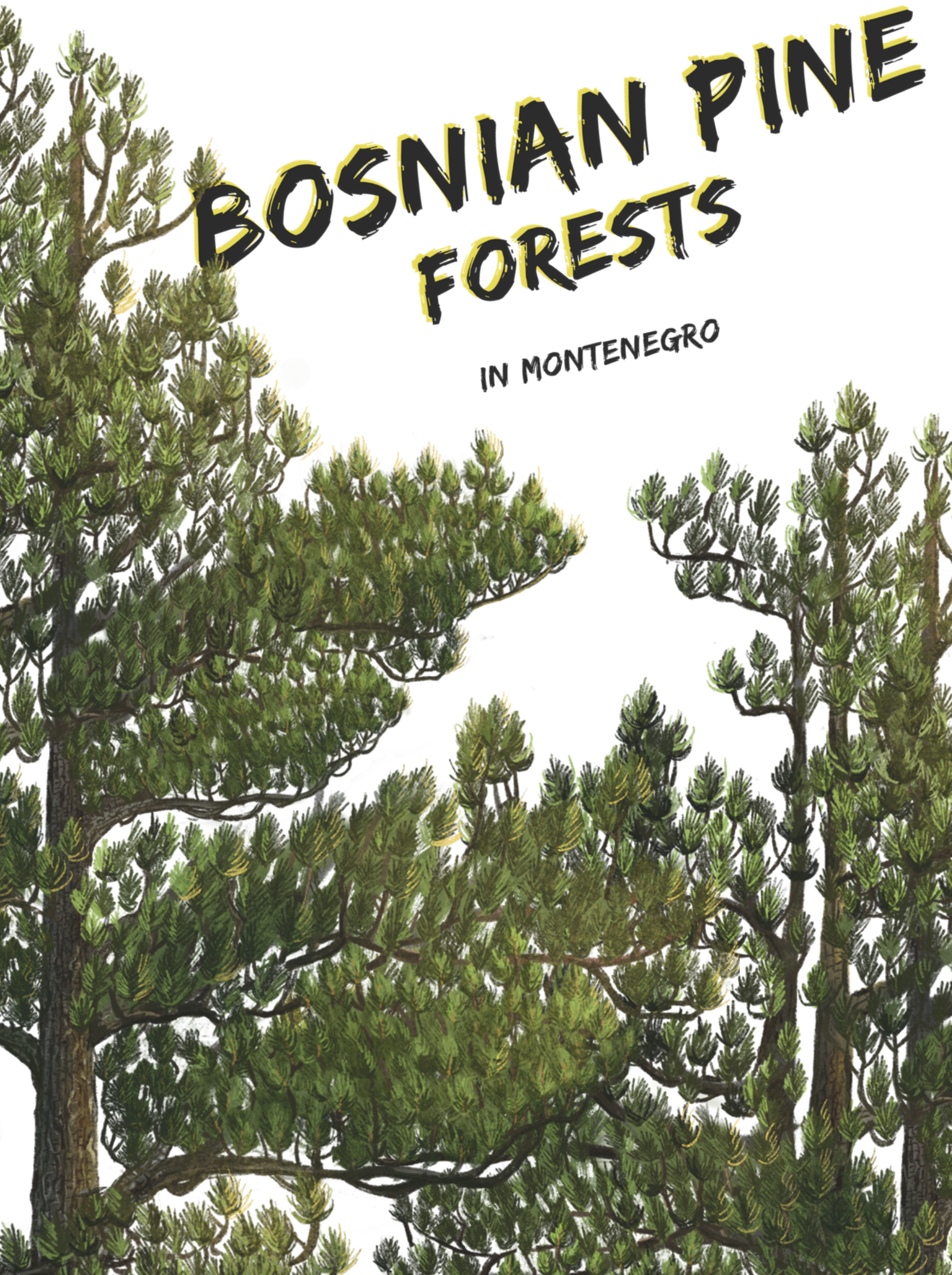


BOSNIAN PINE FORESTS

IN MONTENEGRO





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Projekat kofinansiraju EU i Vlada CG



In the Western tradition there is a recognized hierarchy of beings, with, of course, the human being on top - the pinnacle of evolution, the darling of Creation - and the plants at the bottom.

But in Native ways of knowing, human people are often referred to as 'the younger brothers of Creation'.

We say that humans have the least experience with how to live and thus the most to learn - we must look to our teachers among the other species for guidance. Their wisdom is apparent in the way that they live.

They teach us by example. They've been on the earth far longer than we have been, and have had time to figure things out.

- Robin Wall Kimmerer



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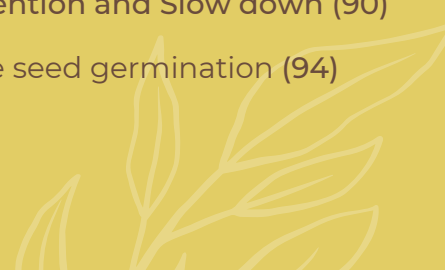
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Munika

Муника

Munjika

Bosnian pine

Heldreich's pine

Черна мура

Ρόμπολο

Pisha e Geldreich

Pino loricato

Borovice Heldreichova

Slangebarkfyr

Schlangenhaut-Kiefer

Soomusmänd

Harmaarunkomänty

Pin de Bosnie

Balkáni páncélfenyő

Ormehamfuru

Bosníufura

Pinus heldreichii

Pinus leucodermis

Acknowledgments

This monograph is part of a project dedicated to Bosnian pine and the struggle of its forests to tackle the consequences of climate change, among which the most dangerous are fires, in which we have already lost the largest part of these forests. For Bosnian pine resin burns easily, and year after year, humans create ever greater fires.

Understanding a single tree can be a challenge in itself, but understanding how an entire habitat thrives in the harsh conditions where forests struggle to grow poses a greater challenge. Yet, the Bosnian pine manages to thrive on high mountain areas, thanks, in part, to the help of fungi. In a similar way, we could not have completed our project and this monograph without the help and expertise of various Bosnian pine experts who provided valuable insights into this remarkable species from diverse perspectives.

Therefore, first of all, we would like to thank *Jelena Lazarević*, who opened the doors to her research, through which her life has become completely intertwined with Bosnian pine forests. We are immensely grateful for her guidance through the fascinating, almost fairytale-like relationship between Bosnian pine and fungi; but also through the devastating, desolate expanses of forests consumed by fires, where Jelena once conducted research and where now, remembering those forests, she studies the behaviour of nature in the process of their recovery.

Bosnian pine forests are not only a collection of trees, but also a network of hundreds of species of plants and animals for which they are home.

We thank *Dragana Saveljić* and *Đorđije Milanović* for guiding us through the plant world of Bosnian pine forests, which was presented to us in such a way that we can clearly see and understand its uniqueness, diversity and value.

On the other hand, the world of insects of Bosnian pine forests was brought closer to us by *Nikola Balević* and *Bogić Gligorović*, who also carried out the first targeted research on this group of animals among Bosnian pines, on Mt Prekornica. Their love for insects is easy to experience when we notice how, in their presence, we naturally feel the inseparability of Bosnian pine and the red wood ant, or the importance of beetles on which the regeneration of these forests depends.

We owe great gratitude to *Kristina Vlaisavljević* for her diving through old stories and songs, and for bringing to the surface records and myths about humans and pines, about humans and forests. This dimension of the story is one of the most important, because it shows us the relationship of our ancestors with nature, and how that bond has changed through time. It reminds us of the true connection between humans and trees, which may have been sleeping within us for a long time, but nevertheless begins to stir as we read the lines Kristina prepared, getting ready to awaken.

Bosnian pine preserves its own stories in its tree rings, recording them for centuries. We owe special gratitude to **Momchil Panayotov**, who, with his extensive knowledge and experience, introduces us in a simple way to the possibilities and scope of dendrochronology, helping us to see Bosnian pine as an incredible natural archive. As we run our fingers across the tree rings, we learn how to recognise records of fires, avalanches, dry, but also comfortable years during the life of a tree, aware that there is still much before us that we have yet to discover and understand.

Bosnian pines are not only the forest and its living world, but also lightning and thunder, soil that barely clings to inaccessible rocky terraces and cliffs, and water that sculpts these rocks and disappears into them without a trace; or wind and avalanches to whose song and power few are as accustomed as Bosnian pine.

It is true that we view Bosnian pine forests through their uniqueness, resilience and beauty, but we must also clearly see them in their increasingly intense struggle for survival. In understanding this struggle, we were helped by **Saša Eremija**, who brought to life for us the struggle of Bosnian pine with wildfires, as well as **Branislav Cvjetković**, who taught us so much about how to help Bosnian pine, carefully collecting its seeds, nurturing its seedlings and returning them to nature, thus helping the forests in their recovery.

We owe great gratitude and a surge of inspiration to **Dalibor Ballian**, who agreed to be the reviewer of this book, but also to open the doors of Bosnian pine's expanses to readers through the Foreword. Dalibor's extensive knowledge and experience in studying Bosnian pine forests, together with his love for every tree and forest, are woven into the review and foreword of this work, which the authors received as a precious gift and confirmation of the value of our shared work and creation.

We owe special gratitude to **Nina Lončarević**, who patiently and with indescribable care found the best ways to turn all these prepared stories into a coherent whole worthy of Bosnian pine.

With great love, we thank **Marija Šoškić Popović** and **Zoran Popović** for the photographs they provided, which teleport readers beneath the ancient Bosnian pines of magical, wild Zeletin, as well as **Radmilo Šoškić**, a lifelong guardian of this mountain, whom, we are certain, Zeletin feels as its ambassador. Their love, interwoven with deep knowledge and respect, represents the most beautiful form of connection between humans and the wilderness within us and around us.

Finally, *we thank Bosnian pine*, which has inspired us and taught us so much about ourselves without saying a word, simply through its existence and example of living. We thank all those who bear witness to the uniqueness of Bosnian pine, feeling that they are part of its story.



Figure 1. Marija, Radmilo and Bosnian pine in Zeletin ©Zoran Popović, 2020.

FOREWORD

Before us lies an exceptionally valuable scientific work entitled *Bosnian Pine Forests in Montenegro*, and it has been a great honour for me to serve as one of its reviewers.

Several years ago, the distinguished team of authors embarked on the ambitious task of compiling all relevant knowledge about this remarkable species of the Montenegrin flora. Their aim was to bring together, in a single volume, the available scientific evidence and present it in a clear and systematic manner, thereby establishing a comprehensive foundation for future research and monitoring of Bosnian pine forests, not only in Montenegro but throughout the species' range. Such a synthesis is particularly important given that Bosnian pine has largely retreated to remote and inaccessible mountain habitats, where it faces numerous threats arising from both human activities and natural processes, most notably climate change.

The authors were confronted with a demanding and rather challenging task: reviewing and synthesizing the available literature on Bosnian pine. This was made particularly difficult by the scarcity of studies and publications originating from Montenegro, as well as from neighbouring countries, despite the ecological and scientific importance of this species. Through dedicated effort, the authors have produced a comprehensive overview of the current knowledge on Bosnian pine in Montenegro while integrating relevant research conducted elsewhere within its natural distribution. As a result, this book brings together the available scientific evidence and the most up-to-date perspectives on this unique species.

The manuscript is logically structured and systematically organized, providing a clear and coherent presentation of contemporary knowledge on Bosnian pine. It introduces readers not only to the species itself, but also to the complex mountain ecosystems in which it occurs, together with the rich diversity of plants and other organisms associated with its forests. A particular strength of this work lies in the numerous high-quality illustrations that complement the text and significantly enhance the reader's understanding of the ecological and biological value of Bosnian pine. Equally valuable is the attention devoted to the traditional use of its wood as a construction material in historic mountain houses and barns, highlighting a cultural heritage that is gradually disappearing together with traditional building knowledge and practices.

Although the manuscript is firmly grounded in relevant scientific literature, it has been written in a manner that makes it highly relevant not only to Montenegro but also to the wider Balkan region. The scientific arguments are presented according to contemporary standards, while the extensive and carefully selected illustrations facilitate the understanding of even the most complex topics addressed throughout the book. For many years there has been a clear need for a comprehensive work of this kind in the region, one that brings together scientifically reliable knowledge about Bosnian pine based on modern research methods, evidence and contemporary scientific understanding.



An additional strength of this manuscript is its potential to serve both as a primary and supplementary teaching resource in secondary schools and universities, particularly in disciplines related to forestry, ecology, biodiversity conservation and the sustainable management of natural resources. Furthermore, it represents a valuable reference for professionals and decision-makers involved in the management and conservation of forest ecosystems, not only in Montenegro but also in all countries where Bosnian pine naturally occurs. Given that no comparable work has previously been produced in the region, this book will undoubtedly represent an important contribution to scientific knowledge and practical conservation, while also serving as an invaluable resource for nature enthusiasts and everyone committed to the protection of biodiversity.

Based on the above, it is my great pleasure to recommend this valuable monograph to all those whose work is connected with Bosnian pine forests. I also warmly recommend it to all readers who share an appreciation for nature and recognize the importance of conserving one of the most remarkable tree species of the Balkan Peninsula.

Sarajevo, January 2025

*Assoc. Prof. Dalibor Ballian, PhD
Faculty of Forestry, University of Sarajevo
Academy of Sciences and Arts of Bosnia and Herzegovina*

BOSNIAN PINE

Bosnian pine (*Pinus heldreichii* H. Christ) is a type of tree very similar to the Black pine. It naturally inhabits the highest forest belt of our limestone mountains (usually those located closer to the sea). But it also inhabits the continental areas affected by sea climate, to a certain extent. These habitats are not favourable and are extremely harsh for any tree species in general.

These areas are characterised by very shallow soil layer, often piled up in crevices between rocks, not making it possible for any other tree species to grow there in its full glory and beauty. That is why Bosnian pine forests (though many of them can hardly be called that), are sparse, often steep, with centuries-old trees scattered across the stony subalpine wilderness. These trees are recognisable from afar by their finely cracked bark, which resembles the scales of a snake. Among the living trees, there is almost always a dead trunk, disfigured and white as snow, defying both time and its death. The trunk remains there for a long time, to tell a story about all the hardships and cruelties of the places where the Bosnian pine lives, dies and resurrects.

In the summer, the Bosnian pine habitats are scorched by the heat and charred by fires. In the winter, trees are being pressed by several meters of snow and debris. During the spring they are smothered by terrible avalanches, and throughout the year lightnings often strike and shake the land where they grow.

Common name for the Bosnian pine in the Balkans is *munika* (formerly called *munjika*). *Munja* is a Montenegrin word for *lightning*. So, the name *munjika* was attributed to the Bosnian pine for its “ability” to attract thunderbolts. How and why the common name changed over time from *munjika* to *munika* (*munika* has no specific meaning), while practically losing the symbolism of this wonderful nickname, goes beyond our domain of knowledge and becomes the subject of work for etymologists.

Bosnian pine is a Balkan-Apennine endemic, a species that grows only in the mountains of the Balkans, from Pirin in Bulgaria to Čvrsnica in Bosnia and Herzegovina, with isolated sites in the Apennines. This is why it is an exceptional representative of very specific southern European and Balkan flora, and must be the subject of special care and attention in all countries where it naturally grows. Some scientists will say that Bosnian pine is an endangered species, others won't, it's a matter of perspective. However, in recent years we have witnessed its disappearance from some localities, either due to drying or due to increasingly frequent fires. That's why one should pay special attention to this pine, carefully plan activities to help it survive in its harsh habitats, and put this species under the supervision of experts. This book is made in order to support those efforts.

Đorđije Milanović



MONOGRAPH BACKGROUND

This monograph was created out of the desire to present the Bosnian pine species as special, fascinating, and worthy of attention in many ways. It is also published as part of an effort to draw attention to the growing challenges this species encounters, which are becoming more complex under the effects of climate change. Additionally, one of the goals of this monograph is to show that forests of today are actually a mirror of our relationship with nature as a whole.

In Montenegro, general awareness about the importance of nature, its biodiversity, and the inextricable impact it has on human beings is very low.

Although forests cover about 60% of the Montenegrin territory, awareness of the characteristics, importance and diversity of forest ecosystems is almost non-existent. The understanding of the importance and roles of forests and their living world in the process of adaptation and mitigation of negative effects on the environment, such as climate change, is very low as well (Government of Montenegro, 2011).

Forest ecosystems are increasingly threatened by the effects of climate change, with forest fires being among the most serious. Unfortunately, these fires are expected to become even more frequent in the future (Box 1). As a result, there are vast areas of burned forests, depleted biodiversity, and devastated habitats for many species, as well as a loss of resources that both nature and the local population depend on.

Box 1: *Biodiversity, climate change, dendrochronology*

Biodiversity – diversity of all living things on planet Earth, including genetic diversity, diversity of species, ecosystem diversity, diversity of landscapes and all the processes performed by organisms in them. For example, Montenegro has about 60% of forest cover, with the diversity of around 90 different tree species.

Climate change – long-term changes in temperature, precipitation patterns, and other climatic factors. While changes in the climate are a natural process that occur over long periods of time, the current acceleration of climate change is largely influenced by human activity, particularly since the industrial revolution in the 19th century.



Burning oil, coal, and gas for industrial purposes releases large amounts of carbon dioxide and other gases into the atmosphere. These accumulate, thereby warming the atmosphere, thus influencing: increasing temperature of the seas, increasing global temperatures, survival of species, more frequent extreme weather conditions, migration of populations from zones of risk, etc.

Oil, petroleum and gas are formed by organic matter. They are deposited for millions of years and are "trapped" in the geological layers of the Earth. Today, humans burn them rapidly and release all that is "trapped" into the atmosphere in a very short period of time. Planet Earth has difficulty coping with this rhythm, hence the temperature abnormalities and other consequences of accelerated climate change.

Dendrochronology - scientific method that utilizes the analysis of tree rings to study temporal, spatial, and other processes in the environment. By examining the growth patterns of trees that are hundreds of years old, we are able to "travel through time" and reconstruct climatic and environmental conditions in which they grew. This data can be compared to the present-day conditions, providing a broader understanding of how environmental conditions have changed. With this information, models can be designed to predict the impact of potential climate and environmental scenarios on the life of trees and forests in the future.

Resulting book is part of the Montenegrin Ecologists Society (MES) project entitled "From Education and Connecting Children Back to Nature, to the Research in Dendrochronology and Raising Awareness on How Climate Has Changed Throughout Past Centuries in Montenegro!" Main goal of the project is to contribute to the mitigation and understanding of climate change in Montenegro by educating local communities about the impact of humans on this phenomenon and vice versa. Additionally, the project aims to raise the awareness of the general Montenegrin public about climate change in recent centuries, using the example of old and representative Bosnian pine trees. This project was created as part of the wider area of work of MES, which permeates and connects all our projects and activities and strives to bring nature closer to humans through the education of local communities and the wider public. MES aspires to contribute to building connections between humans and nature while implying the importance of preserving biodiversity and the human-nature balance.

This project enabled us to carry out the first comprehensive dendrochronological (Box 1) research, and establish the first laboratory for research in dendrochronology in Montenegro. MES established cooperation with experts from surrounding countries in this field, conducted two educational camps for children in Bosnian pine forests, and lead a series of educational workshops in elementary schools. MES initiated research about the history of wildfires in the Bosnian pine forests, and contributed to the development of fire-risk-prediction models, while at the same time collecting Bosnian pine seeds for the reforestation of fire-ravaged areas. Additionally, we conducted initial research of the Bosnian pine forest biodiversity. Obtained scientific information and results of the project are intended to be used in the processes of forming our further activities, but also in the processes of designing management plans for forests, protected areas, etc.

We hope that this monograph will contribute to the improvements in the process of preserving the Bosnian pine and its habitats. Therefore, we hope that the following paragraphs will bring the readers closer to the Bosnian pine forests, prompt them to perceive their importance and beauty, and inspire them to join our preservation efforts.



Figure 2. Educational camp in Bosnian pine forests ©Dejan Lazarević, 2021.



Unique features of Bosnian pine

Bosnian pine (*Pinus heldreichii* H. Christ) belongs to the pine genus, and has been around since the Tertiary period - before the last ice age. As a result, it is considered a tertiary relic and a living fossil. This species is unique to the Balkans and to a small area of the southern Apennine Peninsula, making it a sub-endemic species (Box 2). Bosnian pine is, therefore, a fascinating species in terms of geobotany, taxonomy, chronology, and phytocenology, and is one of the most interesting species in our dendroflora.

Box 2: *Endemic, relict*

Endemic – a species or a taxon that is distributed in a limited, often small area, for example, only across one rocky mountain belt or solely on the Balkan Peninsula, and nowhere else in the world.

Relict – a species or a taxon that survived epochal changes, from the era when different living conditions ruled the Earth. For example, when the climate was much hotter or much colder. Relict species inhabit a limited area, but the original distribution area in the previous geological epoch was much larger.

Once upon a time, Bosnian pine forests covered vast areas, but the evolution caused them to move to high mountain areas, where they managed to adapt to harsh living conditions. This is where they still grow, out of stone, on rocky terraces and cliffs. Their strong roots protect the soil and attract the scarcely available water, creating a home for many other plants, animals, and fungi.

Bosnian pine is a species that is adapted to short vegetative periods of the high mountain zone: hot and dry summers with a high degree of solar radiation, as well as cold and harsh winters. In the past, Bosnian pine forests built a dense high-mountain belt of vegetation in the oro-Mediterranean mountains of the Balkan Peninsula. Due to its specific physiological and ecological characteristics, and especially its adaptation to withstand great climatic extremes between summer and winter, Bosnian pine forms forests in very harsh conditions, unsuitable for the growth and development of other types of trees, or forest vegetation in general.

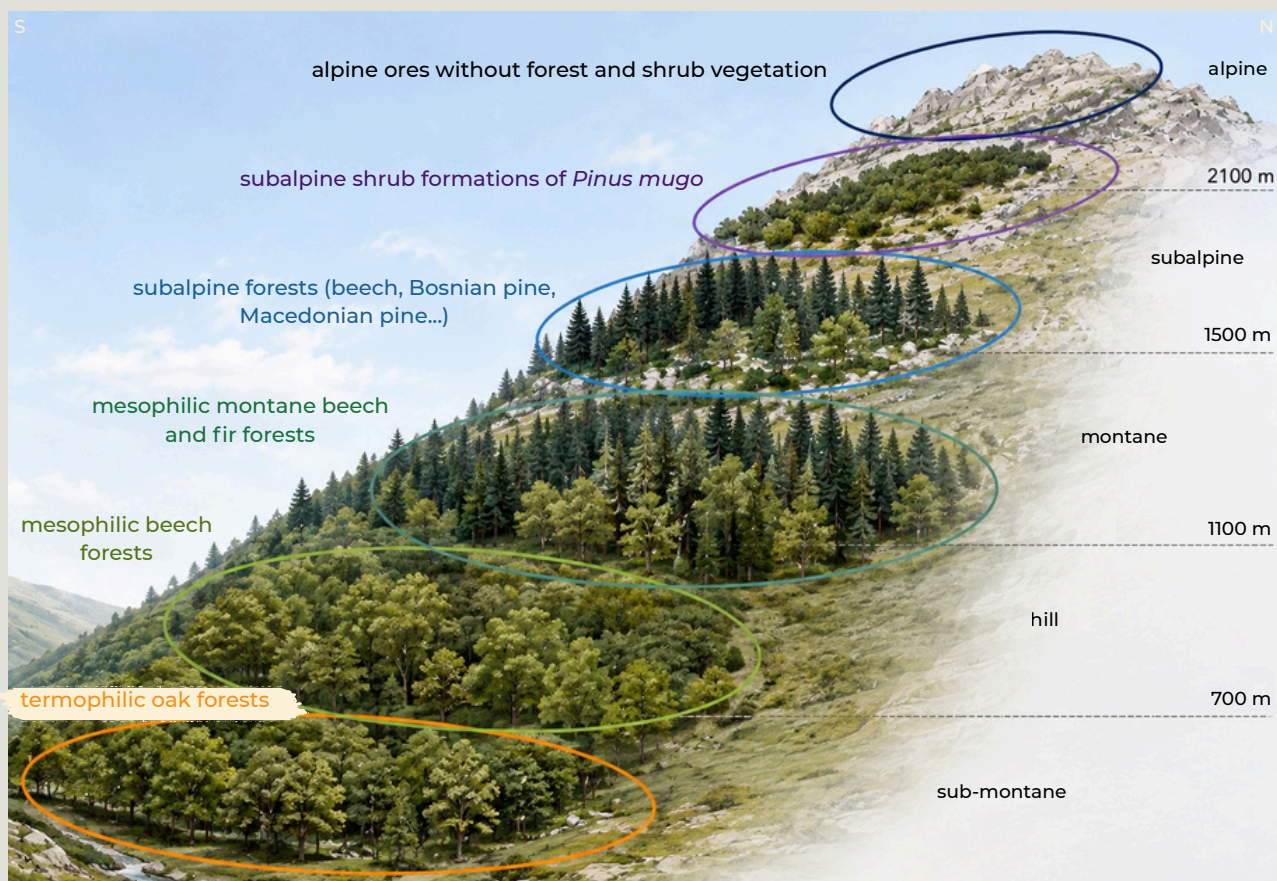


Table 1. Attitudinal zonation of forest vegetation

But, the high mountain forest belt of Bosnian pine is very fragmented in present times. Many forests have been devastated, reduced to the smallest measure, or even completely destroyed on numerous mountain massifs.

In addition to the Bosnian pine, another relict, endemic species - Macedonian pine (*Pinus peuce* Griesb.) formed a significant belt of high mountain forest vegetation on the Balkan Peninsula. Macedonian pine also dates back from Tertiary, it is endemic to the Balkans, and is distributed over a much smaller area than the Bosnian pine, both in Montenegro and across its whole areal.

Both Macedonian and Bosnian pine forests have the same altitudinal distribution. While noting specifics of their ecological and physiological characteristics, as well as the environmental conditions in which they live, these two species both exclude and complement each other.

Box 3: *Altitude zonation of forest vegetation; Upper forest limit*

Altitude zonation of forest vegetation – arrangement of different forest types according to the altitude. A change in the altitude brings different environmental parameters - temperature, humidity, soil composition, sunlight intensity, wind strength, etc. Hence species fragmentation takes place, since different species are adapted to different environmental conditions.

Upper forest limit – an invisible mountain line above which the forest can no longer grow due to unfavourable environmental conditions. Above the forest limit there are mountain pastures, heaths, rocky hills, and eternal snow, where few plant species can survive.

Due to its distribution in the highest vegetation zone (Box 3), forest belt of the Bosnian pine and Macedonian pine has a distinctly protective role. It opposes the devastating and often catastrophic effects of erosion, torrents, and avalanches, thus providing protection for forests and other ecosystems at lower altitudes.



Figure 3. Bosnian pine and Macedonian pine cones ©Marija Šoškić Popović, 2020.

Uniqueness of the flora of the Balkan Peninsula, known for its biodiversity, is reflected in part through the Bosnian and Macedonian pine forests, that grow on different geological substrates where they define the upper zone of forest vegetation on the oro - Mediterranean mountains. These two species, since they are relict endemics that live in harsh environmental conditions, are considered to be among the most interesting elements of the Balkan dendroflora. (Stevanović et al. 1995; Blečić et al. 1969).



Figure 4. Bosnian and Macedonian pine forests on Zeletin ©Jelena Popović, 2021.

1.1 Scientific name and first official findings in Montenegro

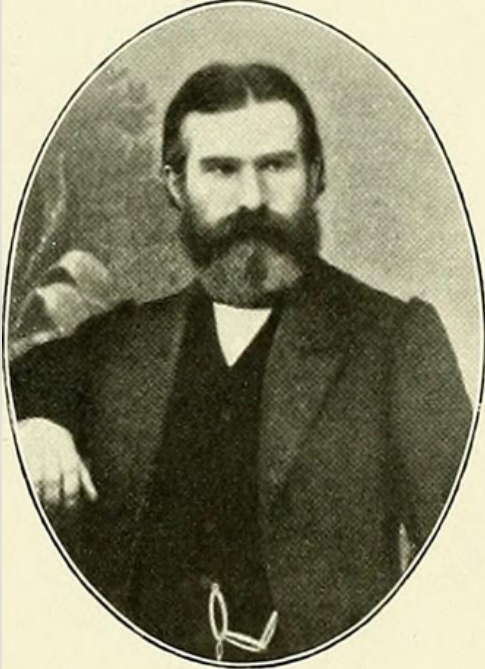


Figure 5. Theodor Heinrich Hermann von Heldreich (1822–1902), after whom *Pinus heldreichii* was named. Source: Acta Horti Bergiani, 1905.

- Bosnian pine got its scientific name (*Pinus heldreichii*) after the German botanist Heldreich (Theodor Heinrich Hermann von Heldreich; 1822-1902).
- The first finding of the Bosnian pine in the Balkan area is linked to Orjen and Bijela Gora, where it was discovered by the Austrian botanist Josef Karl Maly (1797-1866).
- On the basis of a plant material from Orjen, Franz Antoine described a new type of pine in Vienna (1864), under the name *Pinus leucodermis* - pine with white bark. However, the same species was found two years earlier on Olympus (Greece) by Heldreich and Christ and described as *Pinus heldreichii* Christ.
- It is also interesting to note that the Bosnian pine on Prenja in Herzegovina was found and described by the Austrian botanist Beck (Beck, Günthervon Mannagetta und Lerchenau; 1856 - 1931), a professor at the Charles University in Prague, who named it *Pinus prenja*. It was only after some time that it was declared as the same species of now scientifically acknowledged name - *Pinus heldreichii* H.Christ.

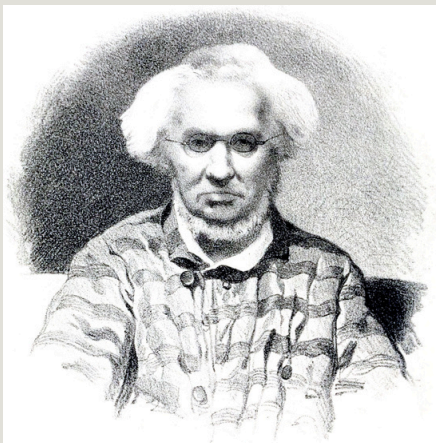


Figure 6. Josef Karl Maly (1797–1866), the first botanist to document Bosnian pine in Montenegro. Lithograph by Eduard Kaiser, 1861.

1.2 Common name

Common Montenegrin names for *P. heldreichii* are *munika*, *munjika* (*munja* meaning *lightning*), and *Balkan munjika* (Avidbegović et al., 2017), as well as *crna mura* (*crna* meaning *black*) and *bor smrč* (*bor* meaning *pine*) (Šilić Č., 1983). Certain Balkan - endemic pine species are believed to have been named by the Slavs in their Thracian - Illyrian language when they settled in the Balkan Peninsula. One of them is the Bosnian pine.

In addition to the common name *munika*, there is also a noted variation *munjika*, derived from the word *munja*, meaning *the one that lives near the lightning*. Semantically, this seems plausible since it is believed that this pine species attract lightning more than others (or lightening simply happens more near those rugged high mountain groves). Additionally, in the part of Italy where Bosnian pine grows, it is described as *a tree shaped by wind, frost, and thunder*, so the name *pine of the lightning* seems quite appropriate. (Loma A., 2002).



Figure 7. Scar from lightning ©J. Popović, 2022.



Figure 8. Bosnian pine after thunderstorm ©J. Popović, 2021.

In English, the name is *Bosnian pine*, as well as *Heldreich's pine* - according to the scientist who described the species.

1.3 Species description

According to the literature, Bosnian pine can grow to a mature height of 35m. However, it is more likely to reach 12-15m, sometimes 20m in height, with a trunk exceeding 1m in diameter.



Figure 9. Old Bosnian pine on Visitor mountain ©Marija Šoškić Popović, 2020.

This species grows slowly when young, reaching a height of 1m after 10 or more years. Bosnian pine crown is of oval-pyramidal or pyramidal shape; trunk is strong, often thickened or bent at the base. Branches are distributed in regular vertebrae. Buds are elongated, ovoid, grayish - silver in color, and produce no resin.

Bark is smooth and light grey when young; in older trees, bark is very thick, grey, and split into plates, resembling a bulletproof vest.



Figure 10. Bosnian pine on Zeletin; the bark ©Marija Šoškić Popović, 2017.

Bosnian pine develops very strong and branched roots, which ensure its stoutness in harsh climates and habitats. Roots penetrate deep into the rocky crevices of the limestone and, in some places, are thicker than the trunk itself.



Figure 11. Pine needles ©Jelena Popović, 2021.

Pine needles are grouped in two, on a short fascicle. Young needles are light green, while older are bright green, stiff, sharp, 6 - 9cm (11cm) long, and about 1.5mm wide.

Needles on the side branches of the Bosnian pine are placed in strands, so that tip of the one reaches half of the other strand. Needles have a life span of 4 - 6 years (when healthy). Bosnian pine blooms from the end of May to the end of June, depending on the habitat altitude and characteristics (Vendramin G. G. et al., 2008).

Pine cones serve the same role as flowers in herbaceous plants - for reproduction. Pine cones protect the seeds from adverse conditions. Cones open up and release the seeds when the environmental conditions are favourable.

Young cones are dark red, but they turn to a purple-brown, slightly ashy colour during the first winter of their growth. They grow and mature during autumn (September, October). Ripe and open cones are egg-shaped, slightly flattened at the base, 7-8cm long, and about 6cm in diameter.

Regarding its appearance, the Bosnian pine mostly resembles the black pine (*Pinus nigra* Ait.). Thus, their genetic closeness was formerly presumed. However, recent genetic research on pines suggests that the Bosnian pine is most closely related to the Mediterranean pine species from the *Pinaster* subsection. These are, namely: maritime pine (*Pinus pinaster*), stone pine (*Pinus pinea*), and the Aleppo pine (*Pinus halepensis*); while black pine (*Pinus nigra*), Scots pine (*Pinus sylvestris*) and bog pine (*Pinus mugo*) belong to the *Pinus* subsection (both *Pinus* and *Pinaster* subsections belong to the *Pinus* section, subgenus *Pinus*). (Lazarević et al., 2016)

1.4 Uses of the Bosnian pine in the past

Bosnian pine wood is known to have been used in shipbuilding and construction, for its durability and water-repellent properties. However, due to the specific weight of the wood which affected ship buoyancy, Bosnian pine was used in combination with other, lighter types of wood.

Beams for covering houses and other objects in katuns were made with Bosnian pine wood (katun refers to the family-owned land and cottages in the mountain areas of Montenegro, used during the summer for livestock grazing). Herders collected Bosnian pine to make troughs and pillars for climbing down snow pits. Bosnian pine resin was useful for boat joints and for repairing fishing nets. Resin was also poured into candles, as well as into vessels with a wick, and used as a light source.

Bosnian pine also found its use as a folk remedy - against sprains and bone fractures (for faster healing), and for calming asthmatic attacks by inhaling vapours from pre - heated resin.



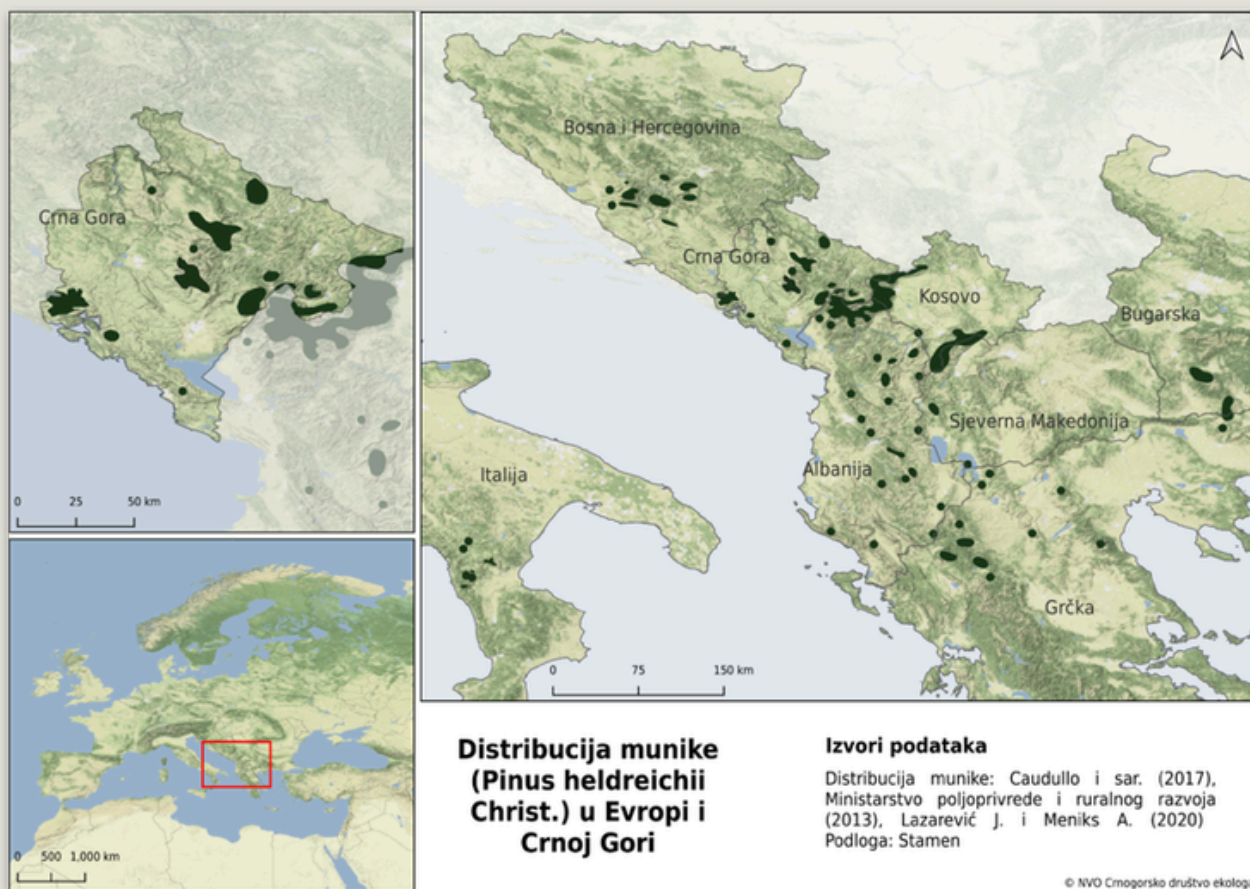
Figure 12. Bosnian pine beams, Žijevo ©Jelena Lazarević, 2015.

Bosnian pine forests in Montenegro

2.1 Bosnian pine distribution

Stands of Bosnian pine forests in the Balkans have been recorded on the mountain Hranisava in Bosnia, on Čvrstica, Čabulja, and Prenj (Herzegovina), and on the border of Orjen. Moreover, stands are recorded on Montenegrin mountains: Lovćen, Bjelasica, Maganik, Kamenik, Komovi, and Koritnik, as well as on the slopes of Prokletije where forests spread to the Albanian mountains. On the South, forest stands spread to Greece, to the mount Olympus and Pindus. In Macedonia, they can be found on Galičica, Korab, Rudoka, on the Kosovo side of Šare, and further east on the Bulgarian mountains of Pirin and Sjavjanka - Ali Botuš. In Albania, Bosnian pine grows from north to the south of the country, on the high oro - Mediterranean mountains. In southern Italy, Bosnian pine grows in a small area of Calabria and Brazilicato (Fukarek, 1949).

Map 1. Bosnian pine distribution in Europe and Montenegro





Bosnian pine forests from various parts of Montenegro differ depending on a number of factors, such as geographical position of the mountains, geological properties, and altitude, on which the composition and the characteristics of Bosnian pine forest stands depend upon. These are further discussed in Chapter 3.1 *World of plants—floristic composition and vegetative structure of Bosnian pine forests*.

2.2. Factors affecting Bosnian pine forest development

Bosnian pine habitats develop in the high mountain zone, under the influence of the sub-Mediterranean climate.

Mediterranean, sub-Mediterranean mountain climate is characterised by short, dry and cool summers, very cold and windy winters, with an annual average temperature of around 3°C. In these areas, temperature ranges from below -30°C in winter, to higher than 35°C in summer. Annual average precipitation is high and amounts to 2000-3800mm. Precipitation in the coastal Dinarides range (Orjen, Lovćen, Rumija) is higher than 5000mm in some years. Distribution of precipitation during the year, however, is not favourable, since during the vegetative period, total amount is very low (summer precipitation makes up about 10% of the total precipitation), which is of much greater importance for the vegetation than the total amount.

Bosnian pine forests in Montenegro typically inhabit limestone terrains covered by various soil types: from sierozem to humus and brown soils, which often erode. These types of soil are shallow, and poorly supplied with nutrients, they are dry and highly water-permeable.

Bosnian pine grows on warm exposures, on steep, rocky, and scarce terrains, clinging strongly with its roots. **No other tree species would have survived on such steep surfaces where the Bosnian pine found its place and beautifully developed into a medium-tall tree.** In such habitats, Bosnian pine grows very slowly. As an example, trees from Prokletije are 150 years old and reach a height of only about 15 m.



Figure 13. Bosnian pine on steep slopes of Orjen ©Jelena Popović, 2020.

Based on this, we are brought to the conclusion that Bosnian pine is adapted to the short vegetative period of the high mountain zone, dry and hot mountain summers with very intense solar radiation, but also harsh cold and windy winters. This is a species of great environmental plasticity, adapted to life in harsh environmental conditions.

Although the primary habitats of Bosnian pine are the carbonate substrates of high mountains in the subalpine belt of the oro-Mediterranean, Bosnian pine stands can also be found on serpentine soil (Šar Mountains) and on some Albanian mountains, as well as on silicate soil in Prokletije. Here it forms mixed stands with Macedonian Pine forests. Bosnian pine grows very slowly in its primary habitat. It favours silicate rather than limestone habitats and can reach impressive heights, especially if there are no competing fast-growing species. Much less often, Bosnian pine forms pure or mixed stands in the mountain belt. Here, as a pioneer species, it inhabits fire and frost areas, or clearings, representing the first stage in a progressive succession that ultimately results in mixed forests. In these forests, Bosnian pine is mixed with black pine or beech, less often with other tree species.

Bosnian pine trees are extremely long-lived. A 1200-year-old Bosnian pine tree found in the Pirin National Park is living proof. Similarly, a tree more than 1100 years old can be found on the mountains of Greece. Also, trees up to 600 years old have been recorded during previous research on Orjen.



Figure 14. Bosnian pine isolated on the limestone terrain, Maganik ©Jelena Lazarević, 2022.

Wildlife of the Bosnian pine forests

3.1. World of plants: floristic composition and vegetative structure of Bosnian pine forests

Bosnian pine belongs to the class of relict pine forests (*Erico-Pinetea* Horvat 1959), which are very distinctive in terms of their floristic composition, ecology, and distribution. Forest crowns allow much sunlight to penetrate below, as well as heat to permeate, thus creating favorable habitat conditions for a variety of species, including shrub and ground cover plants (Janković M.M. and Stefanović K., 1972). These forests are home to a high percentage of Balkan endemic species.



Figure 15. Bosnian pine forest on Štitovo ©Jelena Popović, 2020.



Bosnian pine creates diverse, usually semi-open, seldomly closed-canopy forest communities (forest cover can be closed-canopy; and open, or semi-open-canopy when the trunks and their crowns are far from each other). Forest diversity is determined by a number of factors, like geographical position of the mountains, geological properties, as well as altitude. A large number of communities united in a special association of Bosnian pine forests (*Pinion heldreichii* Horvat 1946).

There are three different forest communities in Montenegro:

- Bosnian pine forests of the oro-Mediterranean mountains;
- Bosnian pine forests of the Prokletije area;
- continental Bosnian pine forests.

(I) The first group of communities includes pine forests of the oro-Mediterranean mountains of Montenegro. This macro-community includes Bosnian pine forests of the mountains around Nikšić: Štitovo, Maganik, and Prekornica, as well as forests of Orjen, Lovćen, and Rumija. Mediterranean montane Bosnian pine forests grow in the zone between 1200 and 1800m above sea level, on carbonate soils, exposures, and slopes between 5° and 40°. In this part of the habitat, they have been exposed to strong anthropogenic influences since ancient times. Despite this, they belong to a group of the most spacious and atypical autochthonous stands, which inhabit the area of a high Dinaric karst, characterised by high temperatures. These stands can also be found in the areas with undeveloped and highly permeable limestones, where a mesophilic species, such as beech, comes to the edge of its ecological niche.

Another fact that supports the theory that the forests in this area are autochthonous, is the vitality of the species, reflected in the age structure. This structure includes natural vegetative and generative death and renewal cycles. Compact stands of Bosnian pine grow on all exposures, which confirms the forest classification: as climatogenic vegetation of the Mediterranean-montane and subalpine belt of the coastal and southeastern Dinarides.

Species that are characteristic for these communities are (Blečić & Lakušić, 1969): *Pinus heldreichii*, *Lonicera formanekiana*, *Lonicera glutinosa*, *Viburnum maculatum*, *Senecio visianianus*, *Dianthus petraeus*, *Gentianella crispata*, *Cerastium grandiflorum* etc. Phytocenotypes spectrum indicates the abundant presence and significant cover values of relict pine forests. Copious companions in the ground level of Bosnian pine forests are plants of mountain ores found on limestone, as well as plants inhabiting limestone rock crevices. These represent the first phase in the development or progradation of Mediterranean-montane and subalpine Bosnian pine forests on the Balkan and Apennine Peninsulas.

Orange Honeysuckle (*Lonicera glutinosa* Vis.) is an upright deciduous shrub that belongs to the honeysuckle family. It has crooked and bent branches and can grow up to 2m in height. This endemic plant blooms during June and July and inhabits the rocky habitats of high mountain peaks, beech, and Bosnian pine forests, as well as the edges of rock creeps, etc. It has thick, hairy, glandular - sticky foliage and a yellowish - white corolla with a reddish tint. Fruits are completely fused, red in color, and poisonous. The *Lonicera* plant genus is named after the German botanist Adam Lonicer, while *glutinosa* means *sticky*, which indicates the characteristic of the foliage. *Lonicera* is also named honeysuckle and trumpet honeysuckle.



Figure 16. Orange honeysuckle (*Lonicera glutinosa*) ©Snežana Vuksanović, 2007.

Viburnum maculatum Pant. locally known as Orjenska hudika, is a relict endemic of the Southeastern Dinarides, from the Adoxaceae family. This is a deciduous shrub 3-5 m high, with a well-developed root system and leaves that are opposite, broad, thick, and rusty-white on the underside. It usually inhabits dry, sunny, and stony terrains, mostly on the southern exposure. Orjenska hudika can also inhabit altitudes over 1000 m above sea level. The Latin name of the genus *Viburnum* is derived from the word *viere*, meaning to



bind, due to the pliability of the young shoots, used in ancient times for embroidery, knitting, as well as crafting arrows. The fruits of Orjenska hudika are edible, but only in limited quantities!

Figure 17. *Viburnum maculatum*
©Đorđije Milanović, 2005.

The rock pink (*Dianthus petraeus* Waldst. & Kit syn. *Dianthus nicolai*) is an endemic of the Balkans, a plant up to 15 cm tall from the Caryophyllaceae family (carnation family), with narrow foliage and relatively small white or light pink flowers. It can be found in mostly dry and rocky habitats. Name of the *Dianthus* genus is associated with the Greek words *dios* meaning *god* and *anthos* meaning *flower*. Its literal translation would be a *divine flower*. Also, epithet *petraeus* indicates that its habitat is characterized by a lot of rock crevices and rocky areas.



Figure 18. The rock pink (*Dianthus petraeus*) ©Jelena Popović, 2021.

Wavy gentianella (*Gentianella crispata* (Vis.) Holub) is a subendem of the Balkan Peninsula and the southern part of the Apennine Peninsula. This herbaceous plant that is up to 15cm tall belongs to gentian family and is characterized by small toothed bluish - purple flowers. Name of the genus *Gentianella* is actually a diminutive of the genus *Gentiana*, which is named in honor of the Illyrian king and physician Gentius, who discovered this genus and used it as a medicine. Epithet of this species, *crispata*, is associated with the word *crispus* meaning *curly*, because of the curly leaves of the calyx. This species is under national protection.

Showy Chickweed (*Cerastium grandiflorum* Waldst.) is another endemic Dinarides species. This is a perennial herb that belongs to the carnation family. It blooms from June to August, and is characterised by a greyish - green upright stem overgrown with desert hairs, alternating pointed foliage, and flowers with five white petals. The name of the genus *Cerastium* comes from the Greek word *keros* since the plant's fruits resemble a horn. It inhabits stony, dry habitats, rock crevices, ores, and rocky pastures in mountain areas.

Upon researching the vegetation of Štitovo, Fukarek mentioned that there is an apparent existence of mixed forests of beech and Bosnian pine here (Fukarek, 1963). These stands were also found in Prokletije, so this geographical division of forests is of informative nature.



Figure 19. Fieldwork, Bosnian pine forests on Orjen ©Jelena Popović, 2020.

(II) **Bosnian pine forests of the Prokletije massif** make up a wide variety of forests and inhabit a wide zone on the carbonate massifs of Prokletije, between 1500 and 2000m above sea level, on all exposures and slopes. Following Blečić's approach, characteristic species of these forests are: *Pinus heldreichii*, *Daphne oleoides*, *Daphne blagayana* ssp. *zogovici*, *Wulfenia bleicicii* ssp. *bleicicii*, *Thymus albanicus*, *Acinos alpinus* ssp. *dinaricus*, *Achillea abrotanoides* ssp. *montenegrina*, *Euphorbia montenegrina* and others. With further evolution of the soil and vegetation, Mediterranean - montane forests transit to firs, beech - firs, and, in the northeastern Prokletije, to spruce - firs forests as well.

Olivelike daphne (*Daphne oleoides* Schreb.) is an evergreen shrub from the Thymelaeaceae family. This plant with greyish - green foliage grows up to 60cm tall and is very branched. It is characterised by orange fruits and white stems that are slightly purple on the outside. It blooms during May and June. It inhabits sunny, stony, and dry habitats at altitudes higher than 1500m above sea level. There are two interpretations of how this plant got its name. According to one, genus *Daphne* (*da* as a prefix used for amplifying the meaning, *phainomai* meaning *to shine*) is associated with its shiny fruits.

According to another belief, this genus got its name after laurel leaves (due to the similarity between these two species). In ancient times laurel was known by the name Daphne, after the nymph, a great love of Apollo.

Blečić's wulfenia (*Wulfenia bleicici* Lakušić) from the Plantaginaceae family includes several of the most interesting species in the European flora. It's named after the famous botanist who discovered this genus in the Carnic Alps in 1779. In Montenegro, the name *prokletijska vučica* (eng. *Prokletian she-wulf*) is also used. Specific structure of the internal and external parts of the plant indicates its phylogenetic age. This genus is considered to be a tertiary relict that survived the last ice age, so we can rarely find it in nature. *Wulfenia bleicici* is described as a stenoendemite and has national and international protection status. It is widespread in the Prokletije massif at altitudes between 1,600 and 2,400m above sea level, and it grows in forests of aspen, spruce, and pine trees, on silicate and limestone sloughs and ores.



Figure 20. Marija taking photographs of Blečić's wilfenia in macedonian pine forests
©Jelena Popović, 2019.

Montenegrin yarrow (*Achillea montenegrina* Beck & Szyszyl.) is a perennial plant from the Asteraceae family, endemic to the western part of the Balkan Peninsula with the status of an endangered species. This plant inhabits harsh habitats - limestone and sloughs, at altitudes of up to 2.000m above sea level. Genus *Achillea* is named after the Greek hero Achilles, who used these plants to treat wounds, which indicates that many species of this genus have medicinal properties. It can be recognized by its branched stem, hairy foliage, and small, white flowers that form a specific inflorescence.



Rock thyme (*Clinopodium alpinum* (L.) Kuntze) is a perennial herbaceous plant from the Caprifoliaceae (honeysuckle) family. With its striking purple color, this plant gives liveliness to the bleak rocky areas it inhabits. It is as well characterized by its strong scent and aromatic and edible leaves that have medicinal properties. It is up to 40cm tall, and can be found in bloom from May to August.

Montenegrin spurge (*Euphorbia montenegrina* (Bald.) K.Malý syn. *Euphorbia verrucosa*) is a perennial herbaceous plant with a strong root that belongs to the Euphorbiaceae family. It's endemic to the Balkans and a sub - endemic to the Dinarides. Grows up to 40-50cm in height. *Euphorbia montenegrina* is characterized by alternate elliptical leaf arrangement, the front side of which is overgrown with tiny hairs. Peculiarity of this plant is its monoeciousness (plant bears both male and female flowers), which facilitates reproduction. Etymologically speaking, genus is named in honour of the Greek physician Euphorbos who lived in the 1st century BC. *E. montenegrina* particularly favors sunny habitats, inhabits limestone and serpentine rock gardens on southern and south - eastern exposures. It finds Bosnian pine forests as a suitable habitats since they are bright and south oriented.

(III) **Continental Bosnian pine forests** are found along the northeastern border of pine forests that spread from Durmitor, Sinjajevina, through Bjelasica, Smiljevica, to Hajla. In this stretch, Bosnian pine intertwines with spruce forests, which are dominant in the mountain and subalpine belt of the continental Dinarides. On the slopes of Durmitor, Sinjajevina, Smiljevica, and Hajla, Bosnian pine forests can be found in small stands, scattered trees in crevices of limestone rocks, or subalpine ores. Contrary to this, compact stands that inhabit dry and southerly exposed warm limestone habitats can be found on Bjelasica mountain. A group of characteristic species commonly found in these forests includes (Blečić & Lakušić, 1969): *Pinus heldreichii*, *Daphne blagayana*, *Pinus sylvestris* var. *dinaricus*, *Thymus balcanus*, *Silene viridiflora*, *Laserpitium marginatum* etc.

It is important to note that spruce - fir forest species are absent in Bosnian pine stands on Bjelasica. This means that these Bosnian pine communities belong to relict pine forests, despite the fact that they develop in Bjelasica's climatogenic spruce zone.

Daphne (*Daphne blagayana* Freyer), an endemic of the Balkans, is a creeping perennial evergreen shrub from the *Daphne* genus and Thymelaeaceae family. It is characterised by dark green, glossy, leathery foliage, yellowish - white flowers with a pleasant scent, as well as bark with long and strong silky fibers. Like other members of this genus, it is poisonous (bark and fruits contain toxic substances daphnin and glycosides). *Daphne blagayana* is one of the first harbingers of spring since it blooms very early, from May to June.

Typical habitats for this species are mountain pastures, karst terrains, as well as light coniferous forests, such as Bosnian pine forests. Etymologically speaking, genus *Daphne* got its name due to the similarity of its leaves to the laurel plant (*daphne* is Greek word for *laurel*), while the epithet *blagayana* refers to the botanist Richard Blagai, who described this species in the first place.



Figure 21.
*Daphne
blagayana*
©Đorđije
Milanović,
2020.

Thyme (*Thymus balcanus* syn. *Thymus praecox* subsp. *polytrichos* A. Kern. Ex Borbàs) is a perennial herbaceous plant that belongs to the Lamiaceae family. This family got its name for its characteristic shape of the flower, resembling lips. Specific types of thyme are all very similar and not easy to tell apart. Most are characterized by an intense, pleasant scent that originates from the evaporation of essential oils. Thyme grows in dry and sunny habitats, which is why it inhabits Bosnian pine forests as well. It usually grows in large groups and blooms from May to September. Etymologically, its name is linked to the Greek word *thymon* meaning *courage*, according to a legend that warriors bathed in thyme water in order to gain more strength. According to other sources, *thymus* is related to the word *thyo* meaning *sacrifice*, since this plant was used in sacrificial rites. In the Balkans, its name was associated with the old Slavic deity *Baba*.

Laserpitium marginatum Walds. & Kit. (syn. *Laserpitium krapfii*) is a perennial plant from the Apiaceae family. Flowers are grouped in inflorescences, resembling a shield (Apiaceae family is named after this characteristic); and are characterized by yellowish petals with a dark red edge. Name of the genus *Laserpitium* is derived from the Greek words *laser* meaning *juice* and *pitiso* meaning *to leak*, because the juice was valued as a spice, and the leaves, seeds, and root are also aromatic and can be used for various purposes. This genus mostly includes species that inhabit moist leeward areas. However, this and several other species inhabit karst, cold areas too. *Laserpitium marginatum* is widespread in the mountain regions of Eastern Europe and the Balkan Peninsula.



Figure 22. Heart-leaved globe daisy (*Globularia cordifolia*) in Bosnian pine habitats on Kula peak, Prekornica ©Jelena Popović, 2020.



Figure 23. Blue alpine daisy (*Aster alpinus*) in Bosnian pine habitat on Štitovo ©Jelena Popović, 2020.

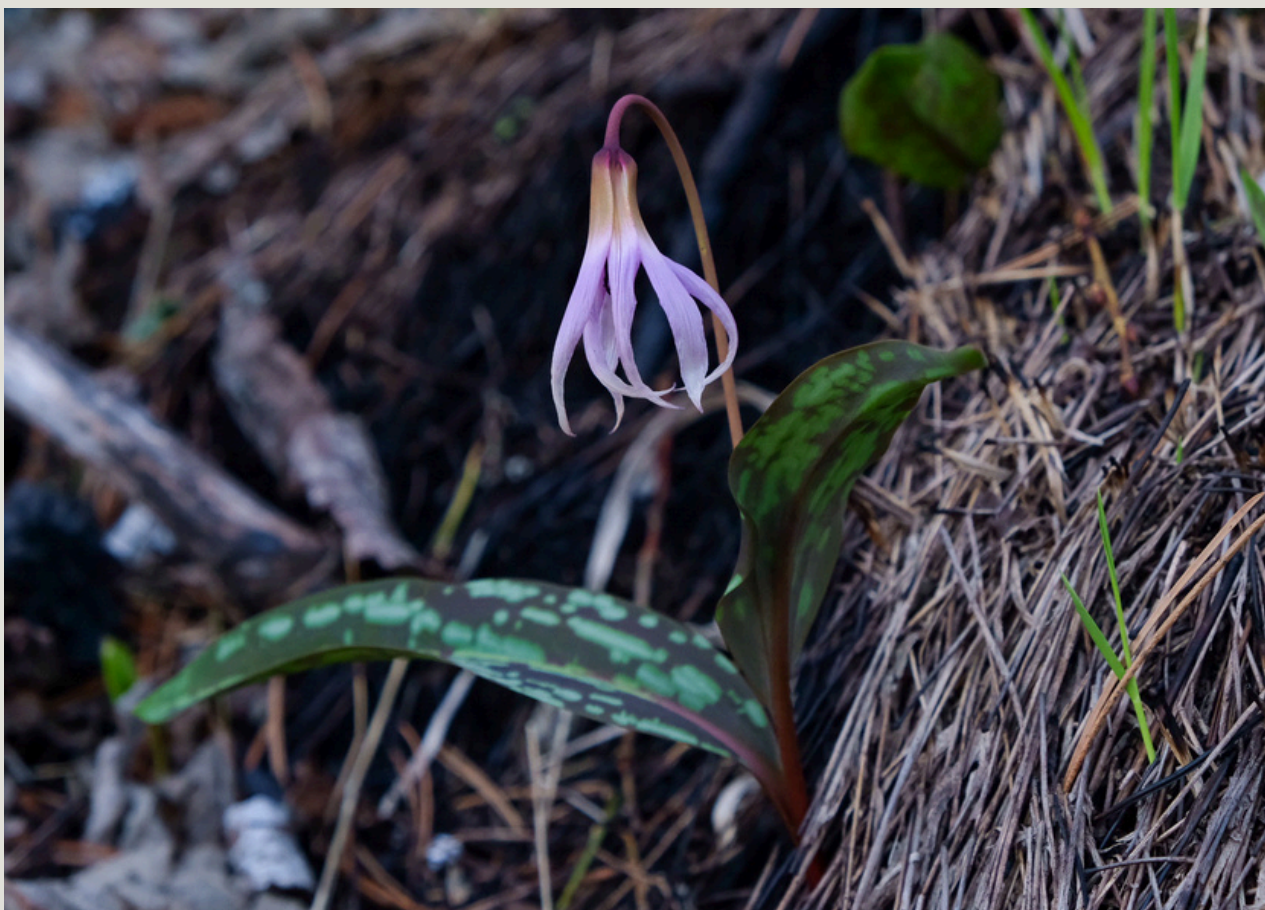


Figure 24. Dogtooth violet (*Erythronium dens-canis*) below Bosnian pine ©J. Popović, 2021.



Fig. 25. Pyrenean columbine (*A. pyrenaica*), Bosnian pine habita on Orjen ©J. Popović, 2020.

Floristic diversity of the Bosnian pine forests is very rich and specific, with the presence of a large number of endemic and relict plant species. This is primarily due to the endemism and specificity of its phytocenoses, biogeography, and specific history of these forests.

Diverse spectrum of different plant species is conditioned by the fact that Bosnian pine builds a wide range of plant communities, from closed - canopy and mesophytic ones formed with beech, to very thinned and almost open - canopy communities, where surrounding rocky outcrops and crevices penetrate into the interior of its stands. These forests hold the largest number of endemic taxa. That is why Bosnian pine forests are among the biodiversity richest and most significant forests in our area (several hundred different taxa of vascular plants). Areas of these forests are so rich in biodiversity that some species, such as moss, have only barely been researched. Lastly, this very general and short overview of plants that form communities with Bosnian pine points to numerous unsolved problems still concerning them, worthy of special attention for botanists and phytocenologists.

3.2. World of insects in Bosnian pine forests

Insects are the most numerous group of animals on the planet. Thus, their role and importance for the survival and functioning of the biosphere is invaluable. About two million species of insects have been described on planet Earth, with the assumption that there are as many as eight million. But, taking into account the number of insect species, it is the least researched group of animals in the world. According to the available data, about 6.000 species have been listed on the territory of Montenegro so far, while estimates suggest that the number is much higher, up to 20.000 - 30.000.



Figure 26.
Educative
research of ants
in Bosnian pine
forest,
Prekornica ©J.
Popović, 2021.

Research of insects in pure and mixed Bosnian pine forests on the Prekornica mountain near Danilovgrad shows that these forests hold a large number of insect species. Great number of umbrella species were found in the researched areas (Box 4). During short research for the purposes of this bo, 174 species of invertebrates were recorded in nine localities with different habitat types belonging to Bosnian pine forests, of which 13 are terrestrial and freshwater snail species (Gastropoda), 9 spider species (Aranea) and 152 species of insects, among which 13 are ants species (Formicidae).

Ants and saproxylic beetles are among the most numerous and important groups of insects in the Bosnian pine forests.

Results of this research do not paint a complete picture of the biodiversity of invertebrate species in pure Bosnian pine forests, but they are a starting point for further and more detailed research.

Box 4: *Umbrella species* - species that have a disproportionately large impact on their natural environment in relation to their representation. For this reason, they are often under protection, because their preservation contributes to the preservation of entire natural areas, since their protection also protects other species in that habitat which are connected to the umbrella species via, for example, food chain.

Saproxylic beetles

Saproxylic beetles (Box 5) represent a group of insects that are closely connected to a living tree or to a tree in the decaying stage of its life cycle. These insects participate in the process of decomposition of wood mass, and have evolved in a way that they depend on that process, and thus play a very important role in the balance and circulation of matter in the forests. Spread of saproxylic species depends on the quantity and quality of dead wood in the forest, on the size of the forest, its fragmentation, and on the way the forest is managed. Substrate of dead trees, fungi, and other organic debris provides a habitat for saproxylic insects. However, sanitary felling, cleaning, and removal of old and rotten trees and stumps have led to the destruction of saproxylic insect habitats. A large number of saproxylic arthropods are protected by European Union directives and international conventions.



Fig. 27. The Art of natural desintegration, Štitovo ©Jelena Popović, 2022.

Box 5: *Saproxyllic invertebrates* are those whose life cycle depends on the processes going on in dead or decaying wood (or on other organisms that are themselves tied to the processes taking place in the decaying tree). A saproxyllic species do not have to be connected to a decaying tree for its entire life cycle, but it may be important for at least one life stage of the species.

Ants as a group of organisms play an incalculable role in natural ecosystems. One of their most important roles is that they affect the distribution of living and non-living biomass in habitats, since they are extremely dominant and represent the largest share of arthropod biomass (from 15-20%) in most ecosystems.

If we look at an ant colony as one coordinated organism, ants are at the top of the food chain. Accordingly, they play a major role in regulating the numbers and biomass of other insects. Depending on the species, some ants are primarily predators, while others are vultures. But in general, they are opportunists and omnivores by nature. Due to their large biomass, ants also serve as food for many other organisms, since isolated workers as individuals are easy prey for many predators.

Out of all the ant species found in Bosnian pine forests, we ought to highlight three that are most likely to have critical effects on the survival of the forest. These species also play an important role in supporting the overall biodiversity: European red wood ant (*Formica pratensis* Retzius) as well as Carpenter ants (*Camponotus vagus* (Scopoli) and *Camponotus ligniperda* (Latreille)).



Figure 28. European red wood ant (*Formica pratensis*) ©Nikola Balević, 2020.

European red wood ant (*Formica pratensis* Retzius) prefers coniferous forests where its life is completely intertwined with its habitat: conifer needles serve as a good substrate for building their nests while at the same time providing good insulation; furthermore, one of the primary food sources for the European red wood ant is the sweet sap of the pine tree aphid; and the coniferous resin is especially important for maintaining the health of their colony - ants bring it into their nests and use it as an antibacterial substance. In Bosnian pine ecosystems, **European red wood ants serve as regulators of the populations of harmful insects.** This is due to the fact that they are primarily predators and by far the most represented species in terms of their total biomass. A single colony of this ant species captures far more insects annually than any other species in these ecosystems. Colonies are extremely productive and resistant to cold, which accounts for their dominance. The hunting ground of one colony is 0.5ha on average, and the ants of one colony can catch up to ten million insects in a year.



Figure 29. Red carpenter (*Camponotus ligniperda*) ©Nikola Balević, 2020.

In addition to the European red wood ant, the **carpenter ant species** are similarly intertwined with conifer forests, and therefore with Bosnian pine forests too. They prefer dead wood mass or natural hollows in trees for making nests. One of their most important roles in the ecosystem is that **they are effective decomposers of wood pulp.**

They are not considered to be pests of healthy trees, but they drill tunnels and nests in trees that are in a decaying stage or have softened due to the effect of various diseases or age. Therefore, carpenter ants indirectly accelerate the biodegradation process. (Munyai T.C., Foord S.H. (2012); Abbott K. et al. (2010) and Adlung KG. (1966)).



Figure 30. *Manica rubida* ©Nikola Balević, 2020.



Fig. 31. Pavement ant (*T. cespitum*) on Bosnian pine needle ©Jelena Popović, 2021.

As was already mentioned, the world of insects in Bosnian pine forests is diverse and very interesting. But it is necessary to carry out detailed research in order to clearly understand which species are related to the Bosnian pine forests and in what ways. The research will also shed light on ways these insects affect the forests and vice versa. With this in mind, we will feature a few more insect species that adorn Bosnian pine expanses i.e. butterflies:

Eros blue butterfly (*Polyommatus eroides* Frivaldsky 1835) is a bright blue butterfly from the Lycaenidae family. It inhabits grassy and rocky mountain slopes at high altitudes, often near or around the forest line. They lay their eggs on plant species belonging to the *Astragalus*, *Chamaecytisus* and *Genista* orders.

Jersey tiger (*Euplagia quadripunctaria* Poda, 1761) is a diurnal moth easily recognised by the four dots on the outer side of the wing which explains how it got the name *quadripunctaria*: *quadri* meaning *four* and *punctaria* meaning *dots*. Name of the genus *Euplagia* comes from the combination of the Greek words *eu* meaning *beautiful* and *plagios* meaning *oblique*, which indicates the transverse stripe on its wings. Jersey tiger is one of the rare moths that can be encountered during the day, considering that moths are mostly nocturnal species. During the second half of the summer, this species is commonly found along watercourses, on wet forest roads, and on rocky resting places. The fact that it forms large swarms has contributed to it becoming one of the most famous moths in the Western world. In some places, this moth is even the subject of tourist tours. One of the most notable gathering places for these moths (more precisely, the subspecies *Euplagia quadripunctaria* subsp. *rhodosensis*) is the Butterfly Valley in Rhodes, which attracts tens of thousands of these moths during the summer.

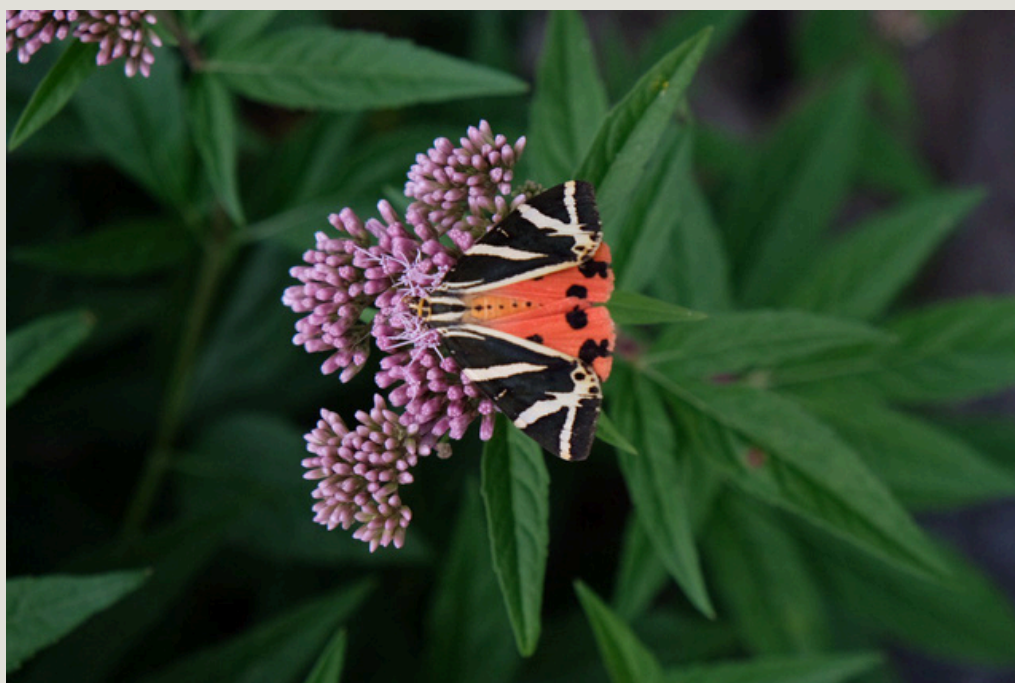


Figure 32. *Euplagia quadripunctaria* ©Jelena Popović, 2019.

Apollo butterfly (*Parnassius apollo* (Linnaeus, 1758)) comes from the family of swallowtails (Papilionidae) named after the lower part of the wing that is similar to a swallow's tail. This species got its name after the Greek god Apollo, who represents the ideal of beauty, indicating the beauty of this species as well. Apollo butterfly can easily be recognised by the bright red spots on its wings. Scientists suppose that the spots were developed as a defense mechanism against predators, to frighten, surprise, or divert attention from otherwise less vital body components. Apollo butterfly prefers hilly and mountainous meadows and pastures in continental regions. Due to a large decrease in the numbers of this umbrella species (Box 4), there are numerous initiatives for its protection.



Fig. 33. Apollo below Bosnian pines, Zeletin ©J. Popović, 2021.



Fig. 34. Apollo butterfly adorning mountain areas ©J. Popović, 2019.

Clouded Apollo (*Parnassius mnemosyne* Linnaeus, 1758) also comes from the swallowtail family and differs from the Apollo butterfly by the black spots on its wings. It inhabits forest meadows and habitats affected by forests. In the initial caterpillar stage, the black Apollo prefers *Corydalis* plants as part of its diet. Epithet given to this species in Latin comes from *Mnemosyne*, the Greek goddess of memory, which perhaps indicates the striking and easy memorability of this beautiful butterfly.



Figure 35. *E. quadripunctaria* in the group ©Jelena Popović, 2019.

3.3. World of reptiles in Bosnian pine forests

Reptiles are exothermic organisms, meaning that they rely on the environment for achieving adequate body temperature since they are physiologically not able to create enough heat themselves. For this reason, reptiles are very sensitive to external changes in their habitat and greatly depend on environmental parameters (Huey R. B., 1991). Reptiles are therefore often the subject of research, for the sake of understanding the effects of environmental changes (e.g. Sinervo et al., 2010). Also, reptiles are among the most important food chain links in various ecosystems where they control the number of insects and rodents, and consequently, reduce the spread of infectious diseases. In this way reptiles also reduce the spread of parasites in forests, gardens, and orchards.

Although at first glance they appear desolate, Bosnian pine forests are an important habitat for several reptile species that are adapted to harsh high mountain conditions. Those species are specific and special in many ways; They are mostly endemic and relict species as is the Bosnian pine.



Fig 36. High mountain habitat of Bosnian pine suitable for reptiles, Štitovo ©J. Popović, 2020.

Bright coniferous forests offer reptiles enough shelter, food, and heat making them a suitable habitat for species that inhabit high-mountain karst areas.

Furthermore, Bosnian pine forests form ideal living conditions for these species since medium - sized rocks (up to 100 cm high) aid reptiles in reaching and maintaining the desired body temperature (Ljubisavljević et al. 2017; Huey R. B., 1991). These rocks have cracks and crevices where seeds often fall into and take root. At the same time, the cracks are an ideal shelter for reptiles. Together with the tree canopy, these habitats provide an ideal combination of shade and sun which is necessary for the survival of these ectothermic vertebrates.

The types of reptiles that inhabit Bosnian pine forests are Mosor rock lizard (*Dinarolacerta mosorensis*) and Prokletije rock lizard (*Dinarolacerta moneteneigrina*). They are members of the genus *Dinarolacerta*, which are small lizards that prefer rocky ground and are endemic to the Dinaric Mountains of the southwestern parts of the Balkan Peninsula.

Mosor rock lizard (*Dinarolacerta mosorensis* (Kolombatović, 1886)) is endemic to the Balkan Peninsula. Epithet *mosorensis* comes from the name of the mountain Mosor, in Croatia, where it was discovered in 1886. Its body length in adults (without the tail) reaches 7cm. Their head and trunk are flattened, which



allows them to hide in the narrowest rock crevices and thus avoid predators such as snakes. Due to the cold and long winters in the mountain regions, the Mosor rock lizard emerges from hibernation at the end of April or the beginning of May. According to the IUCN criteria, the status of the Mosor rock lizard is classified as Vulnerable (VU). Classification stems from the fact that this species inhabits only a small area, has a highly fragmented distribution, and its habitat area and quality are in decline (Crnobrnja - Isailović et al. 2009). However, there are no detailed studies that examine the habitat structure and the factors affecting the abundance of this species.

Figure 37. Mosor rock lizard in Bosnian pine forests of Orjen mountain ©Andrijana Mićanović



Fig. 38. Prokletian rock lizard near Bukumirsko lake ©V. Iković, 2015.

Prokletian rock lizard (*Dinarolacerta montenegrina* Ljubisavljević, Arribas, Džukić, Carranza, 2007) is a species that was discovered very recently, in 2007. Until then it was identified as a Mosor rock lizard. Spatial distribution of these two species is separated by the deep canyon of the Morača river. As its name suggests, it is endemic to Prokletije, living only in Montenegro and Albania.

In Montenegro, it has so far been identified in the area of the Đebeza and Žijovo mountains, and in the wider area of the Bosnian pine forest. Adults can reach a length of up to 6 cm (without the tail). Prokletije rock lizard has a flattened body, an elongated head, a pointed muzzle, and a long and thin tail.

Other important reptile species found in Bosnian pine forests

In the peripheral zones of these forests, where the habitat is more open and where the space is dominated by the common juniper (*Juniperus communis* ssp. *alpina*), we can often find Nose-horned viper (*Vipera ammodytes*), sand lizard (*Lacerta agilis*), common wall lizard (*Podarcis muralis*) and smooth snake (*Coronella austriaca*) individuals. The smallest European venomous viper - meadow viper (*Vipera ursinii*) also lives in these habitats.

Smooth snake (*Coronella austriaca* Laurenti, 1768) is a species that people often confuse with the common European adder (*Vipera berus*), although it has a more elegant and elongated body. Smooth snake is fairly calm, and rarely bites, even when in human hands. It is usually grayish, brown, and sometimes reddish in color. Adult specimens are up to 70cm long, sometimes reaching a size of over 80cm. Females are larger than males. It feeds on lizards and smaller rodents, and very often on young specimens of poisonous snakes such as meadow viper.



Figure 39. Smooth snake, Bosnian pine forest, Orjen ©Andrijana Mićanović, 2020.

Meadow viper (*Vipera ursinii* Bonaparte, 1835) is the smallest European venomous snake. It inhabits high mountain meadows and pastures of limestone mountains surrounded by Bosnian pine forests, 1000 m above sea level. The highest point at which it has been registered so far in Montenegro is at 2213 m above sea level in Prokletije mountains. Meadow viper is usually between 30 - 50 cm long. Its pupil is vertical, as in other venomous snakes. However, its poison is of low intensity and is not dangerous for humans. It is a viviparous species, which means that it does not lay eggs, but gives birth to formed young snakes.

It spends the cold part of the year hibernating. Shortly after hibernation, mating period begins. Meadow viper is currently one of the most endangered species of reptiles in Europe, mainly due to habitat loss and fragmentation (overgrowth of pastures and meadows, etc.) (Console G. et al., 2020).

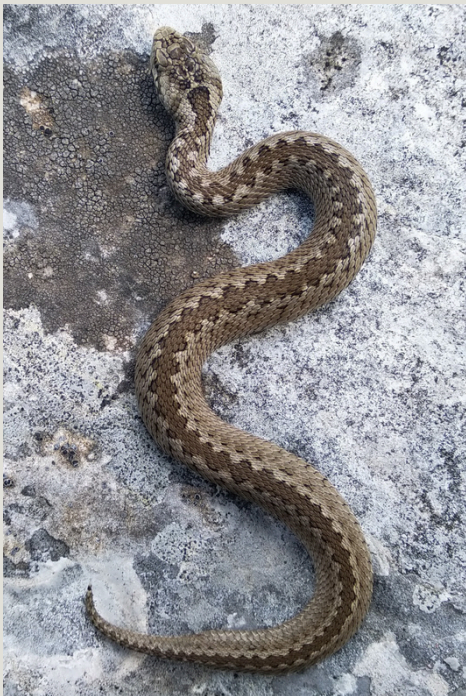


Fig. 40. Meadow viper on Visitor, lower part of Bosnian pine forests ©Vuk Iković



Figure 41. Nose-horned Viper of Visitor ©Andrijana Mićanović

Nose-horned Viper (*Vipera ammodytes* Linnaeus, 1758) is the most widespread poisonous species in Montenegro, inhabiting the entire country. It feeds on small mammals, birds, and other reptiles and is often found in the Bosnian pine forests. This viper is distinguished from other snakes by the horn on the tip of its snout, which is made of skin and connective tissue. The interesting thing is that the purpose of the horn is still unknown. Nose-horned viper is usually between 60 - 70cm long and can sometimes reach up to 100cm in length. Usually enters hibernation at the beginning of autumn, depending on the year and temperature, though it may be active on warm winter days. When threatened, this viper usually hisses but it is not aggressive and never attacks first. It will strike only when there is no other way out.

Sand lizard (*Lacerta agilis* Linnaeus, 1758) inhabits various types of habitats in mountainous areas 1000m above sea level including steppe, sub-alpine and alpine meadows, pastures, and open forests near juniper bushes. Sand lizard has a robust body, reaching up to 9cm in length (without the tail), and has a short head and legs.



Figure 42. Sand lizard ©Aleksandar Simović, 2014.

It has an olive to dark grey back with a clear continuous dark stripe, while the sides of its body are dotted with white colour. It usually feeds on invertebrates, but sometimes also on plants.

Common wall lizard (*Podarcis muralis* Laurenti, 1768) is a small lizard, very variable in color and pattern. It is well adapted to the living conditions in human settlements. This species inhabits various types of habitats: rock gardens, edges of open and degraded forests, roadsides, embankments, old stone walls, etc. It is common in Bosnian pine forests, where it sunbathes on rocky surfaces, but also finds enough shelter and food for survival. Adults can reach a body length of up to 7,5cm (without the tail).



Figure 43. Common wall lizard ©Ignacio Ferre Pérez, 2013.

3.4. World of fungi and Bosnian pine

Fungi play a crucial role in forest ecosystems, performing a variety of important functions. There are three main ecological groups of fungi:

- *Saprotrophic fungi* - these fungi decompose dead organic matter, mainly of plant origin. They play a critical role in breaking down plant waste, which would otherwise accumulate and hinder life on the planet.
- *Parasitic fungi* - these fungi live on living plants and animals and can often cause various diseases, which can lead to large - scale decline or extinction of plant species, so it's essential to study and understand their impact on the environment.
- *Mycorrhizal fungi* - these fungi form a symbiotic relationship with plants, exchanging nutrients and water for plant assimilates. Mycorrhiza has been shown to help plants cope with stress caused by factors such as drought, pathogens, pollution, and other negative impacts.

In Bosnian pine forests, the presence of fungi is limited due to the dryness of the habitat. There are only a few fungi species that appear in small numbers during rainy days in early summer and autumn. Some of the common species found in the forest are *Suillus* and *Lactarius*, *Russula*, *Hygrocybe*, and *Gomphidius*. In open areas and forest clearings, *Macrolepiota*, *Agaricus*, *Licoperdon* and other species are commonly found. The prevalence of fungi species is influenced by various factors including precipitation, altitude, and the type of habitat.

When it comes to the world literature and science, the findings of new species that can be distinguished at the taxonomic level represent true rarity and value. During the last few years, 16 species of fungi new to science were discovered in Montenegro, including two species for which new genera were created (*Pseudoboubovia* and *Perzia*).

Five newly described species are related to the Bosnian pine and its habitats. All these species were collected and described by Branislav Perić, in cooperation with experts for certain taxonomic groups of fungi.

For the fungi discovered on the bark of Bosnian pine branches (on Bindža, Komovi) new genus is described *Perzia*, and to this species the name *Perzia triseptata* Baral & B. Perić (2016) was given.



Figure 44. *Perzia triseptata* ©Branislav Perić, 2016.

New species *Erioscyphella curvispora* Perić & Baral, was described in 2014. on the fallen Bosnian pine needles, in several localities in Kuči mountains.

Species: *Velutarina alpestris* Baral & B. Perić, *Peziza montrivicola* B.Perić, and *Cenangiopsis junipericola* B. Perić are describen on high mountain habitats with mountain willows, beech, common silver fir and juniper, where also Bosnian pine is present. Ongoing research is now being conducted to determine the distribution of these species.

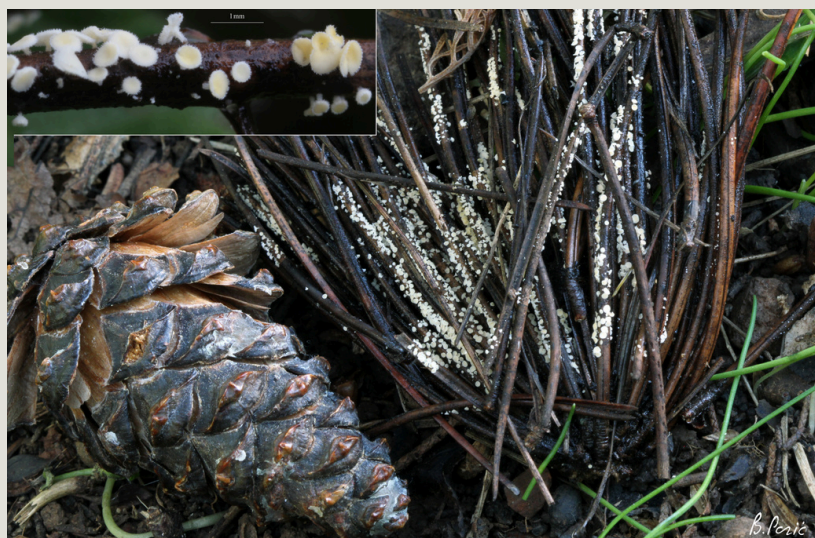


Figure 45. *Erioscyphella curvispora* ©Branislav Perić, 2014.

On the decaying branches of Bosnian pines Ascomycota fungi *Zeus olympius* Minter & Diam is found. This fungi was first discovered in the Bosnian pine forests on Olimp mountain in Greece, and up until now it is found only in the Bosnian pine forests. Apart from Greece it lives in Bulgaria and Montenegro as well. It is suggested to be part of the *IUCN Global Fungal Red List*.

Mycorrhiza between fungi and Bosnian pine

Mycorrhiza is a symbiotic relationship between a fungus and a plant root that plays a crucial role in transferring nutrients. Both partners typically rely on this relationship, with mycorrhiza occurring in approximately 85% of terrestrial plant species. This makes the fungus - plant relationship the norm rather than the exception.

Box 6: *Ectomycorrhiza* is a type of mycorrhizal symbiosis that is formed between Basidiomycota and Ascomycota fungi and forest trees from the families of pine (Pinaceae), beech (Fagaceae), willow (Saliaceae), etc. There are also other types of mycorrhizae e.g. arbuscular, or endomycorrhiza, that are formed between Glomeromycota and various types of grasses (Poaceae), herbaceous plants, and certain types of forest trees.

Ectomycorrhizal (Box 6) fungi, in particular, have evolved with forest trees and are able to acquire nutrients from the soil surface and provide them to the plants. This allows plants to obtain up to 80% of their nitrogen and 90% of their phosphorus needs from mycorrhizal fungi. Moreover, fungi are quick to respond to environmental changes, which helps ensure the survival of long-lived trees.

Around 5.000 – 6.000 species of ectomycorrhizal fungi are known to grow in temperate and cold zone forests, and in the northern hemisphere Mediterranean forests. In Montenegro, there are approximately 380 out of 1.100 known fungal species that belong to the mycorrhizal family.

Moreover, pines are mycorrhizal species that rely solely on mycorrhizal fungi for survival and natural regeneration.

Mycorrhiza not only helps in the uptake and transfer of soil nutrients, but also improves water uptake and helps alleviate stress caused by various environmental factors like drought, pathogens, and pollution.

Mycorrhizal fungi affect soil characteristics and are also involved in soil formation and aggregation processes. Therefore, research on ectomycorrhizal fungi (e.g., Lazarević J. 2003; Lazarević J. et al., 2018, etc.) can be of great importance for the restoration and preservation of Bosnian pine forests, but also of other conifer species in marginal habitats.

In Montenegro, the ectomycorrhizal fungi that form a symbiotic relationship with Bosnian pine have received special attention in terms of the research.



Figure 46. Jelena Lazarević and Bosnian pine, Kučke mountains ©J. Popović, 2021.

In early research on mycorrhiza, it was believed that ectomycorrhizal symbionts of Bosnian pine were well-suited to the conditions of challenging habitats, and thus suitable for the mycorrhization of pine seedlings. This hypothesis was confirmed, as mycorrhizal seedlings were found to be better equipped for survival after reforestation in difficult and dry terrains.

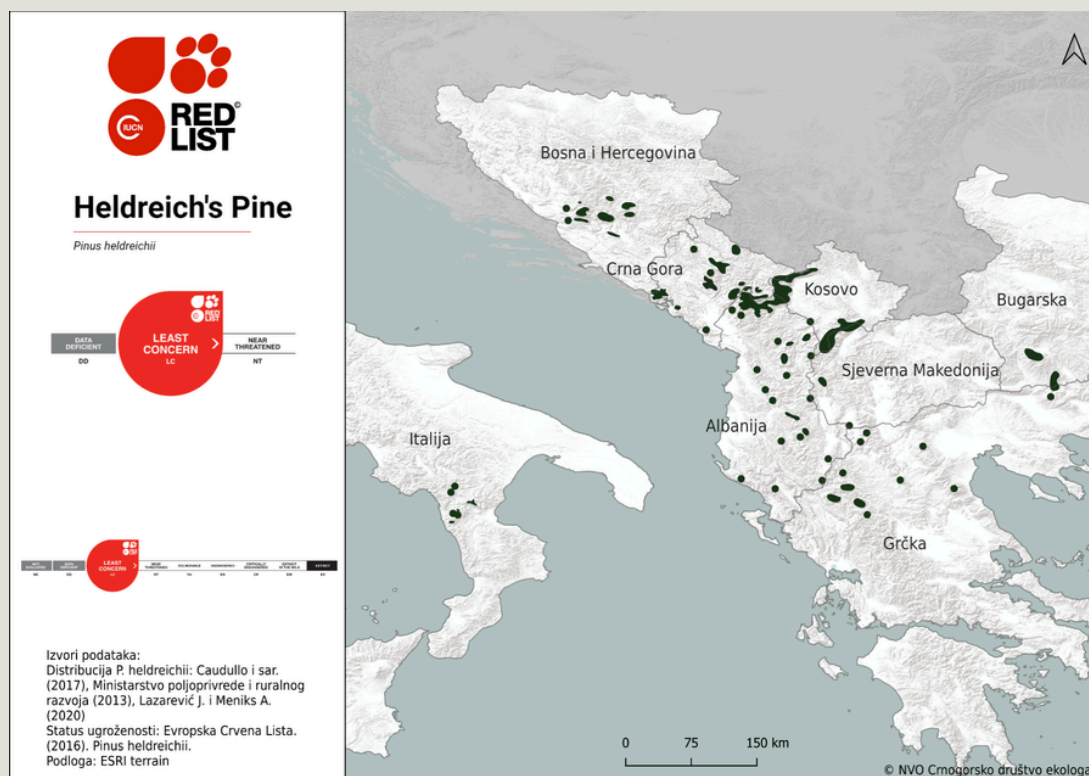
All of the above shows that **mycorrhizal fungi play a crucial role in the overall health of plants**. They can be instrumental in forest restoration efforts and can be used in the formation of seedlings as well as the entire afforestation process, particularly in challenging environmental conditions.

Bosnian pine forest threats

4.1. Conservation status

Bosnian pine is on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Box 7) as a species at low risk of extinction (Map 2). In Montenegro, and in the countries of the former Yugoslavia, Bosnian pine has been on the list of protected plant species since 1976. This means that it is prohibited to cut the Bosnian pine trees, as well as other forms of commercial use, together with other activities that can endanger the individuals and habitats of the Bosnian pine.

Box 7: *Conservation status of the species* - International Union for Conservation of Nature (IUCN) is one of the world's most important organisations for nature protection. In 1964, the IUCN established the Red List of Threatened Species, known today as the world's most comprehensive inventory of the global conservation status of biological species; uses a set of precise criteria for assessing the extinction risks of species and subspecies, relevant for all species and regions of the world. A number of regional red lists are made up by countries or organisations, which assess the risk of extinction of species within a political management unit. The Bosnian pine was given a Least-concern designation in 2016, indicating a low endangerment risk across its entire distribution range (8 countries). However, there has not yet been an assessment of the preservation status of Bosnian pine in Montenegro.



Map 2: Distribution of *P. heldreichii* and its conservation status according to IUCN Red list

Despite being labeled Least Concern, Bosnian pine forests are actually under threat (Caković D. et al., 2017). The once extensive forests have been depleted, destroyed, reduced to a fraction of their original size, or completely destroyed on many mountain massifs.



Figure 47. Trunk of the centuries - old Bosnia pine ©Jelena Popović, 2020.

Bosnian pine forests are facing two major threats: **illegal logging** and **forest fires**. Lacking detailed data on wood felling enables much of it to be “disguised”. However, certain data is collected during the field research by experts. Despite the ban on cutting at the national level, illegal cutting still takes place due to the high quality of Bosnian pine wood. Logging is less prevalent in national parks but is evident outside their borders (Caković D., 2020). The cause of forest fires in Bosnian pine forests is often linked to these illegal logging activities. Moreover, our observations from the field indicate that forest fires occur as a result of the concealment of illegal logging activities. Photos from all over Montenegro show the existence of stumps of centuries old Bosnian pine trees even in burnt forests.

It has long been considered that Bosnian pine forests are also under threat of hybridization with Black pine. Hybridization is reproduction between members of two species (e.g. Black pine and Bosnian pine), which results in a "semi-new" so-called hybrid species.

A hybrid species is not a new species in the biological sense, because it is not genetically separated from its ancestors.

The hybridisation between Bosnian and Black pine is no longer considered a threat as genetic research has proven that Bosnian pine is more closely related to coastal pine species than to Black pine. These two species are so genetically distinct that crossbreeding between them is not possible.



Figure 48. Bosnian pine withstood a great wildfire, Prekornica ©Jelena Popović, 2020.



Figure 49. Hug between Bosnian pine who did and did not survive the wildfire, Štitovo ©Jelena Popović, 2020.



Until recently, the creation of pastures for grazing was a threat to Bosnian pine forests, but with the changes in social conditions in the Balkans after World War II, the intensity of grazing has significantly decreased and no longer poses a significant threat to these forests.

Difficulties in the preservation and survival of the Bosnian pine and its forests depend on its biological and ecological factors as well.

Bosnian pine prefers sunny habitats and its ecological range is restricted to areas with high sunlight exposure. This, as well as the factor of slow growth, cause a decrease in its competitiveness and in ability to expand to larger areas.

Despite being a pioneer species, its natural regeneration is somewhat limited due to certain characteristics of its seeds, such as seed-bearing periodicity and long periods of reduced seed yield, as well as poor germination (Janković M., Stefanović K., 1971).

Additionally, Bosnian pine faces challenges with natural renewal due to unfavorable climatic conditions, including a short vegetation period of only a few summer months and a tendency to experience drought because it grows on south-facing terrain.

Natural regeneration of the Bosnian pine can also be threatened by pathogenic fungi (more on this in chapter 4.3 *Pathogenic fungi and Bosnian pine forests*).

Despite the challenges and specific ecological conditions, Bosnian pine has managed to persist due to its unique characteristics which set it apart from stronger competitive plant species that occupy more favorable terrains.

Bosnian pine primarily grows in southern, steep, dry, and rocky terrains on limestone and dolomite bedrock with harsh mountain climate conditions. In this respect, there is no other species equally capable. These are the places where the harshness of the mountain climate comes to its greatest expression.

It's a pioneer species that tolerates extreme droughts and rainy periods, grows slowly, and has low requirements, making it one of the least demanding species in Europe.

Bosnian pine also occurs secondarily in northern, milder, moist terrains on a silicate substrate with a slightly more favorable climate. Its pioneer character allows it to grow at lower altitudes as the first stage in the progressive succession of mountain forests after primary forest vegetation has been destroyed by fire or human activities such as uncontrolled felling or grazing.



Figure 50. Bosnian pine habitat on Komovi mountains
©Jelena Lazarević, 2022.

4.2. Wildfires

Forest fires disrupt all natural processes in the forest and in its land, adversely affecting natural regeneration, thus posing the greatest danger for the Bosnian pine forests in Montenegro.

Under favorable environmental conditions, forest needs more than 70 years to recover after a fire. However, on such challenging, stony, and dry limestone terrain, the process of natural renewal can be longer, and in some cases even impossible.

Environmental damage from forest fires has negative effects, sometimes even many years after the fire. These include:

- an irreparable loss of biological diversity;
- disappearance of rare, endangered and vulnerable plant and animal species, causing a decrease in the genetic diversity of species;
- changes in the landscape and the beauty of the area - affecting landscape diversity;
- changes in the physical, chemical, and microbiological properties and composition of the soil;
- climate, micro-climate, and water balance: disruption of the hydro-logical regime, reduction of water supplies, and occurrence of floods;
- reduction in the recreational significance of the forests.

In addition to the drastic reduction of forest area, forest fires can also affect the disappearance of adult reproductive trees, leading to a decrease in the genetic diversity of young trees and reducing the forest's potential for adaptation to future changes. Livestock grazing after the fires can further hinder natural regeneration and cause the local extinction of species.

Almost all mountain areas of Bosnian pine forests have suffered fires, some more than once. Fires eliminate the vegetation cover that serves as a habitat for many invertebrates or smaller organisms and destroy pine trees that are home to various birds, fungi, insects, etc. Fires also lead to changes in micro-climatic conditions, that are particularly harmful to reptiles as exothermic organisms. In the end, by wiping out a forest, fires also wipe out our ability to peer far into the past of that area through the long-lived trees that serve as our "windows in time".

It is especially important to highlight the negative effects of fires on biodiversity loss in ecosystems such as Bosnian pine forests, where many endemic species have specific ecological requirements and an organised distribution.



Figure 51. Bosnian pine trunks remain erect for long after the fire, Žižovo ©Ivan Laković, 2016.



Fig. 52. Years after the fire, Maganik ©Jelena Lazarević, 2022.

Research on the succession of fungi in burned habitats indicates that fires have a negative and long-term effect on the diversity of fungi in the soil (Lazarević et al., 2018). Fungi play a vital role in various processes in forest soil, including natural regeneration after fire. However, our understanding of the succession of fungi in the soil after wildfires is limited. Studying the interchanging of fungal species, and the composition and structure of their communities after a fire is important because the information gained can be useful for restoring Bosnian pine forests to their original state after such an event.



Fig. 53. Fireweed - a sign that the fire happened in the area ©J. Popović, 2022.

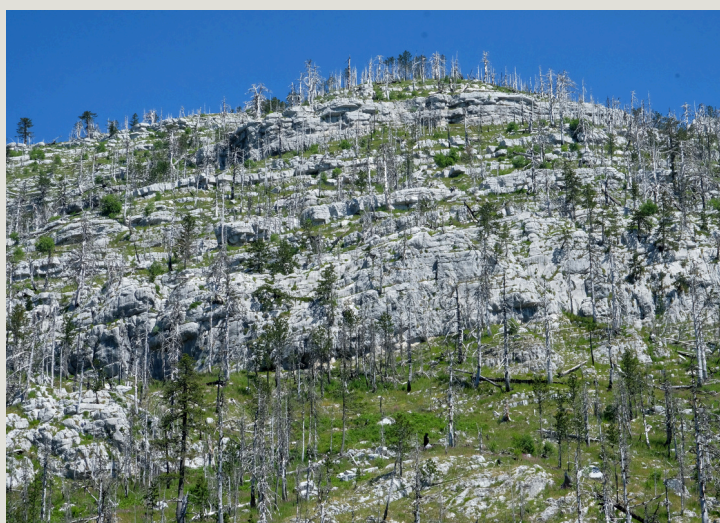


Fig. 54. Burnt Bosnian pine forest on the Kula peak, Prekornica ©J. Popović, 2020.

4.3. Health effects of pathogenic fungi

Bosnian pine in habitats unaffected by human activities is characterized by good health and vitality, despite the presence of numerous pathogens. Appearance of the invasive pathogen *Dothistroma septosporum*, which causes *Red band needle blight disease*, was recorded on brushwood in Prokletije mountains massif in Montenegro, and later in other mountain ranges, which is the first record of this invasive pathogen (Box 8.) in the natural Bosnian pine forests. Still, the intensity of the disease is not high, since it looks like Bosnian pine shows high resistance, in addition to the dry and warm summer climate that does not favor the development of the infection.

However, the disease is more intense in challenging terrains and poor habitat conditions. When combined with other brush pathogens, such as harmful insects, pine shoot beetles (*Tomicus sp.*), and leafroller moths (Tortricidae), it can cause visible damage to younger trees.

Pathogenic and epiphytic fungi have been observed on the needles of Bosnian pine throughout Montenegro. Some of the most abundant and pathogenic species include *Sydowia polyspora*, *Ciclaneusma niveum*, *Cenangium acuum*, and species from the genus *Lophodermium* (Lazarević J. et al., 2017; Lazarević J., 2003; Lazarević J., 2004).

Box 8: *Parasitic (pathogenic) fungi* live on living plants and animals. They are a common problem in agriculture and forestry. Parasites can cause some forest tree diseases which result in large-scale forest decline, and even the disappearance of certain plant species.



Figure 55. Burnt Bosnian pine forest expanses, Prekornica ©Jelena Popović, 2020.

Following a forest fire, there is an increase in the presence of pine needle pathogens and wood-decay fungus, as well as bark beetles (*Ips sp.*) on the burned surfaces. The post-fire conditions create a favourable environment for the proliferation of bark beetles, which can spread and pose a threat even to the forests that were not affected by the fire. (Lazarević et al., 2018).

Bosnian Pine: A Dendrochronological Archive



Figure 56. Dendrochronology, collecting samples on Prekornica ©Jelena Popović, 2022.

Lead by the desire to investigate past climate and ecological changes in Montenegro, to reconstruct how forests have responded to environmental conditions from ancient times to the present day, and to better understand how they may respond to future climate change, we turned to dendrochronology.

Dendrochronology is the scientific discipline that studies tree rings to reconstruct past environmental conditions recorded in wood. In climates with pronounced seasonal variation, such as those found across much of Montenegro, trees typically produce one growth ring each year, creating a natural chronological archive. The width, density and anatomical characteristics of these rings reflect the conditions under which they were formed. Some rings bear evidence of drought, others of fire, insect outbreaks or other disturbances, while some indicate years with particularly favourable conditions for growth. By analysing these patterns, dendrochronology enables the reconstruction of ecological and climatic processes through time, providing insights into tree responses at scales ranging from individual trees to entire forest ecosystems.

Dendrochronology allows us to decipher the unique language written within trees, turning forests into living libraries that preserve the history of their environment.

The observation that tree rings differ in width dates back to antiquity. Ancient Greek observers suggested that these differences might be linked to changing climatic conditions, while during the Renaissance Leonardo da Vinci noted that the width of tree rings in Italy appeared to reflect variations in moisture and drought (Schweingruber, 1996). However, dendrochronology developed as a scientific discipline only during the nineteenth century, when European researchers began systematically investigating the relationship between tree-ring variability and climate.

A major breakthrough came in the early twentieth century through the work of the American astronomer Andrew E. Douglass. Douglass proposed that solar activity and its influence on climate might be well reflected in tree rings, but he also broadened the scope of dendrochronological research by using tree rings to date archaeological sites. His successful dating of Pueblo settlements in New Mexico attracted worldwide attention and was popularised in the National Geographic article *The Secret of the Southwest Solved by Talkative Tree Rings* (Douglass, 1929).

From that point onward, dendrochronology rapidly gained recognition and found applications across numerous scientific disciplines. One remarkable example was the dating of the Santorini (Thera) volcanic eruption through anatomical anomalies observed in the tree rings of *Pinus aristata* (La Marche & Hirschboeck, 1984). These anomalies were caused by unusually cold late-summer conditions in the mountains of the southwestern United States, resulting from global cooling following the massive volcanic eruption thousands of kilometres away in the Mediterranean Sea.

Research on past droughts also led to another extraordinary discovery. Edmund Schulman and his colleagues demonstrated that the twisted bristlecone pines (*Pinus longaeva*) growing in the White Mountains of California were the oldest known living trees on Earth, exceeding 5,000 years of age. This finding fundamentally changed our perception of ancient forests, revealing that trees appearing stunted, weathered or nearly dead may in fact represent some of the oldest living organisms on the planet and preserve environmental information spanning millennia.



Tree rings have the remarkable ability to store information on past events in the surrounding environment in their tree rings.

Today, in the context of accelerating climate change, dendrochronology has become one of the most important tools for understanding past climate variability. Instrumental meteorological records rarely extend beyond the last century, whereas tree rings, especially those preserved in long-lived trees, provide annually resolved archives spanning hundreds or even thousands of years. These natural records allow scientists to place recent climate change into a long-term perspective, assess whether current conditions are unprecedented, and better understand how forests have responded to environmental change through time.

While dendrochronology can be applied to many tree species, not all trees preserve environmental information equally well. The most valuable dendrochronological records are often found in long-lived species growing under environmentally limiting conditions, where annual growth is strongly controlled by climate rather than by competition or local disturbances. Trees growing near the upper treeline, on dry rocky slopes, or at the ecological limits of their distribution therefore provide some of the clearest records of past climatic variability.

Conifers have played a particularly important role in the development of dendrochronology. Many species produce distinct annual rings, are exceptionally long-lived, and often survive in harsh environments for centuries or even millennia. Some, such as the bristlecone pines (*Pinus longaeva*) of western North America, have become iconic archives of past climate because of their extraordinary longevity. Similar characteristics make several Mediterranean and Balkan conifers invaluable for dendrochronological research.

Among them, Bosnian pine (*Pinus heldreichii* Christ) stands out as one of the most remarkable tree species of southeastern Europe. Growing on steep limestone cliffs, rocky ridges and other extreme mountain habitats, it combines exceptional longevity with high sensitivity to environmental conditions. These characteristics make Bosnian pine an ideal natural archive for reconstructing the climatic and ecological history of Montenegro.

5.1 Emergence of Bosnian pine in dendrochronological research

Despite the growing importance of tree-ring research during the twentieth century, some regions of the world remained dendrochronological "white spots" for decades. One such region was the Balkan Peninsula, where, largely due to historical and political circumstances, dendrochronological research developed more slowly than in many other parts of Europe. As a result, the remarkable potential of several native tree species remained largely unexplored.

Among them was Bosnian pine (*Pinus heldreichii* Christ, also referred to in older literature as *Pinus leucodermis*), a relict conifer inhabiting harsh mountain environments across the Balkan Peninsula and southern Italy. Foresters and botanists had long recognized that the species could attain exceptional ages. Individual trees, such as the famous Baikusheva Mura in Bulgaria, were believed to be over one thousand years old.

Nevertheless, the species received surprisingly little scientific attention from dendrochronologists. Early attempts to use Bosnian pine as a climate proxy did not produce convincing results, discouraging further research. During the early 1980s, for example, Fritz Schweingruber collected tree-ring samples from the Pirin Mountains in Bulgaria and measured them for inclusion in the International Tree-Ring Data Bank (ITRDB). Although these measurements later became valuable resources, they did not reveal the exceptional dendrochronological potential of the species, possibly because the sampled trees were relatively young. Similar observations were reported from Italy, where the remarkable longevity of Bosnian pine was acknowledged, but only limited dendrochronological work followed (Biondi, 1992).

Interest in *Pinus heldreichii* was revived in the early 2000s, when several research groups began systematically exploring its dendrochronological potential. Studies from Pollino National Park in southern Italy demonstrated that radial growth responded positively to higher autumn, spring and early summer temperatures, while also highlighting the influence of past human activities on stand structure (Todaro et al., 2007). At approximately the same time, research in the Pirin Mountains of Bulgaria revealed that tree-ring width reflected not only summer temperature but also drought conditions, an unexpected finding for a species growing in high mountain environments where water availability is generally assumed to be sufficient (Panayotov et al., 2010).

Importantly, these studies demonstrated that Bosnian pine could produce continuous chronologies approaching one thousand years in length, opening entirely new possibilities for reconstructing past climate in southeastern Europe.

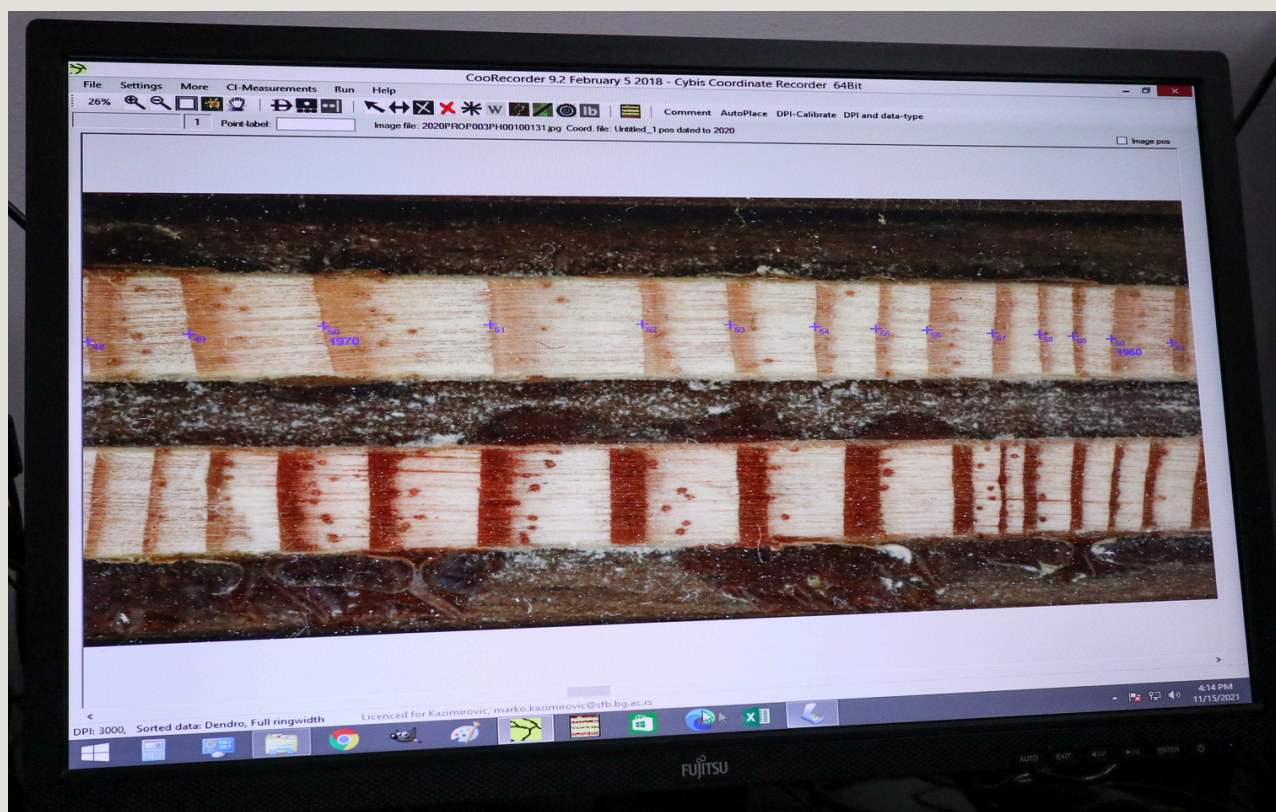


Figure 57. Dating of a Bosnian pine core, Prekornica ©Jelena Popović, 2021.

These pioneering studies stimulated rapid expansion of dendrochronological research throughout the natural distribution of the species. Long chronologies were subsequently developed in Albania, Bosnia and Herzegovina, Bulgaria, Greece, Italy, Kosovo and Montenegro, establishing *Pinus heldreichii* as one of the most promising high-elevation tree species for climate reconstruction in the Mediterranean region.

The growing interest in ancient Bosnian pine forests culminated in several remarkable discoveries. In 2013, Paul Krusic and colleagues identified an individual in the Pindos Mountains of northern Greece that was later shown to be at least 1,075 years old, making it the oldest scientifically dated living tree in Europe (Konter et al., 2017). Shortly afterwards, Piovesan and colleagues demonstrated that root dating could reveal even older individuals, exceeding 1,200 years of age in southern Italy (Piovesan et al., 2018). These discoveries firmly established Bosnian pine among the longest-lived tree species in Europe and highlighted its enormous value as a natural archive of environmental history.



Figure 58. Bosnian pine on Maganik ©Jelena Lazarević, 2022.

However, exceptional longevity alone does not guarantee straightforward climate reconstructions. Unlike many high-latitude conifers whose radial growth is controlled predominantly by summer temperature, tree-ring width in *Pinus heldreichii* reflects the combined influence of several climatic factors, including summer temperature, moisture availability and winter conditions (Panayotov et al., 2010). This mixed climatic signal makes simple tree-ring width chronologies more difficult to interpret, while simultaneously encouraging the development of more advanced dendrochronological approaches.

One of these approaches focuses on xylogenesis - the intra-annual process of wood formation. Through repeated sampling of developing tree rings using specialised tools such as the Trephor, researchers are able to follow cambial activity and monitor the formation and maturation of individual xylem cells throughout the growing season. This, in turn, provides an in-depth understanding of how different climatic factors influence the formation of tree rings.



Xylogenesis studies of *Pinus heldreichii* were pioneered in Italy (Deslauriers et al., 2008), while subsequent research in Bulgaria (Ivanova et al., 2013) demonstrated that the first xylem cells are typically produced between mid-May and early June, depending largely on winter severity and spring temperatures.

Warmer winters promote an earlier onset of cambial activity, whereas prolonged cold conditions delay wood formation. However, a delayed onset does not necessarily result in a narrower tree ring, as the final number and size of cells also depend strongly on summer climatic conditions and the carbohydrate reserves stored during previous growing seasons.

Wood formation usually ceases with the first cold spells in early October, even if warm weather returns later in autumn, indicating a strong seasonal control over cambial activity.

Researchers also discovered that valuable climatic information is preserved in anatomical characteristics beyond tree-ring width. Sometimes certain meteorological situations and harsh conditions cause defects in tree-ring anatomy. An example are frost rings. Although fairly rare in *Pinus heldreichii*, probably due to the thick bark and good isolation, such rings are found and they were noted to be a very solid sign of late spring frosts and cold spells occurring in late May or early June.

Similarly, maximum latewood density (MXD) proved to preserve a much stronger summer temperature signal than tree-ring width alone. Long MXD chronologies developed from Bosnian pine have enabled high-resolution reconstructions of European summer temperatures extending back more than a millennium (Trouet et al., 2012; Esper et al., 2020; Xu et al., 2024). More recently, Blue Intensity (BI) measurements have emerged as a cost-effective alternative to MXD while retaining much of the same climatic information (Tsvetanov et al., 2020). Stable isotope analyses have further expanded the range of environmental variables that can be reconstructed, particularly past precipitation and water-use efficiency (Levanič et al., 2020; Lukač et al., 2021).

5.2 Bosnian pine as a climate archive

As noted earlier, tree-ring widths of *Pinus heldreichii* preserve a complex climatic signal - “mixed signal”, reflecting the combined influence of summer temperature, moisture availability and winter conditions. This complexity often limits their use for straightforward climate reconstructions. Considerably more robust climatic information has been obtained from maximum latewood density (MXD), which is much more strongly controlled by summer temperatures. Early analyses of MXD in *Pinus heldreichii* already demonstrated its remarkable potential as one of the most robust summer temperature proxies available in Europe. Trouet et al. (2012) developed a robust MXD chronology from the Pirin Mountains in Bulgaria and showed its strong relationship with regional summer climate. Klesse et al. (2014) further demonstrated that combining MXD from *Pinus heldreichii* with tree-ring width chronologies of *Pinus nigra* from northern Greece substantially improved the reconstruction of past climatic variability.

Building upon these pioneering studies, increasingly longer MXD chronologies were developed across the distribution range of the species (Trouet, 2014; Esper et al., 2020; Xu et al., 2024). These records established *Pinus heldreichii* as one of the most valuable high-elevation climate archives in Europe, enabling millennium-long reconstructions of summer temperatures.

At the same time, the same chronologies have been successfully used to reconstruct drought variability, periods of increased precipitation, and even large-scale atmospheric circulation patterns such as changes in the position of the Jet Stream (Cook et al., 2015; Klippel, Krusic, Konter, et al., 2018; Esper et al., 2021; Xu et al., 2024). Together, these studies have substantially improved our understanding of climate variability across the Balkan Peninsula and Europe, while providing valuable insights into the links between climate fluctuations and human history.

Despite its great performance, MXD remains relatively expensive and technically demanding to measure. More recently, Blue Intensity (BI) has emerged as a promising and considerably more affordable alternative. Studies on *Pinus heldreichii* have shown that BI preserves a summer temperature signal comparable to MXD, opening new possibilities for constructing high-quality climate reconstructions using less demanding analytical techniques (Tsvetanov et al., 2020).



Further environmental information can be obtained through the analysis of stable isotopes, which have shown considerable potential for reconstructing past precipitation and complementing traditional dendrochronological approaches in *Pinus heldreichii* (Levanič et al., 2020; Lukač et al., 2021). Collectively, these developments have transformed Bosnian pine into one of the most informative natural archives for investigating past climate variability and are becoming increasingly important for understanding how mountain forests may respond to ongoing climate change (Colangelo et al., 2021).

5.3 Applications beyond climate reconstruction

The value of *Pinus heldreichii* tree rings, however, extends far beyond climate reconstruction. Owing to their exceptional longevity and precise annual resolution, they have become important tools in dendroarchaeology, enabling the dating of historical buildings, church icons and other wooden cultural artefacts, as well as in the study of long-term forest dynamics.

The dendroarchaeological potential of the species was already recognized by Kuniholm and Striker (1987), while later studies demonstrated the presence of Bosnian pine tree rings in numerous historically important buildings and religious monuments throughout the Balkans and the eastern Mediterranean (Westphal et al., 2011). More recently, the Balkan-Aegean Dendrochronology Project has significantly expanded the available chronologies by analysing historical timber from archaeological and architectural sites, contributing both to the dating of cultural heritage and to the development of exceptionally long reference chronologies for southeastern Europe (Christopoulou, Fyllas, et al., 2022; Christopoulou, Gmińska-Nowak, et al., 2022; Elzanowska et al., 2024).

Bosnian pine tree rings also preserve invaluable information on the long-term dynamics of mountain forests and the occurrence of natural disturbances. Fires, avalanches and other extreme events often leave distinct anatomical scars that remain preserved within the wood for centuries. Fire history studies conducted in the Pirin Mountains demonstrated that surviving *Pinus heldreichii* trees retain detailed records of past fire events, revealing both the spatial extent of historical fires and their likely climatic drivers (Vasileva & Panayotov, 2016). At the same time, dendroecological analyses of old-growth stands have shown that fire may have played an important ecological role by creating regeneration opportunities and reducing competition from less fire-adapted species (Rangelova & Panayotov, 2013). More recently, the remarkable mechanical resistance and flexibility of Bosnian pine have enabled researchers to reconstruct past avalanche activity, with surviving trees preserving records of multiple destructive events over centuries (Panayotov & Tsvetanov, 2024).



5.4 Future perspectives and conservation importance

The broad spectrum of applications developed over the last two decades demonstrates that the dendrochronological potential of *Pinus heldreichii* extends far beyond traditional climate reconstruction. From reconstructing past climates and atmospheric circulation to dating historical monuments, deciphering forest dynamics and documenting natural disturbances, Bosnian pine has become one of the most informative tree species in southeastern Europe. Nevertheless, current knowledge probably represents only a fraction of the information preserved within these ancient trees. Continued advances in dendrochronology, wood anatomy, stable isotope analysis and other emerging methodologies will undoubtedly reveal new aspects of their environmental archive in the years to come. At the same time, these studies provide an increasingly important foundation for understanding how mountain forests may respond to ongoing climate change.

At the same time, the ongoing loss of old-growth forests and ancient Bosnian pine stands threatens the disappearance of an irreplaceable source of knowledge. Every centuries-old tree that is cut down or lost to disturbance represents the irreversible loss of a unique environmental record that can never be reconstructed. Conserving these forests therefore means preserving not only an exceptional component of Europe's natural heritage, but also one of its most valuable archives of climate history, ecological processes and human interaction with mountain landscapes.



Myths and folklore surrounding pines

Ancient civilizations lived in close connection with nature. Thus, their relationship with the natural world inspired their imagination, archetypal stories, and inner spiritual practices. Consequently, in an attempt to understand cosmic entities greater than themselves, they resorted to myths and art.

With this in mind, the following paragraphs are an attempt to collect and analyze mythical stories about conifers, specifically pines. From North America, Scandinavia, Egypt, and Ancient Greece, there is a similarity in the mythical messages conveyed by pine trees to different peoples.

We have made a concerted effort to gather and research stories about pine trees from our region, in order to gain insight into the intimate relationship our ancestors had with the trees. Although it is difficult to find myths directly related to the Bosnian pine, this chapter is dedicated to pines in general, with the Bosnian pine certainly belonging to this family.

Majestic conifers

Conifers are trees that boast many superlatives - they can be the tallest, thickest, and longest - living among tree species! They are incredibly resilient and can adapt to the harshest environments on our planet, with the ability to survive for hundreds and thousands of years.

Conifers are so old that once upon a time they served as food for dinosaurs. They emerged millions of years before deciduous trees started to spread across the planet Earth.

Given their ancient history, unique characteristics, durability, and versatile everyday use, it's not surprising that conifers hold an important place in the mythologies of many cultures and traditions.



Worldwide myths about pine

The word *pine* is derived from the Indo-European word *bher*, meaning *spike* (likely due to the sharpness of the needles), or the German word *borr*, meaning *wood* and *forest*.

It is noteworthy to emphasize that pine symbolizes similar virtues across many civilizations. The belief that conifers hold the secret of immortality is the most widespread, as they are the only trees that endure while staying green throughout the whole year, even in winter. Additionally, in various world traditions, pine is said to represent peace, strength, wisdom, longevity, etc.

Discovering the common cultural heritage of distant traditions and the similarity in the perception of the pine at the spiritual and mythological level of different peoples is a true delight.

So, what stories do different cultures bring about pine?

Native American myths about pine

Native American tribes hold the pine tree in high regard and see it as a symbol of wisdom and longevity. Their deep respect for pine comes naturally. Native Americans used its trunk, bark, needles, and resin in their daily lives for food, medicine, shelter, and spiritual purposes.

Native Americans held a custom of burning pine and its cones as part of their rituals, believing that this would affect weather conditions and summon the sun or rain.

Also, in some Native American cultures, there is a belief that the first people on Earth were saved from a great flood by taking refuge inside a pine tree.

Greco - Roman myths about pine

In ancient Greece and Rome, pine was widely worshiped and associated with various gods and mythological figures. The pine tree was connected to Zeus, Dionysus, Poseidon, Pan, and nymphs, reflecting its importance in their spiritual and cultural beliefs.

They revered the pine for its height. Also, the rustle of its needles was believed to be the voice of Zeus himself! So, pine was believed to bring a direct connection with the gods. Nevertheless, the ancient Greeks greatly admired magnificence, strength and resilience of a pine tree.

In one of the most persistent Greek myths about the pine, this tree is believed to be guarded by the Oreades (mountain nymphs), and Dionysus - the god of vegetation, fertility, ecstasy, and wine. Consequently, the pine tree was associated with wine, amphoras being sealed with resin, and wine glasses being flavored with resin and pine cones for aromatic, medicinal, and spiritual purposes.

Today, pine barrels are still used to store a special Greek wine with an admixture of resin. In myths, a vine plant was often depicted as wrapping around the pine tree forming a romantic union and symbolizing the connection between the two plants.

In ancient Greek mythology, the Maenads, female followers of Dionysus, were often depicted wearing garlands of pine needles during their ecstatic dances.

Dionysus himself would often carry a staff (a sort of sceptre) topped by a pinecone.



Figure 59. Dancing Maenad holding a pine-cone-tipped thyrsus, Roman marble relief, AD 120–140. Museo del Prado, Madrid.

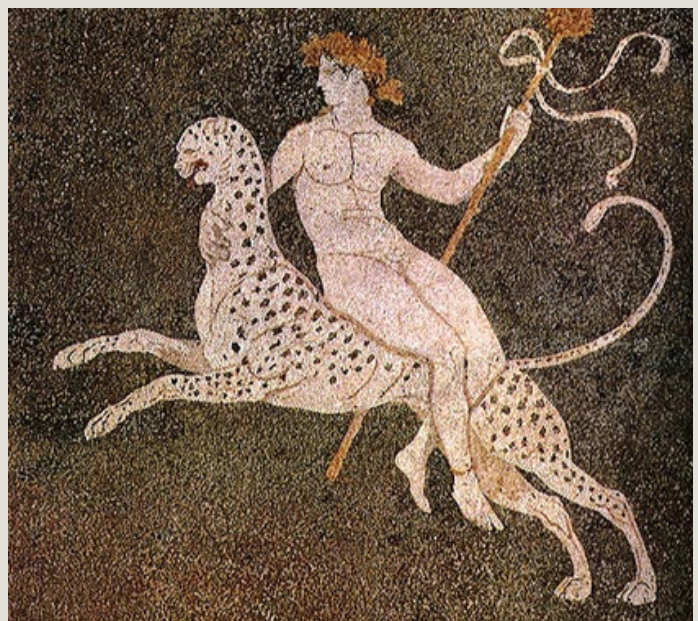


Figure 60. Dionysus riding a panther and holding a pine-cone-tipped thyrsus, pebble mosaic from Pella, late 4th century BC. Archaeological Museum of Pella.

Also, pine cones were placed on posts in the vineyards to protect the area from demons and evil spirits.

In ancient Greece and Rome, pine cones were a symbol of fertility and they were depicted on numerous amulets and important objects associated with the gods. In Roman mythology, pine is associated with Cybele, the goddess of fertility. Pine twigs were used in the rites of her cult.



There is also a Greek myth about the creation of pine trees, involving the nymph Pitis, who was the lover of the god of the forest, Pan, and the god of the northern winds, Boreas. The myth tells of an unfortunate love triangle that leads to Pitis being transformed into a pine tree, with its resin symbolizing her tears. This story highlights the connection between the pine tree and emotions in ancient Greek culture and mythology.

Pine was also associated with Poseidon, the god of the sea, due to its widespread use in shipbuilding. There were beliefs that Poseidon had sacred pine groves, reflecting the importance of this tree in maritime and seafaring traditions.

Scandinavian myths about pine

The people of Northern Europe have a strong connection with conifers, especially pine trees, which were believed to possess the secrets of immortality. During the winter solstice, the shortest day of the year, people would light pine branches and decorate the trees with dried fruit, cloths, and bright objects, in an attempt to bring back fertility, harvest, and warmth to the region. This custom is believed to be the precursor to decorating Christmas trees, and the celebrations and rituals associated with the cycle of nature were known as the Yule holiday in Northern Europe. These traditions reflect the deep reverence and cultural significance of conifers, especially pine trees, in the region.

Some of the other world myths

The previous lines reflected the important symbolism of pine in the Mediterranean, in the Greco-Roman culture, stories of Native American tribes as well as beliefs and rituals in the north of Europe. However, the myths and traditions surrounding pine do not stop there. While noting the prevalence of deep appreciation of this tree, it is important to mention at least a few more world myths about conifers.

Pine was a valuable resource for ancient cultures for a variety of purposes, including religious and sacred ones. The use of pine resin in the mummification process was a common practice in ancient Egypt. Here, pine was also used in the construction of temples and thrones. Additionally, the presence of pine in sacred works is evident in Jewish and Mesopotamian writings.

Pine was also used to build sacred places on the other side of the planet. The ancient Maya people considered pine to be an important cosmological tree and used it to build temples and objects for ritual purposes. By burning pine trees, Mayans offered sacred food to their deities.



Pine is highly regarded in the traditions of East Asian cultures such as China, Korea, and Japan. In these cultures, pine is seen as a symbol of wisdom, virtue, honor, and strength. Pine is associated with animism and has a significant cultural significance in these countries (Box 9).

Box 9: *Animism* is a belief system that holds that all objects, places, and creatures, including plants, animals, stones, rivers, human handiwork, and even words themselves, have a unique spiritual essence or soul.

Coniferous tree is said to be a symbol of wisdom, virtue, honor and strength.

Pine was believed to be a messenger carrying the souls of the dead to the afterlife, which is why many coffins were made from this tree. Pine branches were also hung on doors during the New Year as a symbol of divine blessings and the connection between the gods and humans. These branches symbolized a ladder by which the gods could climb to heaven, further emphasizing the spiritual significance of pine in these cultures.

Walking through pine forests is considered a way to restore one's health, both physically and mentally and pine forests have long been associated with healing in many cultures, including the Scots, Irish, and Germans. In German folklore and folk medicine, inhaling the scent of pine is believed to have therapeutic benefits for the mind, including stabilizing the nervous system, improving mood, and clearing the mind.

Conifers and Early Slavs

Now is the right moment to reflect on what our ancestors thought about pine. Did they make up stories and songs about it? What mythical creatures are believed to have lived in pine forests? And, to what extent were conifers an object of Early Slav worship?

The spirit of nature that reigns in the forests can be found in many stories of Slavic folklore. In Russian *Leši*, in Balkan countries *Lesnik* - the name comes from the old Slavic word *les*, which means *forest*. *Leši*, of Russian folklore especially, was believed to live in pine forests, guard them and help maintain their balance. *Leši* or *Lesnik* had the power to establish harmony between plants, animals, and trees and to revive or turn an animal into another.

In today's words, we can say that *Lesnik* is the main responsible manager for ecological balance and biodiversity in the forest community. It is fascinating how our ancestors gave a mythical being such an important role, and then adequately performed numerous rituals, customs, and processions in celebrations of it.



Lesnik was thought to be a hairy being with horns, a human upper body, and horse or donkey legs, resembling a Centaur. Also, this god (known not to leave a shadow behind him), was associated with the Slavic deity of the underworld, Veles - a name derived from *vlas* meaning *hair*. The size of this deity would vary depending on which part of the forest it resides in. The ones from the forest borders are small, while others from the densest part of the forest are believed to be gigantic. Lesnik as a deity loses his power outside of the forest, and is known for his friendship with a bear. He protects cattle and wolves and does not support hunters. Sometimes he mischievously leads people astray in the forest.

The next time you step into a dense pine forest, think of Lesnik, greet him, and support him in his noble quest. By sharing stories about Lesnik and the importance of preserving forests, we can raise awareness about the need to protect the natural environment which is also a home to the fascinating beings and deities.

A tree connected with the underworld

In Slavic tradition, pine tree is believed to be connected to the underworld and to the souls of ancestors. It's thought to be a suitable tree to plant near cemeteries as a guardian of souls. A pine planted next to a house is believed to harbor the spirits of family members after death. Pieces of furniture made from pine are said to hold the spirit of the person and bring a sense of their presence.

The Bulgarian folk song *Sveta Nedjelja i Sveta Petka* (eng. St. Sunday and St. Petka) tells the story of how two saints built a bridge of pine trees for souls to cross into the afterlife (we saw that Koreans, Japanese, and Chinese have similar beliefs). The Croats on Vlačić Mountain (an interesting correlation of the mountain name with Veles, deity of the underworld) have a unique custom of burying their dead in pine tree trunks. They hollow out and split a pine tree, placing the body inside and covering it with the other half.

In many folk songs and stories, pine tree is depicted as a mysterious and supernatural. Evergreen trees such as fir and pine are often associated with the afterlife, while deciduous trees are linked to life and awakening. In Serbian fairy tales, pine trees grow from murdered children of a certain empress, and similar motifs can be found in other folk songs as well. The vine, another plant of the shadows, is often planted on graves (we saw the connection between the vine and pine trees in Greek myths). Also, some folk songs mention vines that spontaneously sprung from graves without an apparent cause (Pešić R., 1988):



„Te sa'rani dvoje dece svoje:
Na Momiru zelen bor nikao,
Na Grozdani vinova lozica;
Savila se loza oko bora
K'o sestrina oko brata ruka“

“Then she buried her two children:
From Momir, a green pine sprouted,
From Grozdana, a grape vine;
The vine will twine around the pine
Like a sister's arm around her brother.”

Also, Slavic folk poetry hides examples of humans identification with pine trees (many world myths say that humans are created from trees) (Pešić R., 1988):

„Dva su bora naporeda rasla,
Među njima tankovrha jela:
To ne bila dva bora zelena;
Već to bila dva brata rođena“

“Two pines grew side by side,
A thin fir standing in between:
But these were not merely two green pines;
They were two blood brothers here”

A pine tree can also be a gathering place for various magical beings; for example, it can serve as the fairy's seat. In one of Slavic folk songs (Pešić R., 1988), God gives golden horns to a boy and he proceeded to pierce the bark of a tree with them:

"Al' u boru mlada moma,
Pak zasija kao sunce“

“But a young lad shone,
Like the sun in the pine”

Pine as a sacred tree

It's fascinating that the pine tree is considered a deity or sacred tree. Interestingly, there is a three-hundred-year-old pine tree in Kamena Gora village in southwest Serbia, which is believed to be a sacred inscription tree (even though oaks usually serve this purpose). To this day, a liturgy is performed under this pine once a year by a priest. Its branches must not be moved forcibly, and anyone who tries to use its resin is said to be punished in unusual ways throughout time.

There are also noteworthy stories about the pine trees in Nerodimlje, a town in Kosovo. These pines are thought to be special and personally planted by medieval kings from the Nemanjića dynasty. Once upon a time, rulers would plant trees on important dates, or in order to mark victories in wars. The pines from Nerodimlje witnessed many assemblies, knights' games, carousels, and singing of songs (some of which mentioned these pines as well). Unfortunately, the trees were destroyed in a major weather disaster in the middle of the twentieth century, and the remaining wood was used to make iconostasis.

Once upon a time, people in these areas used to say *Bora mi* (eng. *Oh my Pine!*) instead of *Oh my God!* Unfortunately, this comparison has been lost over time. However, the surviving writings still have the power to move us deeply, while reminding us of our ancestors' connection with trees.



Figure 61. Sacred inscription pine, Kamena gora ©Marija Šoškić, 2026.

Bosnian pine and its name

It is very interesting to pay attention to the popular common names of the Bosnian pine (commonly named *munjika* or *munja* meaning *lightning* in the Montenegrin language). We should also shed more light on the importance of thunder and lightning in mythology for it is believed that this tree attracts thunder like no other.

Ancient myths from around the world tell us that the sky is seen as the father and the earth as the mother, and that the earth is fertilized by rain and thunder, while giving birth to all life. This is why many pantheons have gods associated with thunderbolts, such as Zeus, Thor, and Perun, who are considered to be among the most important deities.

In the past, people believed that the ground where lightning strikes was extremely fertile and abundant. As a result, they would roll in that spot in the hope that some of the fertile qualities and prosperity would rub off on them.

According to the folklore, a tree that is struck by lightning was considered to have protective qualities and was used as a house guardian. People believed that placing it in the door of their gate, yard, or home would protect their property and family from evil spirits. However, it was thought that using the tree for anything other than protection would bring misfortune.

It is intriguing to explore the connection between the Bosnian pine (also known as *munika* which comes from the Montenegrin word *munja* meaning *thunderbolt*) and the Slavic god Perun, the god of thunder. One wonders if the name of the tree was inspired by Perun, whose name is linked to the verb to *hit* and who was revered even after the spread of Christianity through the veneration of St. Elijah.

Conservation of Bosnian pine in Montenegro

Forest belt on a high altitude plays a significant role in preserving the diversity and richness of plant and animal life, protecting land, providing sources of drinking water, regulating water flow, combating erosion, managing torrents and avalanches, and many other crucial services. For this and many other reasons, forestry experts in the Balkans invest continuous efforts for the past 70 years in order to highlight the importance of Bosnian pine forest restoration in their natural range.

Janković (1960) observes that the degradation of the Bosnian pine and Macedonian pine forests happened due to human activities in the past, but that their restoration is successfully happening in many areas where human influence is absent. Pine trees have a remarkable vitality and ability to adapt to high mountain forest zones in the sub-Mediterranean, leading to rapid and efficient natural regeneration. This is confirmed by current observations from various locations in Montenegro, where the Bosnian pine is being restored effectively through reduced grazing in areas above 1000 – 1200 - 1400 meters above sea level.

Bosnian pine's exceptional resistance to harsh weather and environmental conditions, combined with its status as a pioneer species, make it a suitable option for afforestation of poor, dry, and rocky terrains (including terrains outside the natural Bosnian pine habitat, and more temperate habitats). As a sub-endemic and tertiary relict species found in the Balkans and a small part of the Apennine peninsula, it is scientifically significant, but also has untapped potential for forestry and erosion control. Despite being one of the most oligotrophic species in the Balkans, Bosnian pine has a pronounced role in protection, social impact, pioneering, and production. In the past, there were attempts to introduce Bosnian pine outside its natural area, including small groups or cultures established in northern parts of Serbia.



Figure 62. Natural restoration of the Bosnian pine habitat on Štitovo ©Jelena Popović, 2020.

Protecting the Bosnian pine from forest fires is extremely complex, due to the karst terrain where its stands usually grow. That is why it is of utmost priority to apply:

(a) Measures for assessing the probability of fires. By creating maps that reflect the level of fire risk, it is possible to efficiently plan and implement both fire prevention and suppression tactics. These maps will highlight the areas with the greatest risk of fires and provide guidance on how they should be treated.

a) Preventive measures which aim to decrease the chance of a fire occurring or to minimize the extent of the burned area. These measures will include both biological and technical measures that enhance the defenses of the Bosnian pine forest.

In addition to other fire prevention techniques such as mechanical cleaning and controlled burning, targeted grazing can be an effective solution for hard-to-reach and abandoned areas. This approach is particularly useful in regions affected by droughts caused by climate change, as well as in rural areas that have been abandoned for extended periods of time and have become overgrown with shrubs and trees, providing ample fuel for fires.

When fires occur in these areas, they are more challenging to control and contain, making targeted grazing an important strategy for reducing the risk of fire. This method has been utilized in Spain for over two decades, where shepherds receive compensation to graze their animals in overgrown regions. The project, which now involves over 100.000 animals, has saved the authorities an estimated 75% of the costs associated with mechanical vegetation removal.

7.1 Forest protection in Montenegro

Institutionally, in Montenegro and other neighboring countries, the main strategy for conserving species such as the Bosnian pine has been to protect them within protected natural areas, including national and nature parks. These resources serve as important reserves for the preservation of plant, animal, fungi, and other ecosystems. However, not all populations of the Bosnian pine are located within these protected areas.

In recent decades, valuable forest genetic resources in Montenegro have been greatly endangered by excessive logging, forest fires, and habitat destruction. To ensure the preservation of forests for future generations and the survival of certain species, it is critical to find an effective solution to reverse or significantly reduce this trend. This requires the design and implementation of initiatives that raise social awareness and increase the responsibility of decision makers. Consequently, the preservation of the genetic diversity of the Bosnian pine, and other key forest species, now encompasses broader social, economic, and legal issues in addition to ecological and genetic research and outcomes.

There is available data on the genetic diversity of Bosnian pine populations in Italy and Greece, but such information is lacking for other Balkan countries. With the help of genetic research, a proper conservation strategy for the species can be developed. For instance, in Italy, where Bosnian pine grows in five isolated stands, studies have shown that fragmentation has led to reduced gene flow and increased genetic drift, resulting in a low effective population size. At least three out of the five populations are at risk of losing significant genetic diversity in future generations (Vendramin et al., 2008).

Researchers from the Biotechnical Faculty of the University of Montenegro, in partnership with scientists from the National Research Council of the Institute for Biosciences and Bioresources in Italy, have initiated the genetic characterization of Bosnian Pine populations in Montenegro.

Previous research on three populations showed that Bosnian Pine has a high level of intraspecific diversity (i.e., diversity among populations and individuals), that there is a genetic differentiation between the studied populations, as well as a certain degree of diversity on the level of individuals, with low levels of inbreeding (the phenomenon of reproduction among closely related individuals that can result in offspring which is weaker than their parents, reducing their chances of survival) (Lazarević et al. 2017). These studies reveal that Bosnian pine is a **globally significant forest genetic resource that must be conserved for future generations.**

Preserving the genetic diversity and adaptability of the Bosnian pine species for future generations can be achieved by maintaining large populations of locally adapted trees through natural regeneration. For the Bosnian pine, these conditions can be met in autochthonous forest stands larger than 20ha, which are a considered units for the genetic conservation of the species. These forest stands should be managed sustainably and adaptively and should not contain Bosnian pine of unknown or foreign origin. Careful monitoring of natural regeneration and support through local seed sowing, if necessary, is also important. These forests should further be managed in accordance with the principles of sustainable and adaptive forest management. It should not be allowed to introduce Bosnian pine of unknown or foreign origin in or near these forests. Natural regeneration should be carefully monitored and, if necessary, supported by sowing only locally collected seeds.

In order to ensure the preservation of valuable forest genetic resources, including one of the Bosnian pine, it is important for societies to take a responsible and proactive approach in this regard. This can be achieved through social and professional collaboration to establish *in situ* conservation units, where forests are managed in a way that effectively protects the target species and its genetic resources while allowing for evolutionary changes over time.

In conclusion, preservation of the Bosnian pine and its genetic diversity requires a concerted effort and cooperation from all relevant stakeholders, including government institutions, researchers, and the general public. Creation of the species conservation plan, establishing protection of large forest stands, and the adoption of sustainable forest management practices are crucial steps in ensuring the survival of this globally significant forest genetic resource for future generations. Through responsible and collective action, it is possible to protect this unique and endemic species of pine and make new advancements in nature conservation in Montenegro.

7.2 Future research

Natural distribution of the Bosnian pine is limited, and its remaining forest populations are fragmented and small in size, with a constant threat of forest fires. As a result, the specie's *gene pool* (Box 10) is potentially endangered. The loss of genetic diversity is common in forest tree species before they reach a state where their survival is considered threatened. Local populations, which are well adapted to the prevailing environmental conditions, can disappear even when the species as a whole is not endangered. Thus, in order to ensure its preservation, it is crucial to conduct research and gain knowledge about the existing genetic potential and forest genetic resources of the Bosnian pine.

Genetic variations of species in peripheral or isolated populations should be preserved to maintain their tolerance to different environmental conditions, including resistance to drought, specific soil conditions, cold, pests, and diseases, which can aid in their adaptation to future climate changes (Riegel et al., 2001). Genes from these precise populations can be of great importance for the future adaptation of forests (in conditions of global warming) and it is necessary to take appropriate measures to protect all such populations. Preservation of a species of a small area, with populations scattered in inaccessible mountain forests, is of global importance, as it transcends local and national interests.

Box 10: *Park on paper, gene pool*

Park on paper refers to protected area that lacks the necessary infrastructure and resources for proper management. It often focuses solely on generating revenue through tourist visits, rather than monitoring and preserving its species and natural habitats. This type of protected area often lacks proper management practices, leading to a failure.

Gene pool refers to all of the genes present in a particular specie's population. High genetic diversity, as indicated by a large gene pool, gives a species the ability to respond effectively to various environmental challenges. Preservation of the gene pool of forest tree species, as well as other plant species, is crucial, particularly in populations near or at the limit of distribution, high altitude populations, populations in unfavorable ecological conditions, and populations in mixed forests.



Figure 63. Bosnian pine tree on Vučji zub peak, Orjen ©Đorđije Milanović, 2018.

Instead of a conclusion: Pay attention and slow down

There is a type of pine whose memories go beyond the last ice age. Since then, this pine has taken refuge in the cruelest parts of our karst mountains, where life in the forests is barely possible. It proudly resides there to this day.

The name of this species is *Bosnian pine*. It builds forests in places where other species cannot survive: on cliffs and rock surfaces, where its roots intertwine with the rocks, providing stability and holding onto the limited water supply. These forests serve as a home for numerous plant, animal, and fungi species, creating a complex web of life.

The bark of the Bosnian pine, carved like armor, becomes silver as it ages, resembling a knight. Just underneath the bark, there is a layer that is alive, which enables the tree to grow, so after every year the tree leaves behind one more tree ring, that tells a story about each year a pine managed to survive.

Bosnian pine can grow very old. The oldest known to this day is located in Italy, soon celebrating its 1.231st birthday. Its trunk holds 1.231 tree rings. This tree was born during the Roman Empire, it remembers the great Viking colonisation, and during the first years of its life, it even witnessed the Carolingian Renaissance.

Bosnian pine is sub - endemic of the central and western Balkans, as well as southern parts of the Apennine Peninsula. This means that it lives only here and nowhere else in the world. What's more, Montenegro holds some of its most beautiful and biggest populations.

Bosnian pine's common name is *M u n j i k a* (from Montenegrin *munja*, meaning *thunder*) - the one that lives near thunderbolts. Its pungent resin is highly flammable, so once the fire starts it hardly ever stops before destroying everything along the way. It is seldom that fires are caused by thunderbolts, but humans have managed to cause a fire that has spread from Danilovgrad to Nikšić, wiping away one of the biggest (80%) Bosnian pine forest in Montenegro.

Huge fires have swallowed Bosnian pine forests in Kuči, Orjen and other Montenegrin mountains as well.

Bosnian pine's tissue is such that its trunk stands erect for decades after its death. Over time, the color of the trunk becomes silver - like, almost completely white and smooth. Consequently, in these areas, we can witness real monuments of the destruction of one of the most valuable forest habitats in Montenegro. But we can also witness the miraculous process of its regeneration, since Bosnian pine is one of the most resilient tree species there is.

However, some Bosnian pine forests will not be able to recover - before the roots have the chance to develop, the soil will erode and the trees won't have anything to cling to.

It's true that the oldest Bosnian pine known today lives in Italy. But who is to say that there is not the older one living in the Montenegrin mountains, amongst gigantic Bosnian pine trees on, for example, Zeletin mountain that may host a specimen that dates back to the 7th century AD and connects us with the times of Duklea beginnings.

In case you haven't realized so far, Bosnian pine is a wonderful type of tree. But, nevertheless, every species in this world can tell an equally wondrous story, since they all share the life force which, in the most creative and complex ways, sculpts the biosphere, the organic layer of the planet Earth.

Humans are a tiny part of this story. In the last 200 years, humankind is getting more detached from nature, building a symbiotic relationship resembling parasitism. Humans tend to take all they can from their host, while remaining completely unaware of the fact that we are cutting a branch on which we are sitting. Because, upon killing the host, the parasite dies too (if it fails in an attempt to find a new one).

However, there is a more beautiful, mutually beneficial type of symbiosis as the one that can be observed in algae and fungi when they form lichen. In this case, the boundaries between humans and nature could not easily be discerned. Here, nature with all its benefits, can support the development of humankind, in return only asking for us to protect her.

Bosnian pine is a symbol of the ways we behave towards the most exceptional parts of nature (and of ourselves too).

Don't you think it is the right time for us to start a new chapter, where humans have become the guardians of the Bosnian pine, protecting it from fires? To let the forest keep and tell the stories about us to our descendants who will be living on a much different Planet Earth, 1000 years from now?



Figure 64. Bosnian pine growing from the stone ©Jelena Popović, 2020.

So, in your next walk among the pines, awakened by the scent and healing power of these forests, remember Lesnik, pine cones in wine, ancestors in trees, thunderbolts, and fertility.

Remember that the cross section of the tree and its branches are irresistibly reminiscent of the furrows on your fingers.

Or that the tree itself can teach us how important it is to develop our roots and to water ourselves so that we can spread our arms towards the heavens: to the freedom, inspiration, and love.

Remember that nature supports itself. Remember how lucky you are that you can witness fascinating processes such as mycorrhiza - the combined life of fungi and plants, each one helping the other to survive and to thrive.

Once we perceive the intricate connection of nature around and within ourselves, it becomes easy to understand the beauty that humans have been exposed to for thousands of years.

Humans will then naturally slow down and allow nature to be the guide in all their subsequent adventures.

Slowing down can heal the planet.

Let's start by bringing back the phrase Bora mi - Oh my Pine!



Figure 65. Bosnian pine tree and a woman ©Jelena Popović, 2022.

Annex:
Protocol for Bosnian pine seed germination

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