D. 1979. Some characteristics of the Plecoptera fauna in Bosnia and Herzegovina (Yugoslavia). Gewässer und Abwässer. 64: 49-55.

Kaćanski D, Zwick P. 1970. Neue und wenig bekannte Plecopteren aus Jugoslawien. Mitteilungen der Schweizerischen Entomologischen Gesellschaft. 43: 1-16. https://doi.org/10.5169/SEALS-401605

Klapálek F. 1899. Prilozi k poznavanju faune Trichoptera i Neuroptera Bosne i Hercegovine. Glasnik Zemaljskog muzeja u Bosni i Hercegovini. 11: 323–338.

Kryštufek B, Reed JM. 2004. Pattern and Process in Balkan Biodiversity — An Overview. In: Griffiths HI, Kryštufek B, Reed JM, editors. Balkan Biodiversity. Dordrecht: Springer Netherlands. p. 1-8. https://doi.org/10.1007/978-1-4020-2854-0_1

Kučinić M, Previšić A, Graf W, Šerić Jelaska L, Stanić-Koštroman S, Waringer J. 2011. Larval description, genetic and ecological features of *Drusus radovanovici radovanovici* Marinković-Gospodnetić, 1971 (Trichoptera, Limnephilidae) with some phylogenetic and taxonomic data on the bosnicus group in the Balkan Peninsula. Deutsche Entomologische Zeitschrift. 58: 135-153. https://doi.org/10.1002/mmnd.201100010

Kučinić M, Previšić A, Gottstein S, Hrašovec B, Stanić-Koštroman S, Pernek M, Delić A. 2008. Description of the larvae of *Drusus radovanovici septentrionis* Marinkovic-Gospodnetic, 1976 and *Drusus croaticus* Marinkovic-Gospodnetic, 1971 (Trichoptera: Limnephilidae) from Bosnia and Herzegovina, and Croatia. Zootaxa. 1783(1): 1-17. https://doi.org/10.11646/zootaxa.1783.1.1

Kühne G, Kosuch J, Hochkirch A, Schmitt T. 2017. Extra-Mediterranean glacial refugia in a Mediterranean faunal element: the phylogeography of the chalk-hill blue *Polyommatus coridon* (Lepidoptera, Lycaenidae). Scientific Reports. 7: 43533. https://doi.org/10.1038/srep43533

Malicky H. 2004. Atlas of European Trichoptera / Atlas der Europäischen Köcherfliegen / Atlas des Trichoptères d'Europe. 2nd ed. Dordrecht: Springer. https://doi.org/10.1007/978-1-4020-3026-0

Murányi D. 2007. New and little–known stoneflies (Plecoptera) from Albania and the neighbouring countries. Zootaxa. 1533(1): 1-40. https://doi.org/10.11646/zootaxa.1533.1.1

Murányi D, Kovács T, Orci KM. 2016. Contribution to the taxonomy and biology of two Balkan endemic *Isoperla* Banks, 1906 (Plecoptera: Perlodidae) species. Zoosymposia. 11: 73-88. https://doi.org/10.11646/zoosymposia.11.1.11

Neu PJ, Malicky H, Graf W, Schmidt-Kloiber A. 2018. Distribution atlas of European trichoptera. Harxheim: ConchBooks.

Nowinszky L, Kiss O, Puskás J. 2014. Effect of weather conditions on light-trap catches of Trichoptera in Hungary (Central Europe). Polish Journal of Entomology. 83: 269-280. https://doi.org/10.2478/pjen-2014-0021

Oláh J, Kovács T. 2013. New species and records of Balkan Trichoptera II. Folia historico-naturalia Musei Matraensis. 37: 109-121.

Oláh J, Kovács T. 2014. New species and records of Balkan Trichoptera III. Folia historico-naturalia Musei Matraensis. 38: 97-131.

Pellaud M. 2007. Ecological response of a multi-purpose river development project using macro-invertebrates richness and fish habitat value [doctoral thesis]. [Lausanne]: EPFL. https://doi.org/10.5075/EPFL-THESIS-3807

Pešić V, Grabowski M, Hadžiablahović S, Marić D, Paunović M. 2019. The biodiversity and biogeographical characteristics of the river basins of Montenegro. In: Pešić V, Paunović M, Kostianoy AG, editors. The rivers of Montenegro. Cham: Springer International Publishing. (The Handbook of Environmental Chemistry; vol. 92). p. 157-200. https://doi.org/10.1007/698_2019_414

Petrović A, Simić V, Milošević D, Paunović M, Sivec I. 2014. Diversity and Distributional Patterns of Stoneflies. Acta Zoologica Bulgarica. 66: 517-526.

Poff NL, Allan JD, Bain MB, Karr JR, Prestegaard KL, Richter BD, Sparks RE, Stromberg JC. 1997. The Natural Flow Regime. BioScience. 47: 769-784. https://doi.org/10.2307/1313099

Popijač A, Sivec I. 2009. Diversity and distribution of stoneflies in the area of Plitvice Lakes National Park and along the Mediterranean river Cetina (Croatia). Aquatic Insects. 31: 731-742. https://doi.org/10.1080/01650420902745521

Previšić A, Graf W, Vitecek S, Kučinić M, Bálint M, Keresztes L, Pauls S, Waringer J. 2014. Cryptic diversity of caddisflies in the Balkans: the curious case of Ecclisopteryx species (Trichoptera: Limnephilidae). Arthropod Systematics & Phylogeny. 72: 309-329. https://doi.org/10.3897/asp.72.e31792

Psonis N, Antoniou A, Karameta E, Leaché AD, Kotsakiozi P, Darriba D, Kozlov A, Stamatakis A, Poursanidis D, Kukushkin O, et al. 2018. Resolving complex phylogeographic patterns in the Balkan Peninsula using closely related wall-lizard species as a model system. Molecular Phylogenetics and Evolution. 125: 100-115. https://doi.org/10.1016/j.ympev.2018.03.021

Richardson JS. 2019. Biological Diversity in Headwater Streams. Water. 11: 366. https://doi.org/10.3390/w11020366

Schinegger R, Trautwein C, Melcher A, Schmutz S. 2012. Multiple human pressures and their spatial patterns in European running waters. Water and Environment Journal. 26: 261-273. https://doi.org/10.1111/j.1747-6593.2011.00285.x

Schmidt-Kloiber A, Hering D. 2015. www.freshwaterecology.info – An online tool that unifies, standardises and codifies more than 20,000 European freshwater organisms and their ecological preferences. Ecological Indicators. 53: 271-282. https://doi.org/10.1016/j.ecolind.2015.02.007

Skoulikidis NT, Zogaris S, Karaouzas I. 2022. Rivers of the Balkans. In: Tockner K, Zarfl C, Robinson CT, editors. Rivers of Europe. 2nd ed. Amsterdam: Elsevier. p. 595-655. https://doi.org/10.1016/B978-0-08-102612-0.00015-8

Stanić-Koštroman S, Kučinić M, Kolobara A, Škobić D, Durbešić P. 2012. Light-trapped caddisflies (Insecta: Trichoptera) as indicators of the ecological integrity of the Lištica River, Bosnia and Herzegovina. Entomologia Croatica. 16(1-4): 21-36.

Stanić-Koštroman S, Previšić A, Planinić A, Kučinić M, Škobić D, Dedić A, Durbešić P. 2015. Environmental determinants of contrasting caddisfly (Insecta, Trichoptera) biodiversity in the Neretva and Bosna river basins (Bosnia and Herzegovina) under temperate and Mediterranean climates. International Review of Hydrobiology. 100: 79-95. https://doi.org/10.1002/iroh.201301631

Strayer DL, Dudgeon D. 2010. Freshwater biodiversity conservation: recent progress and future challenges. Journal of the North American Benthological Society. 29: 344-358. https://doi.org/10.1899/08-171.1

Teufl P, Graf W. 2024. A new species of *Protonemura* Kempny, 1898 (Plecoptera, Nemouridae) from Albania. Biodiversity Data Journal. 12: e129725. https://doi.org/10.3897/BDJ.12.e129725

Vörösmarty CJ, McIntyre PB, Gessner MO, Dudgeon D, Prusevich A, Green P, Glidden S, Bunn SE, Sullivan CA, Liermann CR, Davies PM. 2010. Global threats to human water security and river biodiversity. Nature. 467: 555-561. https://doi.org/10.1038/nature09440

Vučković I, Kučinić M, Ćukušić A, Vuković M, Ćuk R, Stanić-Koštroman S, Cerjanec D, Plantak M. 2021. Biodiversity, DNA barcoding data and ecological traits of caddisflies (Insecta, Trichoptera) in the catchment area of the Mediterranean karst River Cetina (Croatia). Ecologica Montenegrina. 44: 69-95. https://doi.org/10.37828/em.2021.44.10

Waringer JA. 1991. Phenology and the influence of meteorological parameters on the catching success of light-trapping for Trichoptera. Freshwater Biology. 25: 307-319. https://doi.org/10.1111/j.1365-2427.1991.tb00493.x

Weiss S, Apostolou A, Đug S, Marčić Z, Mušović M, Oikonomou A, Shumka S, Škrijelj R, Simonović P, Vesnić A, Zabric D. 2018. Endangered fish species in Balkan rivers: their distributions and threats from hydropower development. Riverwatch & EuroNatur. https://doi.org/10.13140/RG.2.2.22638.10563

SUPPLEMENTARY MATERIAL

Table S1. Overview about the collected species between 2. 6. 2023 and 5 .6. 2023. Abbreviations: KR=Krupac, NV=Neretva, NV TR=Neretva tributary, LJ=Ljuta, J=Jezernica, J TR=Jezernica tributary. Determination: Wolfram Graf.

Tabela S1. Pregled zbranih vrst med 2. 6. 2023 in 5. 6. 2023. Okrajšave: KR=Krupac, NV=Neretva, NV TR=pritok Neretve, LJ=Ljuta, J=Jezernica, J TR=pritok Jezernice. Določitev: Wolfram Graf.

Tabela S1. Pregled prikupljenih vrsta između 2. 6. 2023. i 5. 6. 2023. Skraćenice: KR=Krupac, NV=Neretva, NV TR=Pritoka Neretve, LJ=Ljuta, J=Jezernica, J TR=Pritoka Jezernice. Determinacija: Wolfram Graf.

River	Longitude	Latitude	Date	Taxon	M	W	L	Leg.	Method
KR	43.329538	18.425545	2. 6. 2023	*Brachyptera tristis*	1			PT, CN	Handnet
KR	43.329538	18.425545	2. 6. 2023	*Drusus radovanovici*	3	5		PT, CN	Handnet
KR	43.329538	18.425545	2. 6. 2023	*Perla marginata*		1		PT, CN	Handnet
KR	43.329538	18.425545	2. 6. 2023	*Potamophylax luctuosus*	1			PT, CN	Handnet
KR	43.329538	18.425545	2. 6. 2023	*Amphinemura sulcicollis*	1			PT, CN	Handnet
KR	43.330444	18.427254	2. 6. 2023	*Diplectrona atra*	2	1		PT, CN	Lighttrap
KR	43.330444	18.427254	2. 6. 2023	*Leuctra inermis* gr.	6	9		PT, CN	Lighttrap
KR	43.330444	18.427254	2. 6. 2023	*Wormaldia bosniaca*	5			PT, CN	Lighttrap
KR	43.330444	18.427254	2. 6. 2023	*Brachyptera tristis*	1	1		PT, CN	Handnet, Sieve
KR	43.330444	18.427254	2. 6. 2023	*Isoperla tripartita* gr.	2	2	1	PT, CN	Lighttrap, Sieve
KR	43.330444	18.427254	2. 6. 2023	*Amphinemura sulcicollis*		5		PT, CN	Lighttrap
KR	43.330444	18.427254	2. 6. 2023	*Drusus radovanovici*	1		2	PT, CN	Handnet, Sieve
KR	43.330444	18.427254	2. 6. 2023	*Ecclisopteryx keroveci*			1	PT, CN	Sieve
NV	43.423056	18.308889	2. 6. 2023	*Isoperla bosnica*	8	13		PT, CN	Handnet
NV	43.423056	18.308889	2. 6. 2023	*Brachycentrus montanus*			1	PT, CN	Sieve
NV	43.423056	18.308889	2. 6. 2023	*Beraeamyia schmidi*			1	PT, CN	Sieve
NV	43.423056	18.308889	2. 6. 2023	*Hydropsyche dinarica*			4	PT, CN	Sieve
NV	43.423056	18.308889	2. 6. 2023	*Chloroperla tripunctata*	2	6		PT, CN	Handnet
NV	43.423056	18.308889	2. 6. 2023	*Synagapetus iridipennis*			5	PT, CN	Sieve
NV	43.331111	18.421667	2. 6. 2023	*Dinocras megacephala*	1	2		PT, CN	Handnet
NV	43.331111	18.421667	2. 6. 2023	*Beraea pullata*	1			PT, CN	Handnet
NV	43.331111	18.421667	2. 6. 2023	*Drusus radovanovici*	1	4		PT, CN	Handnet
NV	43.331111	18.421667	2. 6. 2023	*Perla marginata*	2	4		PT, CN	Handnet
NV	43.331111	18.421667	2. 6. 2023	*Leuctra hippopoides*		3		PT, CN	Handnet
NV	43.331111	18.421667	2. 6. 2023	*Leuctra inermis* gr.	3	3		PT, CN	Handnet
NV	43.331111	18.421667	2. 6. 2023	*Stenophylax mitis*		1		PT, CN	Handnet
NV	43.331111	18.421667	2. 6. 2023	*Brachyptera tristis*	1			PT, CN	Handnet
NV	43.331111	18.421667	2. 6. 2023	*Amphinemura sulcicollis*	1	2		PT, CN	Handnet
NV	43.331111	18.421667	2. 6. 2023	*Protonemura intricata*		1		PT, CN	Handnet
NV	43.416667	18.313056	2. 6. 2023	*Dinocras megacephala*	1			PT, CN	Lighttrap
NV	43.416667	18.313056	2. 6. 2023	*Perla marginata*	1			PT, CN	Lighttrap
NV	43.416667	18.313056	2. 6. 2023	*Silo piceus*	1			PT, CN	Lighttrap
NV	43.416667	18.313056	2. 6. 2023	*Brachycentrus montanus*	2			PT, CN	Lighttrap
NV	43.416667	18.313056	2. 6. 2023	*Odontocerum albicorne*	1	5		PT, CN	Lighttrap
NV	43.416667	18.313056	2. 6. 2023	*Ecclisopteryx keroveci*	1			PT, CN	Lighttrap
NV	43.416667	18.313056	2. 6. 2023	*Potamophylax luctuosus*	2			PT, CN	Lighttrap
NV	43.416667	18.313056	2. 6. 2023	*Stenophylax mitis*		1		PT, CN	Lighttrap
KR	43.329538	18.425545	3. 6. 2023	*Perla marginata*	1			PT, CN	Handnet
KR	43.329538	18.425545	3. 6. 2023	*Drusus radovanovici*	3			PT, CN	Handnet

River	Longitude	Latitude	Date	Taxon	M	W	L	Leg.	Method
KR	43.329538	18.425545	3. 6. 2023	*Potamophylax luctuosus*	1			PT, CN	Handnet
KR	43.330444	18.427254	3. 6. 2023	*Chloroperla tripunctata*	2	2		PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Drusus schmidi*			1	PT, CN	Sieve
KR	43.330444	18.427254	3. 6. 2023	*Isoperla tripartita* gr.		2		PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Protonemura intricata*	5	5		PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Leuctra hippopoides*		2		PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Leuctra inermis* gr.	2			PT, CN	Lighttrap
KR	43.329538	18.425545	3. 6. 2023	*Brachyptera tristis*		1		PT, CN	Handnet
KR	43.330444	18.427254	3. 6. 2023	*Protonemura auberti*	2			PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Amphinemura sulcicollis*	2			PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Nemurella pictetii*		1		PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Diplectrona atra*		1		PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Brachyptera tristis*	1	1		PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Amphinemura triangularis*	1	12		PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Rhyacophila loxias*	3			PT, CN	Lighttrap
KR	43.330444	18.427254	3. 6. 2023	*Potamophylax luctuosus*	1	1		PT, CN	Lighttrap
NV	43.375833	18.358056	3. 6. 2023	*Dinocras megacephala*		1	2	PT, CN	Handnet, Sieve
NV	43.375833	18.358056	3. 6. 2023	*Perla marginata*	4	4	3	PT, CN	Handnet, Sieve
NV	43.375833	18.358056	3. 6. 2023	*Amphinemura sulcicollis*	2			PT, CN	Lighttrap
NV	43.375833	18.358056	3. 6. 2023	*Protonemura intricata*	2	7		PT, CN	Lighttrap
NV	43.375833	18.358056	3. 6. 2023	*Chloroperla tripunctata*		2		PT, CN	Lighttrap
NV	43.331111	18.421667	3. 6. 2023	*Dinocras megacephala*		1		PT, CN	Handnet
NV	43.331111	18.421667	3. 6. 2023	*Ecclisopteryx keroveci*			4	PT, CN	Sieve
NV	43.331111	18.421667	3. 6. 2023	*Perla marginata*	1			PT, CN	Handnet
NV	43.331111	18.421667	3. 6. 2023	*Drusus radovanovici*	1			PT, CN	Handnet
NV TR	43.340556	18.4125	3. 6. 2023	*Rhyacophila tristis*	2	1		PT, CN	Handnet
NV TR	43.340556	18.4125	3. 6. 2023	*Diplectrona atra*	1		1	PT, CN	Handnet, Sieve
NV TR	43.340556	18.4125	3. 6. 2023	*Beraeamyia schmidi*			1	PT, CN	Sieve
NV TR	43.340556	18.4125	3. 6. 2023	*Brachyptera seticornis*		2		PT, CN	Handnet
NV TR	43.340556	18.4125	3. 6. 2023	*Protonemura intricata*		1		PT, CN	Handnet
NV TR	43.340556	18.4125	3. 6. 2023	*Brachyptera tristis*		1		PT, CN	Handnet
NV TR	43.340556	18.4125	3. 6. 2023	*Wormaldia bosniaca*	2			PT, CN	Handnet
J	43.411389	18.283889	4. 6. 2023	*Perla marginata*		1		CN	Handnet
J	43.411389	18.283889	4. 6. 2023	*Protonemura intricata*	2	1		CN	Handnet
J	43.411389	18.283889	4. 6. 2023	*Brachyptera seticornis*		1		CN	Handnet
J	43.411389	18.283889	4. 6. 2023	*Isoperla tripartita* gr.	1			CN	Handnet
J	43.411389	18.283889	4. 6. 2023	*Amphinemura triangularis*		1		CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Protonemura intricata*	5	5		CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Rhyacophila polonica*	3			CN	Handnet
J	43.411389	18.283889	4. 6. 2023	*Brachyptera tristis*		10		CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Synagapetus iridipennis*	1	4		CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Nemoura cinerea*	1	1		CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Brachyptera tristis*	1			CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Protonemura intricata*	4	4		CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Wormaldia bosniaca*	4	4		CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Leuctra hippopoides*	1			CN	Handnet

River	Longitude	Latitude	Date	Taxon	M	W	L	Leg.	Method
J	43.410000	18.267222	4. 6. 2023	*Rhyacophila loxias*	1			CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Isoperla tripartita* gr.	1			CN	Handnet
J	43.410000	18.267222	4. 6. 2023	*Brachyptera beali*	1	2		CN	Handnet
J TR	43.411423	18.283712	4. 6. 2023	*Perla marginata*		1		CN	Handnet
LJ	43.510185	18.308297	4. 6. 2023	*Perla marginata*		1		TS	Handnet
LJ	43.535593	18.300643	4. 6. 2023	*Perla marginata*	1			TS	Handnet
LJ	43.55606	18.30388	4. 6. 2023	*Drusus radovanovici*		1		TS	Handnet
LJ	43.55606	18.30388	4. 6. 2023	*Leuctra hippopoides*		1		TS	Handnet
LJ	43.55606	18.30388	4. 6. 2023	*Protonemura auberti*		1		TS	Handnet
LJ	43.55606	18.30388	4. 6. 2023	*Brachyptera tristis*	6	5		TS	Handnet
LJ	43.55606	18.30388	4. 6. 2023	*Brachyptera seticornis*		2		TS	Handnet
LJ	43.55606	18.30388	4. 6. 2023	*Brachyptera beali*	1			TS	Handnet
LJ	43.556120	18.303693	4. 6. 2023	*Perla marginata*		1		TS	Handnet
LJ	43.556120	18.303693	4. 6. 2023	*Ecclisopteryx keroveci*			6	TS	Sieve
LJ	43.556120	18.303693	4. 6. 2023	*Nemoura minima*	1			GS	Handnet
LJ	43.556120	18.303693	4. 6. 2023	*Amphinemura sulcicollis*	1			GS	Handnet
LJ	43.556120	18.303693	4. 6. 2023	*Rhyacophila loxias*			1	GS	Sieve
LJ	43.563660	18.303400	4. 6. 2023	*Perla marginata*	2	12		GS	Handnet
LJ	43.563660	18.303400	4. 6. 2023	*Drusus radovanovici*		1		GS	Handnet
LJ	43.563660	18.303400	4. 6. 2023	*Brachyptera seticornis*		3		GS	Handnet
LJ	43.60012	18.308872	4. 6. 2023	*Perla marginata*	1	11		GS	Handnet
LJ	43.60012	18.308872	4. 6. 2023	*Protonemura intricata*		2		GS	Handnet
LJ	43.60012	18.308872	4. 6. 2023	*Leuctra inermis* gr.		1		GS	Handnet
LJ	43.60012	18.308872	4. 6. 2023	*Philopotamus montanus*	1			GS	Handnet
LJ	43.60012	18.308872	4. 6. 2023	*Leuctra hippopoides*		1		GS	Handnet
LJ	43.60012	18.308872	4. 6. 2023	*Brachyptera tristis*		2		GS	Handnet
LJ	43.60012	18.308872	4. 6. 2023	*Beraeamyia schmidi*			2	GS	Sieve
NV	43.375833	18.358056	4. 6. 2023	*Silo piceus*	1	2		PT, CN	Lighttrap
NV	43.375833	18.358056	4. 6. 2023	*Brachycentrus montanus*	4			PT, CN	Lighttrap
NV	43.375833	18.358056	4. 6. 2023	*Potamophylax luctuosus*		5		PT, CN	Lighttrap
NV	43.375833	18.358056	4. 6. 2023	*Perla marginata*	1			PT, CN	Lighttrap
NV	43.375833	18.358056	4. 6. 2023	*Hydropsyche dinarica*	6	6		PT, CN	Lighttrap
NV	43.375833	18.358056	4. 6. 2023	*Synagapetus slavorum*	1			PT, CN	Lighttrap
NV	43.416667	18.313056	4. 6. 2023	*Perla marginata*	1			PT, CN	Lighttrap
NV	43.416667	18.313056	5. 6. 2023	*Rhyacophila nubila*		1		PT, CN	Lighttrap
NV	43.416667	18.313056	5. 6. 2023	*Odontocerum albicorne*	3			PT, CN	Lighttrap
NV	43.416667	18.313056	5. 6. 2023	*Stenophylax mitis*		2		PT, CN	Lighttrap
NV	43.416667	18.313056	5. 6. 2023	*Brachycentrus montanus*	2			PT, CN	Lighttrap
NV	43.416667	18.313056	5. 6. 2023	*Hydropsyche dinarica*		1		PT, CN	Lighttrap

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 140–147
»Neretva Science Week 2023«

KRATKA ZNANSTVENA VEST /
SHORT COMMUNICATION

DOI: 10.14720/ns.20047
Objavljeno na spletu / Published online: 12. 11. 2025

Prejeto / Received: 24. 10. 2024
Sprejeto / Accepted: 30. 4. 2025

Assessing soil biodiversity in different land uses of the Nevesinje Field

Vid NAGLIČ

ABSTRACT

This study investigates soil biodiversity in agricultural landscapes and focuses on the Nevesinje field in Bosnia and Herzegovina, which was sampled as part of the Neretva Science Week 2023. Soil microarthropods, including mites and springtails, play an important role in ecosystem health through nutrient cycling and organic matter decomposition. Using separate approaches — morphological techniques with the QBS-ar index and metabarcoding of DNA extracted from soil samples — we investigated the diversity and abundance of soil microarthropods at different sites. Our results showed that the arable field had the highest abundance of soil microarthropods, especially Acarina and Collembola, while the orchard had the lowest abundance but the highest QBS-ar value, which reflects higher soil quality according to the QBS-ar index. Insects (Insecta) dominate with 68.6% of identified taxa, followed by arachnids (Arachnida) with 20.2%. The arable field next to the Zalomka River showed the highest taxonomic richness. The area faces imminent threats from the proposed dam construction, which could alter the hydrological dynamics and integrity of the habitat. Continued monitoring and further sampling are important to assess the ecological impact and develop conservation strategies to maintain soil biodiversity amid developmental pressures.

IZVLEČEK

Ocenjevanje biodiverzitete različnih tipov rabe tal na Nevesinjskem polju

Ta študija raziskuje biotsko raznovrstnost tal v kmetijski krajini Nevesinjskega polja v Bosni in Hercegovini, ki je bilo vzorčeno v okviru Neretva Science Week 2023. Talni mikronevretenčarji, vključno s pršicami in skakači, imajo pomembno vlogo pri zdravju ekosistema z vplivom na kroženje hranil in razgradnjo organske snovi. Z dvema različnima pristopoma, morfološkimi tehnikami z indeksom QBS-ar in metabarkodiranjem DNK iz talnih vzorcev, smo raziskali raznolikost in številčnost talnih organizmov na različnih lokacijah. Naši rezultati so pokazali, da je imela njiva največjo številčnost talnih mikronevretenčarjev, zlasti Acarina in Collembola, medtem ko je imel sadovnjak najmanjšo številčnost, vendar najvišjo vrednost QBS-ar, kar kaže na visoko kakovost tal glede na QBS. Taksonomska analiza DNK je pokazala prevlado žuželk (Insecta) s 68,6 %, z 20,2 % so pomembno prispevali še pajkovci (Arachnida). Njiva ob reki Zalomki je bila najbolj taksonomsko pestra od vseh zbranih vzorcev. To območje se sooča z neposrednimi grožnjami zaradi predlagane gradnje jezu, ki bi lahko spremenila hidrološko dinamiko in celovitost habitata. Stalno spremljanje in nadaljnje vzorčenje je pomembno za oceno ekološkega vpliva in razvoj strategij za ohranjanje biotske raznovrstnosti tal v luči razvojnih pritiskov.

Agricultural institute of Slovenia,
Hacquetova ulica 17, SI-1000 Ljubljana,
Slovenia; E-mail: vid.naglic@kis.si

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

KEY WORDS:
soil microarthropods, DNA metabarcoding, QBS-ar, mesofauna, Upper Horizons project

KLJUČNE BESEDE:
talni mikronevretenčarji, DNA metabarkodiranje, QBS-ar, mezofavna, projekt Gornji Horizonti

KLJUČNE RIJEČI:
mikroartropodi u zemljištu, DNK metabarkodiranje, QBS-ar, mezofauna, projekat Gornji Horizonti

APSTRAKT

Procjena biodiverziteta različitih tipova korištenja zemljišta u Nevesinjskom polju

Ova studija istražuje biodiverzitet zemljišta u poljoprivrednom području Nevesinjskog polja u Bosni i Hercegovini, koji je proučavan u okviru Sedmice nauke Neretva 2023. Zemljišni mikroartropodi, uključujući grinje i skokune, igraju važnu ulogu u održanju zdravih ekosistema utičući na kruženje hranjivih materija i razgradnju organske materije. Koristeći dva različita pristupa, morfološke tehnike s QBS-ar indeksom i metabarkodiranje DNK iz uzoraka zemljišta, istražili smo raznolikost i brojnost organizama u zemljištu na različitim lokacijama. Naši rezultati su pokazali da je obradivo zemljište imalo najveću zastupljenost mikroinvertebrata, posebno Acarina i Collembola, dok je voćnjak imao najmanju zastupljenost, ali najvišu QBS-ar vrijednost, što ukazuje na visok kvalitet zemljišta prema QBS indeksu. Insekti (Insecta) dominiraju sa 68,6 % identifikovanih taksona, a slijede ih paukoliki zglavkari (Arachnida) sa 20,2 %. Obradivo zemljište uz rijeku Zalomku bilo je taksonomski najraznovrsnije od svih prikupljenih uzoraka. Ovo područje se suočava sa neposrednim prijetnjama zbog predložene izgradnje brane, koja bi mogla promijeniti hidrološku dinamiku i integritet staništa. Kontinuirano praćenje i dalje uzorkovanje su važni za procenu ekološkog uticaja i razvoj strategija zaštite kako bi se održao biodiverzitet zemljišta usled razvojnih pritisaka.

INTRODUCTION

Soil microarthropods are crucial for maintaining soil health and play a key role in ecosystem stability through processes such as nutrient cycling and organic matter decomposition (Wall & Lynch 2000; Coleman et al. 2004). Despite their importance, these small soil organisms are often overlooked when assessing soil quality (Parisi et al. 2005). In agricultural landscapes, especially those exposed to anthropogenic pressures, the diversity and abundance of soil microarthropods can serve as important indicators of ecosystem health and resilience (Menta 2012; Postma-Blaauw et al. 2010). The Nevesinje field in Bosnia and Herzegovina is an agriculturally important region that mostly features traditional extensive type of agriculture. That area could soon experience significant environmental changes due to the planned construction of a dam (Gallop 2023). Such developments may lead to changes in land use and potentially affect soil biodiversity (Foley et al. 2005). In order to assess the potential ecological impact of such infrastructure projects, it is important to understand the current biodiversity of soil organisms in this region. The aim of our research was to assess the biodiversity of soil microarthropods in the Nevesinje field using two complementary approaches: morphological analysis with the QBS-ar index and DNA metabarcoding (defined here as DNA extracted from homogenized bulk soil samples without prior removal of soil organisms, also referred to as eDNA). The former provides a qualitative assessment of soil biological quality based on the presence of soil-adapted microarthropods (Parisi et al. 2005), while the latter provides a detailed genetic insight into the soil community and identifies organisms that may be missed by conventional microscopy (Taberlet et al. 2012, 2018). Morphological analysis is highly time-consuming, requiring careful extraction and identification of microarthropods, which limited the number of samples that could be processed. Due to time constraints, we were only able to collect morphological samples from three sites, while DNA metabarcoding was applied to samples from six sites. We hypothesized that the agricultural land of the Nevesinje field would harbor a rich and diverse soil fauna due to its habitat diversity (Wardle et al. 2004). By combining traditional morphological techniques with modern genetic tools, this study aims to provide a basic understanding of soil biodiversity in this little-studied region.

MATERIAL AND METHODS

STUDY AREA AND SAMPLING

Soil samples were collected from six sites within the Nevesinje field, Bosnia and Herzegovina, representing different types of agricultural use. They included a meadow, an orchard, an arable field, a riparian habitat, an arable field near Zalomka river, and an oak forest. These locations were chosen on the basis of land use and proximity to the proposed dam construction site.

GPS coordinates were recorded for each sampling location:

- Meadow: N 43.184816, E 18.160509 (QBS, DNA)
- Orchard: N 43.179056, E 18.158028 (QBS, DNA)
- Arable field: N 43.178778, E 18.157995 (QBS, DNA)
- Riparian habitat near Zalomka river: N 43.210843, E 18.221617 (DNA)
- Arable field near Zalomka river: N 43.211345, E 18.222782 (DNA)
- Oak forest: N 43.185420, E 18.121981 (DNA)

Sampling was conducted over two days (5. and 6. 6. 2023), approximately at the same time of the day. Descriptions of sampling locations are included in the supplementary material. Samples for morphological analysis (QBS-ar) were taken at three sites (arable field, meadow, orchard). At each, three subsamples of soil were taken from the top 10 cm of the soil profile using a soil corer with a diameter of 11.3 cm. Samples for DNA analysis were collected at six sites. On each site, three subsamples for DNA analysis were collected, using the same sampling technique as for the QBS. Subsamples were joined and manually homogenized in the field. Both the QBS and DNA samples were stored in a cool box immediately after collection to preserve their integrity. Three days after sampling, the QBS samples were processed using a Kempson extractor with the organisms heat-extracted and stored in ethanol, while the DNA samples were frozen until subsequent analysis.

MORPHOLOGICAL ANALYSIS

Morphological analysis of soil samples was performed using the QBS-ar (Biological Soil Quality Index) method (Parisi et al. 2005). This index assesses soil biological quality by examining the presence of soil microarthropods with morphological adaptations to life in the soil. The organisms were identified to class or order level under a stereomicroscope, and a combined value of QBS-ar was calculated for each site based on three collected samples. The QBS-ar index is calculated as the sum of the Ecomorphological Index (EMI) values assigned to taxa identified in the sample. EMI values range from 1 to 20, with higher values assigned to taxa with greater adaptation to soil life. In addition, the abundance of animals was recorded in all subsamples.

DNA EXTRACTIONS FROM SOIL, LIBRARY PREPARATIONS, SEQUENCING AND BIOINFORMATIC ANALYSIS

Six composite samples underwent DNA analysis using the DNeasy PowerLyzer PowerSoil isolation kit (Qiagen, Denmark). Approximately 40 ml of soil per sample was used. Soil samples were freeze-dried for 72 hours and homogenized with a Bead Ruptor Elite (Omni International) at 4 m s^{-1} for 30 seconds, the process was repeated three times. For the PowerSoil extractions, 0.25 g of homogenized soil was used, following the manufacturer's instructions. DNA concentrations were quantified using a Qubit 4.0 Fluorometer (Invitrogen, USA). The COI region was amplified with mlCOIintF/jgHCO2198 primers (Geller et al. 2013) using a two-step PCR and dual indexing for Illumina MiSeq sequencing. Final PCR products were cleaned with HighPrep™ magnetic beads (MagBio Genomics Inc.) and pooled for sequencing. Illumina reads were processed in QIIME2 (v2020.10.0) (Bolyen et al. 2019), where primer sequences were trimmed, and reads truncated after 230 base pairs. Reads were filtered, denoised, merged, and dereplicated using DADA2 (Callahan et al. 2016), producing Amplicon Sequence Variants (ASVs). Details about the number of reads before and after processing are included in the supplementary material. Taxonomic classification was performed via BLAST against the NCBI database (Sayers et al. 2022). ASVs associated with the thirty-three taxonomic groups used for QBS-ar index identification were retained, including soil microarthropods (e.g. Acari, Collembola), myriapods (Diplopoda, Chilopoda, Pauropoda, Symphyla), isopods, insects (Coleoptera, Hymenoptera, Diptera), and other soil-dwelling arthropods. Data analysis and visualization were conducted in Python, version 3.13.

RESULTS AND DISCUSSION

We morphologically identified individuals in the soil samples to the level of morphospecies and counted cumulative abundance of important classes, number of EMI groups and QBS-ar index, for three sites. The arable field and orchard had QBS-ar values higher than 93.7 (Tab. 1), the tentative threshold value to distinguish high-quality soils (Menta et al. 2018), while the meadow had a lower QBS-ar value (Tab. 1). Based on morphological identification, the arable field had the most EMI groups, followed by the meadow and the orchard (Tab. 1). The arable field had the highest cumulative abundance (absolute counts of individuals) of soil microarthropods, especially mites (Acarina) and springtails (Collembola) (Fig. 1), while meadow and orchard had lower cumulative abundances.

Table 1. QBS-ar index and number of ecomorphological (EMI) groups for each site.

Tabela 1. Indeks QBS-ar in število ekomorfoloških (EMI) skupin za vsako lokacijo.

Tabela 1. QBS-ar indeks i broj ekomorfoloških (EMI) grupa za svaki lokalitet.

Site	QBS-ar	Number of EMI groups
Arable Field	102	14
Orchard	106	11
Meadow	86	12

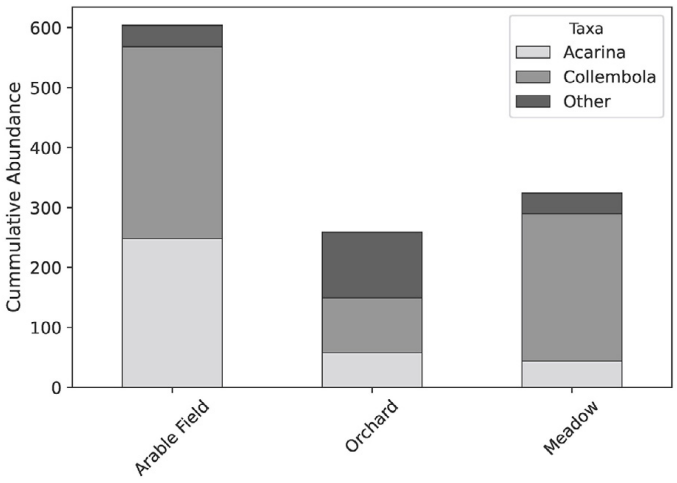

Figure 1. Cumulative abundance of soil microarthropods for each site.

Slika 1. Kumulativna številčnost talnih mikronevretenčarjev za vsako lokacijo.

Slika 1. Kumulativna brojnost mikroartropoda u tlu za svaki lokalitet.

We acknowledge that statistical comparison between different localities cannot be made, since we do not have biological replicates. However, the first results are in congruence with our expectations for all analysed types of soil. For example, low QBS-ar value of the meadow can be explained with lower plant diversity and soil compaction due to grazing or use of machinery, which can have a negative effect on the microarthropod communities in the soil, resulting in lower diversity and abundance of soil microarthropods (Wardle et al. 2004; Beylich et al. 2010). The reason could also be the low organic matter content in the soil, which may limit the availability of food resources necessary to sustain a diverse and abundant microarthropod community, although this was not directly tested as no physico-chemical analysis of the soil was conducted. Overall, first insights based on QBS-ar index point to the fact that agricultural land of the Nevesinje field indeed harbors a rich and diverse soil fauna.

Next, we employed the DNA metabarcoding approach to analyse the taxonomic composition of soil microarthropods at six different sites. We filtered out ASVs associated with fauna groups used in QBS-ar index and analysed taxon richness (Fig. 2) and relative abundance of most represented classes and orders (Fig. 3).

Taxon richness for each site was calculated as the number of unique ASVs identified and assigned to analysed taxonomic groups, for each site (Fig. 2). The agricultural lands had higher taxon richness of soil related taxa than natural habitats. These results are preliminary and based on a single sampling event, yet they align with several studies, that showed that agricultural practices, particularly in arable fields, may promote soil biodiversity by increasing organic matter and creating diverse microhabitats, which are known to increase the diversity of soil microarthropods (Mäder et al. 2002; Wardle et al. 2004). In contrast, the riparian habitat and the meadow had lower taxon richness, probably due to specific habitat characteristics that limit the occurrence of certain soil taxa. Riparian zones, although dynamic, can also have fluctuating moisture levels that may limit the diversity of certain soil fauna (Naiman & Décamps 1997). Meadows, on the other hand, may have lower taxon richness due to factors already described in the first part of the results chapter: we obtained similar results by means of morphological identification with the meadow having the lowest QBS-ar score out of the three sampled sites. These patterns we observe may also reflect the fact that certain habitats (i.e. those used for QBS assessment) inherently contain fewer taxa that were included in our analysis. Additionally, limitations in

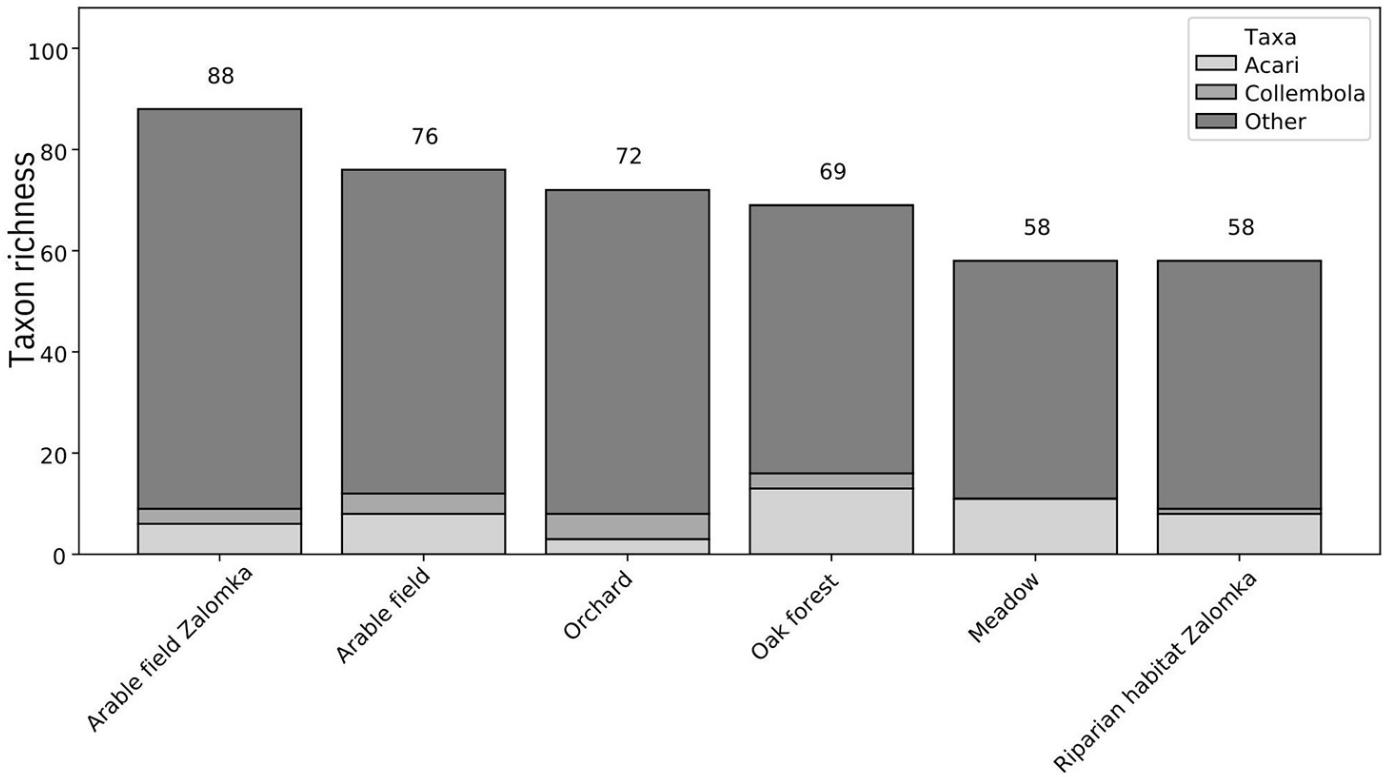

Figure 2. Taxon richness across various habitats. The numbers above each bar represent the total taxon richness (calculated as the number of unique ASVs identified) for each habitat. The bar colors indicate the proportional contributions of Acari (light gray), Collembola (dark gray), and other taxa (black) to the total richness.

Slika 2. Taksonomska pestrost v različnih habitatih. Številke nad posameznimi stolpci predstavljajo skupno taksonomsko pestrost (izraženo kot število unikatnih ASV-jev, ki so bili identificirani) za vsak habitat. Barve stolpcev označujejo proporcionalni prispevek pršic (Acari) (svetlo siva), skakačev (Collembola) (temno siva) in drugih taksonov (črna) k skupni pestrosti.

Slika 2. Taksonomsko bogastvo vrstama u različitim staništima. Brojevi iznad svake kolone predstavljaju ukupnu taksonomsko bogastvo (izraženu kao broj jedinstvenih ASV-ova koji su identifikovani) za svako stanište. Boje u stupcima označavaju proporcionalni doprinos grinja (Acari) (svijetlosiva), skokuna (Collembola) (tamnosiva) i ostalih taksona (crna) ukupnoj raznolikosti.

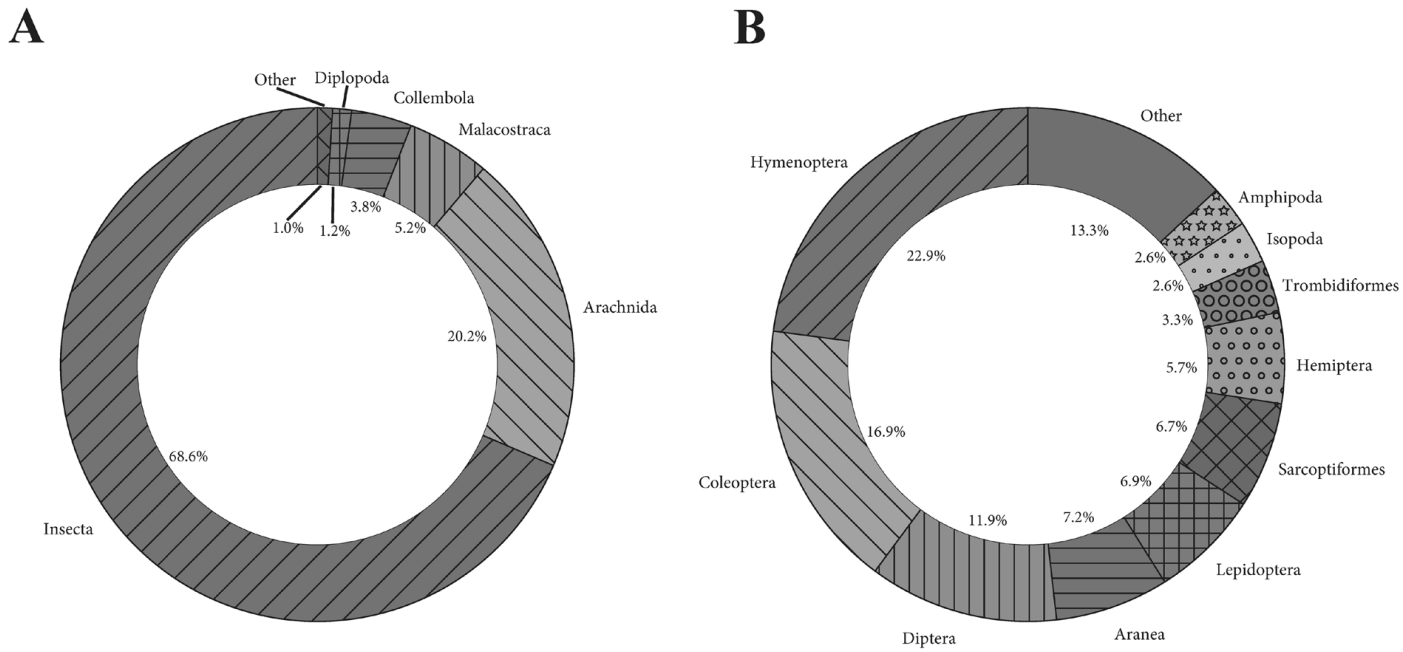

Figure 3. Relative abundance of taxonomic classes (A) and orders (B) of soil microarthropods across all sampling sites.

Slika 3. Relativna številčnost taksonomskih razredov (A) in redov (B) talnih mikronevretenčarjev na vseh vzorčnih mestih.

Slika 3. Relativna brojnost taksonomskih klasa (A) i redova (B) mikroartropoda u zemljištu na svim mjestima uzorkovanja.

taxonomic databases, particularly for some microarthropod groups, or the relatively low number of our samples, combined with the rapid, non-replicated sampling approach, could have influenced the observed richness patterns. With the given time constraints, this was the most comprehensive assessment we could achieve.

The taxonomic composition of soil invertebrates derived from the DNA metabarcoding analysis for different habitats is shown in the pie charts in Fig. 3. The left-hand diagram (Fig. 3A) shows the distribution of ASVs across the five most represented classes. Insects (Insecta) account for 68.6% of the ASVs identified, followed by arachnids (Arachnida) with 20.2%. Other classes, such as Malacostraca, Collembola, and Diplopoda, were represented at lower percentages. The diagram on the right (Fig. 3B) shows the distribution of ASVs assigned to the ten most represented orders in our dataset. Hymenoptera accounted for 22.9% of the identified ASVs, followed by Coleoptera with 16.9%. It is important to note that these percentages represent the proportion of ASVs classified within each order, not the actual abundance of organisms in the soil community. The observed percentages reflect the taxonomic resolution achieved through DNA metabarcoding, which depends on reference databases and the biases associated with PCR amplification.

When comparing these results with morphological identification, it is important to note that the two different approaches – morphology-based abundance and DNA-based diversity of soil microarthropods – do not necessarily correlate. Nevertheless, we find that two orders of mites (Sarcoptiformes and Trombidiformes) are among the most represented orders in our DNA analysis, and they were also abundant in morphological analysis. In contrast, Collembola were among the most abundant taxa in the morphological results but was only represented at the class level in the DNA data. Different Collembola orders were included in the »Other« category in Fig. 3B because their relative representation among the identified ASVs was insufficient to rank them among the top ten orders. We also found that many Collembola sequences could not be identified at a higher taxonomic resolution, possibly due to the limited capabilities of the reference databases for Collembola in the soil. This highlights the challenges in metabarcoding studies associated with incomplete reference libraries, which can hinder accurate taxonomic assignment (Porco et al. 2013). Improving these databases is crucial to increase the resolution and reliability of metabarcoding in soil biodiversity assessment.

The results should be interpreted as the first qualitative observations in the area rather than definitive conclusions about soil diversity. This is a snapshot study based on a single sampling event, which does not account for biological replicates, temporal variability or the full extent of soil biodiversity. However, it offers the first insight into soil diversity of this remote, understudied and critically endangered area. The results highlight the ecological significance of the study area, suggesting that the relatively high soil quality in agricultural lands may be attributed to a combination of extensive farming and traditional agricultural practices. This biodiversity is threatened by the planned dam construction, which could disrupt hydrological patterns, destroy and fragment habitats and ultimately reduce the richness and abundance of the soil microarthropods. Fast changes in water flow and habitat structure could lead to the loss of important microhabitats. Given the potential impact on this fragile ecosystem, continuous sampling is essential to monitor these changes and develop strategies to protect soil biodiversity in the face of development pressure. This study represents the first attempt to assess the quality of soil, using a combination of traditional and DNA techniques in this area. We hope that it will shed some light on this hidden yet important ecosystem, which is tightly connected with local traditions and human use of the landscape.

POVZETEK

V raziskavi smo preučevali biotsko raznovrstnost talnih organizmov na območju Nevesinjskega polja v Bosni in Hercegovini, kjer načrtovana gradnja jezu predstavlja potencialno grožnjo za tamkajšnji ekosistem. Zbrali smo vzorce tal na šestih različnih lokacijah, ki vključujejo dve njivi, sadovnjak, travnik, obrežni habitat ob reki Zalomki in hrastov gozd. Raziskava je temeljila na dveh pristopih: morfološki analizi preko QBS-ar indeksa ter DNA metabarkodiranju, kar nam je omogočilo vpogled v genetsko pestrost talnih organizmov. Morfološki rezultati kažejo, da je bila največja številčnost talnih mikronevretenčarjev, predvsem pršic (Acarina) in skakačev (Collembola), zaznana na njivi, medtem ko je imel sadovnjak najmanjšo številčnost, a najvišji QBS-ar indeks (106), ki nakazuje na visoko biološko kakovost tal. Nasprotno je bil QBS-ar indeks na njivi 102, na travniku pa 86. Z metabarkodiranjem smo največjo taksonomsko pestrost mikronevretenčarjev zaznali na njivi ob reki Zalomki, kar kaže na bogato biotsko raznovrstnost tega območja, medtem ko sta travnik in obrežni habitat pokazala nižjo pestrost. Taksonomska analiza DNA je razkrila prevlado žuželk (Insecta), ki so predstavljale 68,6 % vseh prepoznanih taksonov, z znatno prisotnostjo pajkovcev (Arachnida) (20,2 %). Med najbolj pogostimi redovi so bili kožekrilci (Hymenoptera) in hrošči (Coleoptera). Red Collembola je bil vključen v analizo, vendar njihova relativna številčnost taksonomskih skupin ni dosegla prve deseterice kljub temu, da so bile glede na morfološke rezultate vsaj v nekaterih vzorcih najštevilčnejše, kar nakazuje na potrebo po izboljšanih podatkovnih bazah za njihovo natančnejšo identifikacijo. Ti rezultati kažejo na pomembno biotsko raznovrstnost Nevesinjskega polja, ki pa je zaradi načrtovane gradnje jezu resno ogrožena. Nadaljnje spremljanje stanja in dodatno vzorčenje sta ključnega pomena za oceno dolgoročnih ekoloških posledic in za razvoj strategij, ki bodo zagotovile ohranitev talne biotske raznovrstnosti v tem občutljivem okolju.

SAŽETAK

Tokom istraživanja smo proučavali biodiverzitet organizama u zemljištu na području Nevesinjskog polja u Bosni i Hercegovini, gdje planirana izgradnja brane predstavlja potencijalnu prijetnju lokalnim ekosistemima. Uzorke zemljišta prikupili smo na šest različitih lokacija, uključujući dva obradiva polja, voćnjak, livadu, priobalno stanište uz rijeku Zalomku i hrastovu šumu. Istraživanje je zasnovano na dva pristupa: morfološkoj analizi putem QBS-ar indeksa i DNK metabarkodiranju, što nam je omogućilo da steknemo uvid u genetsku raznolikost organizama u zemljištu. Morfološki rezultati pokazuju da je najveća brojnost mikroartropoda u zemljištu, uglavnom grinja (Acarina) i skokuna (Collembola), otkrivena na polju, dok je voćnjak imao najmanju brojnost, ali najviši QBS-ar indeks (106), što ukazuje na visok biološki kvalitet tla. Nasuprot tome, QBS-ar indeks na polju je bio 102, a na livadi 86. Korištenjem metabarkodiranja, detektovali smo najveću taksonomsku raznolikost mikroinvertebrata na polju uz rijeku Zalomku, što ukazuje na bogatu biodiverzitet ovog područja, dok su livadsko i priobalno stanište pokazali nižu raznolikost. Taksonomska analiza DNK otkrila je dominaciju insekata (Insecta), koji su predstavljali 68,6% svih prepoznatih taksona, sa značajnim prisustvom paučnjaka (Arachnida) (20,2%). Među najčešćim redovima bili su Hymenoptera i Coleoptera. Red Collembola je uključen u analizu, ali njihova relativna brojnost taksonomskih grupa nije dostigla prvih deset uprkos tome što su bili najbrojniji prema morfološkim rezultatima u barem nekim uzorcima, što ukazuje na potrebu za poboljšanim bazama podataka za njihovu precizniju identifikaciju. Ovi rezultati ukazuju na važan biodiverzitet Nevesinjskog polja, koji je ozbiljno ugrožen planiranom izgradnjom brane. Daljnje praćenje i dodatno uzorkovanje ključni su za procjenu dugoročnih ekoloških posljedica i razvoj strategija koje će osigurati očuvanje biodiverziteta tla u ovom osjetljivom okruženju.

ACKNOWLEDGEMENTS

I would like to thank Špela Di Batista Borko for inviting me to participate in the Neretva Science Week, Marija Kravanja for her invaluable assistance during the fieldwork in Bosnia, Irena Bertoncelj for the introduction to the field of soil biodiversity and the Agricultural Institute of Slovenia for funding this research. I also extend my gratitude to the Environmental Microbiology section at the Department of Environmental Science, Aarhus University, for their support and collaboration. I would also like to acknowledge the Research Infrastructure ELIXIR-SI (https://elixir-slovenia.org), funded by the European Regional Development Fund, the Ministry of Science, Education and Sports, and the Slovenian Research and Innovation Agency, which provided me with the computing resources needed for the bioinformatics analysis.

REFERENCES

Beylich A, Oberholzer H-R, Schrader S, Höper H, Wilke B-M. 2010. Evaluation of soil compaction effects on soil biota and soil biological processes in soils. Soil Tillage Research. 109(2): 133-143. https://doi.org/10.1016/j.still.2010.05.010

Bolyen E, Rideout JR, Dillon MR, Bokulich NA, Abnet CC, Al-Ghalith GA, Alexander H, Alm EJ, Arumugam M, Asnicar F, et al. 2019. Reproducible, interactive, scalable and extensible microbiome data science using QIIME 2. Nature Biotechnology. 37(8): 852-857. https://doi.org/10.1038/s41587-019-0209-9

Callahan BJ, McMurdie PJ, Rosen MJ, Han AW, Johnson AJA, Holmes SP. 2016. DADA2: High-resolution sample inference from Illumina amplicon data. Nature Methods. 13(7): 581-583. https://doi.org/10.1038/nmeth.3869

Coleman DC, Crossley Jr. DA, Hendrix PF. 2004. Fundamentals of Soil Ecology. 2nd ed. Burlington, MA: Elsevier Academic Press.

Foley JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, et al. 2005. Global consequences of land use. Science. 309(5734): 570-574. https://doi.org/10.1126/science.1111772

Gallop P. 2023. The Upper Horizons complex, Bosnia and Herzegovina. Prague (CZ): Bankwatch Network; [accessed 10. 9. 2024]. https://bankwatch.org/publication/the-upper-horizons-complex-bosnia-and-herzegovina

Geller J, Meyer C, Parker M, Hawk H. 2013. Redesign of PCR primers for mitochondrial cytochrome c oxidase subunit I for marine invertebrates and application in all-taxa biotic surveys. Molecular Ecology Resources. 13(5): 851-861. https://doi.org/10.1111/1755-0998.12138

Mäder P, Fliessbach A, Dubois D, Gunst L, Fried P, Niggli U. 2002. Soil fertility and biodiversity in organic farming. Science. 296(5573): 1694-1697. https://doi.org/10.1126/science.1071148

Menta C. 2012. Soil fauna diversity—Function, soil degradation, biological indices, soil restoration. In: Larramendy ML, Soloneski S, editors. Biodiversity Conservation and Utilization in a Diverse World. Rijeka (HR): InTech. p. 59-94.

Menta C, Conti FD, Pinto S, Bodini A. 2018. Soil Biological Quality index (QBS-ar): 15 years of application at global scale. Ecological Indicators. 85: 773-780. https://doi.org/10.1016/j.ecolind.2017.11.030

Naiman RJ, Décamps H. 1997. The ecology of interfaces: Riparian zones. Annual Review of Ecology and Systematics. 28: 621-658. https://doi.org/10.1146/annurev.ecolsys.28.1.621

Parisi V, Menta C, Gardi C, Jacomini C, Mozzanica E. 2005. Microarthropod communities as a tool to assess soil quality and biodiversity: a new approach in Italy. Agriculture, Ecosystems & Environment. 105(1-2): 323-333. https://doi.org/10.1016/j.agee.2004.02.002

Porco D, Skarżyński D, Decaëns T, Hebert PDN, Deharveng L. 2013. Barcoding the Collembola of Churchill: A molecular taxonomic reassessment of species diversity in a sub-Arctic area. Molecular Ecology Resources. 13(6): 1132-1137. https://doi.org/10.1111/1755-0998.12172

Postma-Blaauw MB, de Goede RGM, Bloem J, Faber JH, Brussaard L. 2010. Soil biota community structure and abundance under agricultural intensification and extensification. Ecology. 91(2): 460-473.

Sayers EW, Bolton EE, Brister JR, Canese K, Chan J, Comeau DC, Connor R, Funk K, Kelly C, Kim S, et al. 2022. Database resources of the national center for biotechnology information. Nucleic Acids Research. 50(D1): D20-D26. https://doi.org/10.1093/nar/gkab1112

Taberlet P, Coissac E, Pompanon F, Brochmann C, Willerslev E. 2012. Towards next-generation biodiversity assessment using DNA metabarcoding. Molecular Ecology. 21(8): 2045-2050. https://doi.org/10.1111/j.1365-294X.2012.05470.x

Taberlet P, Bonin A, Zinger L, Coissac E. 2018. Environmental DNA: For Biodiversity Research and Monitoring. Oxford (UK): Oxford University Press.

Wall D, Lynch JM. 2000. Soil biodiversity and ecosystem functioning. In: Balázs E, Galante E, Lynch JM, Schepers JS, Toutant J-P, Werner D, Werry PAThJ, editors. Biological resource management connecting science and policy. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-662-04033-1_24

Wardle DA, Bardgett RD, Klironomos JN, Setälä H, van der Putten WH, Wall DH. 2004. Ecological linkages between aboveground and belowground biota. Science. 304(5677): 1629-1633. https://doi.org/10.1126/science.1094875

SUPPLEMENTARY MATERIAL

DESCRIPTION OF LOCATIONS

The meadow was a hay meadow with extensive management, showing no visible signs of recent fertilization or heavy grazing. The arable field had been recently ploughed, with no crops present at the time of sampling. The orchard consisted of *Prunus* trees, with a high undergrowth of various grasses and other vegetation, suggesting a less intensively managed system. The riparian habitat near the Zalomka River had a rocky soil structure with scarce vegetation, likely due to occasional flooding that limits plant establishment. The arable field near the Zalomka River was similarly ploughed at the time of sampling, with no visible crops. The oak forest consisted primarily of deciduous oak trees, with a well-developed litter layer and relatively sparse undergrowth, indicating a stable, less-disturbed environment.

Table S1. Sequence processing summary for DNA metabarcoding analysis. Details of the sequence processing pipeline, including the number of raw sequences, sequences retained after quality filtering, denoising, merging, and chimera checking, as well as their respective percentages, for each sample.

Site	Input	Filtered	% Input Passed Filter	Denoised	Merged	% Input Merged	Non-chimeric	% Input Non-chimeric
Oak forest	52599	47691	90.67	44200	36983	70.31	35578	67.64
Meadow	90556	82478	91.08	79486	70565	77.92	60280	66.57
Arable field near Zalomka river	68107	58259	85.54	55795	49413	72.41	47350	69.52
Riparian habitat near Zalomka river	36063	30273	83.94	28275	25423	70.5	24761	68.66
Arable field	76867	65772	85.57	62432	56006	72.86	54729	71.2
Orchard	41986	35864	85.42	33882	30662	73.03	30132	71.77

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

NATURA SLOVENIAE
vol. 27, no. 3 (2025): 148–152
»Neretva Science Week 2023«

KRATKA ZNANSTVENA VEST /
SHORT COMMUNICATION

DOI: 10.14720/ns.19684
Objavljeno na spletu / Published online: 29. 10. 2025

Prejeto / Received: 31. 8. 2024
Sprejeto / Accepted: 14. 3. 2025

Clarifying the picture – complementing field data on large carnivore presence in the area of the Upper Neretva and Ljuta Rivers catchments

Manuela HABE[1],
Emir DELIĆ[2*],
Robert OROZ[3]

[1] Independent researcher, Vienna, Austria;
E-mail: habemanu@gmail.com

[2] Society for biodiversity research and protection, Banjaluka, 501. Slavne brigade 71, Bihać, Bosnia and Herzegovina;
E-mail: emir.delicc@outlook.com

[3] Eko Gotuša Fojnica, Luke 40, 71275 Gojevići, Bosnia and Herzegovina;
E-mail: ekogotusa@gmail.com

* Korespondenčni avtor /
Corresponding author

KEY WORDS:
Bosnia-Herzegovina, large carnivores, Upper Neretva, Ljuta, wildlife corridor, Emerald network

KLJUČNE BESEDE:
Bosna in Hercegovina, velike zveri, Gornja Neretva, Ljuta, koridor za divje živali, omrežje Emerald

KLJUČNE RIJEČI:
Bosna i Hercegovina, velike zvijeri, Gornja Neretva, Ljuta, koridor divljih životinja, Emerald mreža

ABSTRACT

To gain a clearer picture on large carnivores in the Upper Neretva region we exclusively focused on recording evidence of brown bear (*Ursus arctos*), grey wolf (*Canis lupus*), Eurasian lynx (*Lynx lynx*) and wild cat (*Felis silvestris*) presence in the field. For the Neretva Science Week 2023, the research area stretched over the Upper Neretva, the Ljuta and the Zalomka river. Focusing on the Upper Neretva valley, we investigated 87 km of transects and installed camera traps in the predefined focus area. Considering the short research time, we used a participatory approach to complement our data. Two indications of the presence of lynx in the area could not be confirmed within the survey week. With a total of 49 large carnivore records collected, we were able to confirm the presence of brown bear, grey wolf and wild cat for the Upper Neretva Valley, with wolf presence recorded up until Jezero. Bear presence was also confirmed for the Zelengora plateau and close to Nevesinje, while the presence of both species could be confirmed for the Ljuta river and for the Ulog dam reservoir before intense logging and filling.

IZVLEČEK

Razjasnitev slike – dopolnitev terenskih podatkov o prisotnosti velikih zveri na območju porečij gornje Neretve in Ljute

Da bi pridobili boljšo sliko o velikih zvereh na gornji Neretvi, smo se osredotočili izključno na beleženje terenskih znakov rjavega medveda (*Ursus arctos*), sivega volka (*Canis lupus*), evrazijskega risa (*Lynx lynx*) in divje mačke (*Felis silvestris*). Za Neretvanski teden znanosti 2023 se je raziskovalno območje raztezalo čez gornjo Neretvo, Ljuto in reko Zalomko. S poudarkom na dolini gornje Neretve smo preiskali 87 km transektov in namestili foto pasti v vnaprej določenem fokusnem območju. Glede na kratek čas raziskave smo za dopolnitev podatkov uporabili participativni pristop. Dveh indicev o prisotnosti risa na območju nam v tednu raziskave ni uspelo potrditi. S skupno 49 zbranimi zapisi o velikih zvereh smo lahko potrdili prisotnost rjavega medveda, sivega volka in divje mačke v dolini gornje Neretve, in prisotnost volka vse do Jezera. Medtem ko je bila navzočnost medveda potrjena tudi za planoto Zelengore in v bližini Nevesinja, je bilo mogoče prisotnost obeh vrst potrditi za reko Ljuto in za akumulacijo Ulog, v stanju pred intenzivno sečnjo in zalitjem.

APSTRAKT

Pojašnjenje slike – dopuna terenskih podataka o prisutnosti velikih zvijeri na području slivova gornje Neretve i Ljute

Kako bismo dobili jasniju sliku o prisustvu velikih zvijeri u gornjem dijelu rijeke Neretve, fokusirali smo se isključivo na snimanje terenskih znakova prisustva mrkog medvjeda (*Ursus arctos*), sivog vuka (*Canis lupus*), euroazijskog risa (*Lynx lynx*) i divlje mačke (*Felis silvestris*). Za Sedmicu nauke o Neretvi 2023. područje istraživanja protezalo se preko gornje Neretve, Ljute i Zalomke. Sa fokusom na dolinu gornje Neretve, pregledali smo 87 km transekata i postavili fotozamke u unaprijed određene lokalitete. Obzirom na kratko trajanje istraživanja, koristili

Izdatajelj/Issued jointly by: Biotehniška fakulteta Univerze v Ljubljani in Nacionalni inštitut za biologijo / Biotechnical Faculty at University of Ljubljana and National Institute of Biology
Založila/Published by: Založba Univerze v Ljubljani/University of Ljubljana Press

smo participativni pristup za dopunu podataka. Nismo uspjeli potvrditi dvije indikacije o prisutnosti risa na tom području tokom sedmice istraživanja. Sa ukupno 49 prikupljenih zapisa o velikim zvijerima, uspjeli smo potvrditi prisustvo mrkog medvjeda, sivog vuka i divlje mačke u dolini gornje Neretve, te prisustvo vukova sve do lokaliteta Jezero. Prisustvo medvjeda potvrđeno i na visoravni Zelengora i kod Nevesinja, a prisustvo obje vrste moglo je biti potvrđeno na rijeci Ljuta i akumulaciji Ulog, u stanju prije intenzivne sječe i poplava.

INTRODUCTION

Bosnia-Herzegovina, due to its remaining biodiversity hotspots with largely intact wilderness and a high number of rare and threatened species over a range of taxa, is at the heart of wildlife and nature conservation in Europe, which faces big challenges due to a lack of protection measures and the inadequate enforcement of nature protection laws (IMPAQ 2020). The Upper Neretva Valley is a case study for the difficulties of thorough nature conservation implementation, as despite of its importance for the Emerald Network in the Balkans and clear recommendations by the Council of Europe (Assenov et al. 2017; SCCE 2022), its intactness is threatened by habitat fragmentation and bound to change due to the finalization of the Ulog dam and the filling of the large reservoir.

Principally, the collection of basic, qualitative data across taxa should be a natural component in any Environmental Impact Assessment (EIA) before hydropower construction, but the lack of data from the area before the development makes conclusions on its impact difficult (Alho 2011). To account for this and complement the scarce data on large carnivore abundance produced during the previous Science Week (Habe 2023), we joined the second round to clarify the picture on large carnivore distribution in the surroundings of the Upper Neretva, Ljuta and Zalomka river.

Large carnivores are seen as integral parts of functioning ecosystems in a reciprocal relation to species assemblage, environmental productivity, landscape and predation risk and predominantly affected by the potential for human interference in these contexts (Haswell et al. 2017).

With wolves recolonizing vacant habitats in Europe, a rise in the number of human-wildlife conflicts, not only due to livestock predation, have brought them back to the political stage in Europe (Rode et al. 2021; EC 2024). The myriad of effects arising from the change of their conservation status will likely provoke a setback for wolf populations and ongoing conservation and coexistence efforts for large carnivores.

MATERIAL AND METHODS

With the knowledge gained and data collected during the previous year (Habe 2023) and a thorough scouting mission in April 2023, we predefined a focus area for the installation of opportunistic camera traps (CT) on trails (Fig. 1).

In the run-up to the excursion, one CT was set up from 5. to 31. 5. 2023. In addition, 2 CTs were in operation from 29. 5. to 6. 6. 2023 and two more from 1. 6. to 6. 6. 2023. Cameras were set to photo + video (20 s) mode, with the shortest shooting interval.

During the Neretva Science Week 2023 (NSW23) we tracked a total of 87 km of transects (walked 29 km, drove 58 km) corresponding to the research points defined by the organizers to be representative of the Upper Neretva valley (Borko et al. 2023).

In addition, we joined the one-day expeditions to Ljuta and Zalomka rivers and road tracked the Morine plateau to get a clearer picture of the interconnections (12 km).

To get the most out of the short research period, we invited the participants of the NSW23 to inform us about the evidence of large carnivore presence they encounter. This participatory science component was performed using a short field guide, explaining how to collect verifiable large carnivore records.

Non-invasive DNA samples were collected with the EuroNatur sampling kit from fresh scats of brown bear and wolf and sent to the Faculty of Natural Sciences and Mathematics of the University of Banja Luka for further analyses. Each sampling kit consisted of a plastic bag, including 2 sampling sticks and a container with ethanol with a sticker to document the animal species, area, coordinates, date and the data collector. The kit was accompanied by a measure and a brochure from the Environmental Centre in Banja Luka and Euronatur explained the basic principles for collecting genetic samples.

The collected field data (field records, genetic samples and camera trap footage) was classified into C1 – hard facts, C2 – confirmed indication and C3 – unconfirmed indication, as described in the SCALP-methodology for lynx monitoring in the Alps (Molinari-Jobin et al. 2003).

RESULTS AND DISCUSSION

The favourable conditions (muddy dirt roads, moderate temperatures, abundance of prey species) and the helpful contributions of other scientists enabled us to collect a total of 49 large carnivore records (C1: 8, C2: 32 and C3: 9) within the given time frame (Fig. 2).

Out of the 49 collected field records, 14 accounted for the brown bear, 32 for the grey wolf and three for the wild cat. Brown bear and wolf presence was confirmed on both sides of the Neretva River as well as the Ljuta River, while personal information on lynx sightings around Jablanići and Dubrova could not be verified. On the one-day expedition to the Zalomka river we did not find any field evidence of large carnivores within the research focus area but were able to confirm bear presence close to Nevesinje.

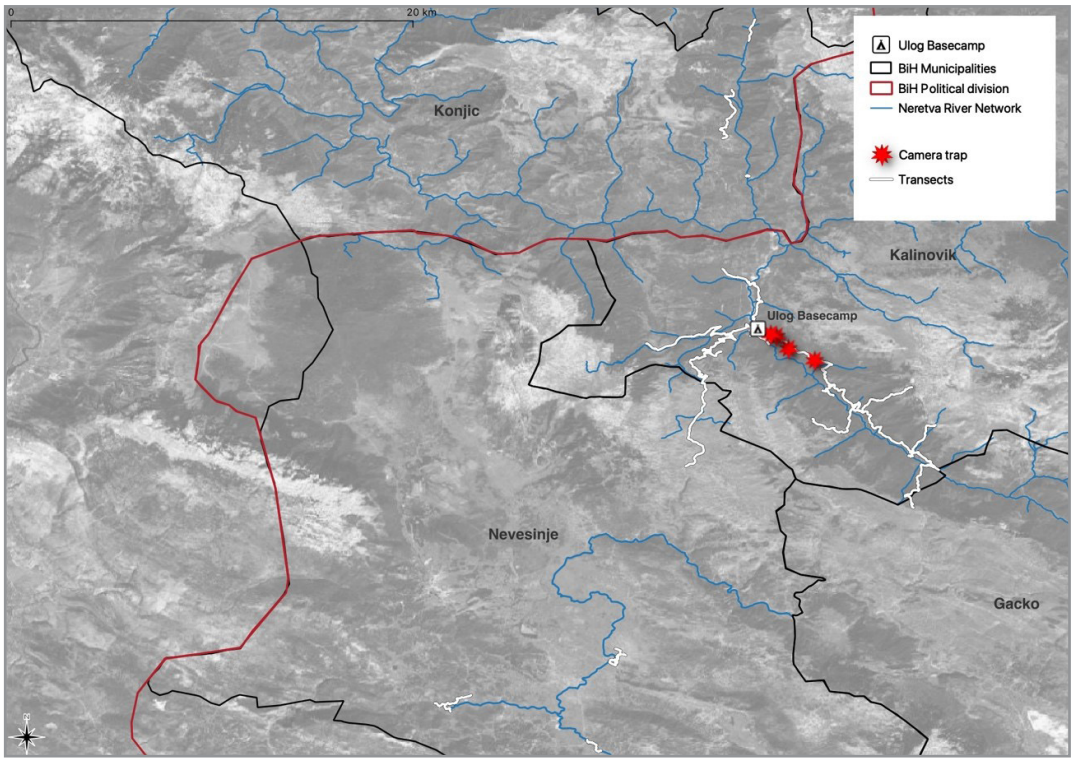

Figure 1. Research area (with political borders) spanning the Neretva River Network indicating the locations of the Basecamp, covered transects and camera traps installed during the NSW23.

Slika 1. Območje raziskave (s prikazanimi političnimi mejami), ki se razteza čez porečje reke Neretve, z označenim taborom, preučevanimi transekti in lokacijami kamer, v sklopu Tedna znanosti Neretva 2023.

Slika 1. Istraživano područje (sa prikazanim političkim granicama) koje se proteže duž sliva rijeke Neretve, sa označenim kampom, proučavanim transektima i lokacijama kamera, u sklopu Sedmice nauke Neretva 2023.

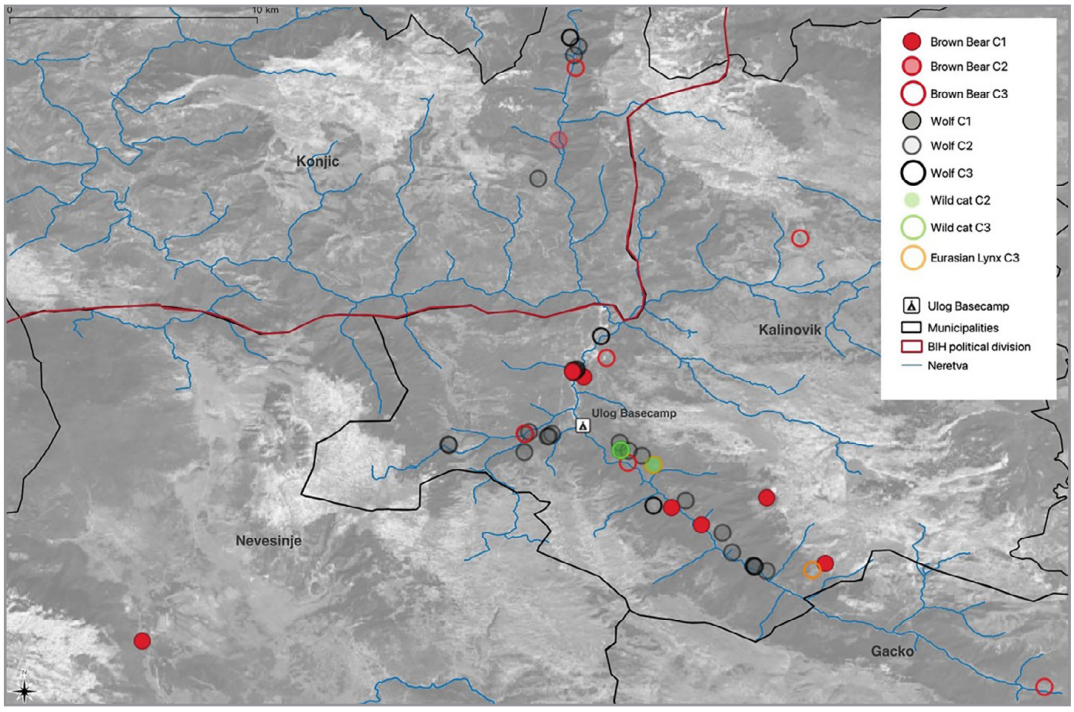

Figure 2. Documented large carnivore records close to the Upper Neretva, Ljuta River and Nevesinje during the NSW2023, specified according to species and record category (C1 – hard facts, C2 – confirmed indication and C3 – unconfirmed indication).

Slika 2. Dokumentirani podatki o prisotnosti velikih zveri blizu gornje Neretve, Ljute in Nevesinja med NSW2023, določeni glede na vrsto in kategorijo zapisa (C1 –dejstvo, C2 – potrjena indikacija in C3 – nepotrjena indikacija).

Slika 2. Dokumentovani podaci o velikim zvijerima u blizini gornje Neretve, Ljute i Nevesinja tokom NSW2023, utvrđeni prema vrsti i kategoriji zapisa (C1 – izvjesna činjenica, C2 – potvrđena indikacija i C3 – nepotvrđena indikacija).

All large carnivore records were found at the edge of or within the forest zone, including the presence of brown bear and wolf confirmed at the reservoir of the Ulog dam.

As a side result, we collected 29 records from further eight mammal species, namely *Lepus europaeus*, *Lutra lutra*, *Martes martes*, *Capreolus capreolus*, *Meles meles*, *Sciurus vulgaris*, *Sus scrofa* and *Vulpes vulpe*s. The repeated joint finding of fresh wild boar and wolf tracks, as well as wild boar claws and hair in wolf and bear faeces, allow the conclusion that young wild boar form a substantial part of wolf diet during this season, which has also been proven for other areas (Trbojević et al. 2020).

With the four camera traps set (Black IR LEDs, 12MP X-trail game camera, Wild Game Camera 31646), we collected 33 animal records (CTRO1: 19, CTRO: 0, CTMH1: 10, CTMH2: 4), confirming wolf (n = 1) and wild cat (n = 2) close to Ulog. One of the documented wild cats was suspected to be a hybrid so – as no genetic sample could be obtained for the target species – the camera records for the wild cats were classified as C2. Further mammal species documented with the camera traps included European badger, European hare, pine marten, red fox, roe deer and wild boar.

From a total of 25 scat records, we collected eight genetic samples, three for brown bear and five for wolf. With the wolf sample from the Ljuta River and a brown bear sample collected close to Nevesinje, the remaining interconnectedness of the existing populations, demonstrated by Kaczensky et al. (2024), might be confirmed through genetic analyses.

POVZETEK

Osredotočili smo se na dokumentiranje prostorske porazdelitve rjavega medveda (*Ursus arctos*), sivega volka (*Canis lupus*), evrazijskega risa (*Lynx lynx*) in divje mačke (*Felis silvestris*) v širši okolici gornje Neretve, okoli reke Ljuta, planote Morine in na Nevesinjskem polju. Pri načrtovanju smo se oprli na podatke, pridobljene na Tednu znanosti Neretva 2022 (Habe 2023). Med Tednom znanosti Neretva 2023, ki je potekal od 29. maja do 6. junija, smo prehodili približno 90 km raziskovalnih transektov in namestili foto pasti na vnaprej določenem ciljnem območju pri Ulogu. Zaradi kratkega raziskovalnega obdobja smo svoje raziskovalne dejavnosti dopolnili s participativnim pristopom, tako da smo zbirali prispevke o zapisih o velikih zveri drugih udeležencev tedna znanosti. Verjetno so nam ugodne vremenske razmere in gnezditvena doba divjih prašičev omogočile, da smo v kratkem raziskovalnem obdobju zbrali skupno 49 zapisov velikih zveri, med njimi osem genetskih vzorcev. Posledično smo lahko potrdili prisotnost rjavega medveda, sivega volka in divje mačke za dolino gornje Neretve, prisotnost sivega volka pa smo potrdili vse do Jezera. Prisotnost medveda je bila potrjena na planoti Zelengora in v okolici Nevesinja, volka in medveda pa okoli reke Ljuta in za akumulacijo Ulog, v stanju pred intenzivno sečnjo in zalitjem (Sl. 2).

Zaradi razdrobljenosti habitata in polnjenja velikega akumulacijskega jezera po dokončanju jezu Ulog se bodo medsebojna povezanost in okoljske razmere za obravnavane vrste v tej regiji drastično spremenile. Med raziskavo smo sledili načelu osnovnega, kvalitativnega zbiranja podatkov in potrebi po dopolnitvi redkih kvalitativnih podatkov o razširjenosti velikih zveri, zlasti za območja divjine z velikim razvojnim potencialom za izkoriščanje naravnih virov (npr. hidroelektrarne, proizvodnja lesa itd.).

SAŽETAK

Na osnovu preliminarnih rezultata sa Neretva Science Week 2022 (Habe 2023), fokusirali smo se na dokumentovanje prostorne distribucije mrkog medvjeda (*Ursus arctos*), sivog vuka (*Canis lupus*), evroazijskog risa (*Lynx lynx*) i divlje mačke (*Felis silvestris*) na širem području gornjeg toka Neretve, uključujući područja oko rijeke Ljute, visoravni Morina i Nevesinjskog polja. Tokom planiranja oslanjali smo se na podatke dobijene tokom Sedmice nauke 2022. (Habe 2023). Tokom Sedmice nauke 2023., koja se održala od 29. maja do 6. juna, prešli smo otprilike 90 km istraživačkih transekata i postavili kamere na unaprijed određena područja u blizini Uloga. Zbog kratkog perioda istraživanja, naše istraživačke aktivnosti dopunili smo participativnim pristupom prikupljanjem priloga o evidenciji velikih mesoždera od drugih učesnika Sedmice nauke. Vjerovatno su nam povoljni vremenski uslovi i sezona razmnožavanja divljih svinja omogućili da u kratkom periodu istraživanja prikupimo ukupno 49 zapisa velikih zvijeri, uključujući osam genetskih uzoraka. Kao rezultat toga, uspjeli smo potvrditi prisustvo mrkog medvjeda, sivog vuka i divlje mačke u dolini gornje Neretve, a prisustvo sivih vukova potvrđeno je sve do lokaliteta Jezero. Prisustvo medvjeda potvrđeno je na visoravni Zelengore i u okolini Nevesinja, dok su vukovi i medvjedi pronađeni oko rijeke Ljute i iza akumulacije Ulog, u stanju prije intenzivne sječe i poplava (Sl. 2).

Fragmentacija staništa i popunjavanje velikog rezervoara nakon završetka brane Ulog drastično će promijeniti međusobnu povezanost i staništne uslove za navedene vrste u ovoj regiji. Tokom istraživanja slijedili smo princip prikupljanja osnovnih, kvalitativnih podataka i potrebu dopunjavanja oskudnih kvalitativnih podataka o rasprostranjenosti velikih zvijeri, posebno za područja sa visokim razvojnim potencijalom za korištenje prirodnih resursa (npr. hidroenergija, proizvodnja drveta, itd.).

ACKNOWLEDGEMENTS

Representative for all the valued information, we thank Stefan Andjus, Piotr Bednarek, Saudin Merdan, Ester Premate and Thea Schwingshackl for their contributions, as well as Riverwatch and EuroNatur for enabling us to collect this data.

REFERENCES

Alho JRC. 2011. Environmental effects of Hydropower Reservoirs on Wild Mammals and Freshwater Turtles in Amazonia: A Review. Oecologia Australis. 15(3): 593-604. https://doi.org/10.4257/oeco.2011.1503.11

Assenov A, Grigorov B, Kostadinov, S. 2017. Conceptual design for spatial coherence of the future ecological network NATURA 2000 in the border areas between Serbia, Bosnia and Herzegovina, Montenegro and Kosovo. Eastern Academic Journal 3: 78-87.

Borko Š, Singer G, Eichelmann U, editors. 2023. Science Week 2023, Neretva River, Bosnia and Herzegovina. Preliminary Report for Riverwatch and EuroNatur Foundation.

[EC] European Council. 2024. Bern Convention: EU will propose changing the conservation status of wolves. European Council; [accessed 8. 11. 2024]. https://www.consilium.europa.eu/en/press/press-releases/2024/09/26/bern-convention-eu-will-propose-changing-the-conservation-status-of-wolves/#:~:text=The%20wolf%20species%20is%20currently,over%20the%20last%20few%20decades

Habe M. 2023. Leading the way – presence of brown bear Ursus arctos, lynx Lynx lynx and grey wolf Canis lupus underlines the integrity and corridor function of the upper Neretva Valley in Bosnia and Herzegovina. Natura Sloveniae. 25(3): 201-211. http://dx.doi.org/10.14720/ns.25.3.201-211

Haswell PM, Kusak J, Hayward MW. 2017. Large carnivore impacts are context dependent. Food Webs. 12: 3-13. https://doi.org/10.1016/j.fooweb.2016.02.005

[IMPAQ] IMPAQ International. 2020. Bosnia and Herzegovina Biodiversity Analysis and addressing the Biodiversity Needs. Monitoring and Evaluation Support Activity II (Measure II). FAA 119 Analysis, Feb 2020. USAID, AID-167-I-17-00004. IMPAQ International; [accessed 26. 5. 2022]. https://www.measurebih.com/bosnia-and-herzegovina-biodiversity-analysis-and-addressing-biodiversity-needs

Kaczensky P, Ranc N, Hatlauf J, Payne JC, Acosta-Pankov L, Álvares F, Andrén H, Andri P, Aragno P, Avanzinelli E, et al. 2024. Large carnivore distribution maps and population updates 2017 – 2022/23. Report to the European Comission under contract N° 09.0201/2023/907799/SER/ENV.D.3 »Support for Coexistence with Large Carnivores«, »B.4 Update of the distribution maps«. IUCN/SSC Large Carnivore Initiative for Europe (LCIE) and Istituto di Ecologia Applicata (IEA).

Molinari-Jobin A, Molinari P, Breitenmoser C, Wölfl M, Stanisa C, Fasel M, Stahl P, Vandel JM, Rotelli L, Kaczensky P, et al. 2003. The pan-Alpine conservation strategy for Lynx. Strasbourg: Council of Europe Publishing. Nature and Environment 130.

Rode J, Flinzberger L, Karutz R, Berghöfer A, Schröter-Schlaack C. 2021. Why so negative? Exploring the socio-economic impacts of large carnivores from a European perspective. Biological Conservation. 255: 108918. https://doi.org/10.1016/j.biocon.2020.108918

[SCCE] Standing Committee of the Council of Europe. 2022. Convention on the Conservation of European Wildlife and Natural Habitats. 42nd meeting, Strasbourg, hybrid meeting, 28 November – 2. Dec. 2022, T-PVS(2022)MISC. p. 21, 49-50; [accessed 5. 12. 2022]. https://balkanrivers.net/uploads/files/3/MISC_E_2022.pdf

Trbojević I, Penezić A, Kusak J, Stevanović O, Ćirović D. 2020. Wolf diet and livestock depredation in North Bosnia and Herzegovina. Mammalian Biology. 100: 499-504. https://doi.org/10.1007/s42991-020-00053-7

Vsebina je dostopna pod pogoji licence Creative Commons Priznanje avtorstva 4.0 Mednarodna (CC BY 4.0), ki omogoča neomejeno uporabo, razširjanje in reproduciranje v kateremkoli mediju ali obliki, pod pogojem, da sta ustrezno navedena izvirni avtor in vir.

The content is distributed under the terms of the Creative Commons Attribution 4.0I nternational License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.