



Bark Beetle Outbreak in Central Europe – Consequences and Future Challenges

Book of Abstracts



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Forests' Future 2025

Bark Beetle Outbreak in Central Europe – Consequences and Future Challenges

Průhonice, September 22nd – 25th 2025

Book of Abstracts

Edited by Vít Šrámek, Miloš Knížek et al.



Conference is organized under the auspices of the Czech Minister of Agriculture Marek Výborný



Conference is organized as joint meeting with IUFRO WP 7.03.10: Methodology of forest insect and disease survey

Conference partners:



Dear participants of the Forests' Future conference,



The subtitle of the conference mentions bark beetle outbreak, its consequences and future challenges. Considering the outbreak itself we can be cautiously optimistic. The amount of felled wood due to bark beetle infestation in the Czech Republic has been decreasing for the fourth year in a row, and the total of 2.4 million m³ is the lowest since 2015. Despite the positive trend, we are aware that the overall infestation is still high locally and that the situation could easily reverse in the case of unfavourable weather conditions – especially after dry and hot spring. We are also registering increased risk in regions that have been up to now relatively resistant to bark beetles as higher mountain areas or (as colleagues from Scandinavia will mention) in higher latitudes, which keeps us on our toes. I appreciate that other types of pests will be mentioned during the

conference, because protecting forests and ensuring their stability and sustainability should be comprehensive and prepared for unexpected situations. One of the current issues related to ongoing climate change is, among other things, the improvement of fire protection in forests.

The outbreak has confronted us with the task of reforestation on an unusually large scale.

The area of clearings (unstocked areas) accumulated as a result of intensive logging during the bark beetle calamity is being successfully reduced. Over the past three years, more clearings have been reforested each year than were created as a result of logging activities. In 2024, approximately 40,000 hectares were reforested, of which approximately 75% was artificial reforestation. As of December 31, 2024, approximately 41,000 hectares of clearings remained to be reforested, which is almost half of the total recorded as of December 31, 2021. More important than the total area, however, is the quality and future potential of newly established forest.

We appreciate that the proportion of natural forest regeneration increases year by year, while the proportion of deciduous tree species in artificial regeneration increases. As the Ministry of Agriculture, we support forest owners in planting melioration and strengthening tree species to increase the stability of future forests.

Nevertheless, the road to stable, productive and environmentally valuable forests is long and faces many unexpected and currently unrecognized obstacles. I hope that your meeting will help us all steer our forests towards a future in which all the beneficial function and services of forests for society are ensured and even enhanced.

I wish you fruitful meeting

A handwritten signature in blue ink, consisting of a stylized first name and a long horizontal line for a surname.

Marek Výborný

Minister of Agriculture of the Czech Republic

Preliminary Programme

TUESDAY 23. 9. 2025

8:15 - 9:00 Registration

9:00 - 9:15 Welcome

Session 1, chair: Wojciech Grodzki

- 9:15 - 9:30 **Ferenc Lakatos et al:** To monitor or not to monitor – three decades of bark beetle monitoring in the Sopron mountains
- 9:30 - 9:45 **Andrej Kunca et al:** Bark Beetle Outbreak in Spruce Forests of the Horehronie Region Following the 2022 Drought
- 9:45 - 10:00 **Wojciech Grodzki:** Overview of the spruce bark beetle *Ips typographus* (L.) outbreaks in Poland during last 20 years – patterns and implications
- 10:00 - 10:15 **Jan Lubojacký et al:** Occurrence of forest damaging factors in Czechia
- 10:15 - 10:30 **Gernot Hoch et al:** Spruce bark beetle outbreaks – the dominant forest protection problem in Austria since 2015

10:30 - 11:00 Coffeebreak

Session 1 continuing, chair: Gernot Hoch

- 11:00 - 11:15 **Mária Potterf et al:** Hotter drought increases population levels and accelerates phenology of the European spruce bark beetle *Ips typographus*
- 11:15 - 11:30 **Mihai-Leonard Duduman et al:** Status of spruce bark beetle outbreaks in forests managed by the Romanian State Forest Fund for the last 10 years (2015-2024)
- 11:30 - 11:45 **Zoran Zavrtanik et al:** The Bark Beetle Situation in Slovenia: A 1995-2024 Overview
- 11:45 - 12:00 **Robert McElderry et al:** Modelling effects of environmental drivers of spruce bark beetle outbreaks in Switzerland; presented by Eckehard Brockerhoff
- 12:00 - 12:15 **Paal Krokene et al:** Bark beetles in boreal forests: Calm before the storm?
- 12:15 - 12:30 **Agnis Šmits et al:** Do sanitary selective cuttings improve the health of *Ips typographus* infested spruce stands?

12:30 - 12:50 Poster session appetizer I

12:50 - 14:15 Lunch

Session 1 continuing, chair: Andrej Kunca

- 14:15 - 14:30 **Tiina Ylioja et al:** Tree mortality in Finnish forests: linking bark beetle infestations and fungal infections under warming climate
- 14:30 - 14:45 **Päivi Lyytikäinen-Saarenmaa et al:** Novel methodology for detecting and modelling bark beetle-induced forest disturbances in Finland
- 14:45 - 15:00 **John Alexander Pulgarín Díaz et al:** Impacts of forest stand and landscape variables on the formation of *Ips typographus* damage hotspots in Finland
- 15:00 - 15:15 **Max Blake et al:** Research innovations in the face of unprecedented long-distance dispersal – managing *Ips typographus* in the UK
- 15:15 - 15:30 **Youngwoo Nam et al:** Recent Local Outbreak of *Ips* Bark Beetles in Korea: Emerging Threat or Limited Impact?; presented by Won IL Choi
- 15:30 - 15:45 **Nick Schafstall et al:** Sub-fossil bark beetle remains as indicator of past outbreaks

15:45 - 16:05 Poster session appetizer II

16:05 - 16:30 Coffeebreak

Session 1 continuing, chair: Tobias Frühbrodt

- 16:30 - 16:45 **José Pedro Ribeiro-Correia et al:** Recent detections of non-native ambrosia beetles and their fungal associates in Switzerland
- 16:45 - 17:00 **Cathal Ryan:** First finding in Ireland of *Pseudips mexicanus* - a non-European bark beetle
- 17:00 - 17:15 **Marcelo Ramires et al:** Phytotron-based assay to investigate induced molecular defense response of *Picea abies* against *Ips typographus*; presented by Carlos Trujillo-Moya
- 17:15 - 17:30 **Rastislav Jakuš et al:** Challenges and Improvement Strategies for Using Semiochemicals to Protect Spruce Stands.
- 17:30 - 17:45 **Veronika Rau et al:** The nematode diversity in *Ips typographus* during an ongoing outbreak in South Tyrol
- 17:45 - 18:00 **Sunil Kr. Ghosh:** Sustainable management of leaf miner (*Phytomyza spp.*) infesting som plant (*Machilus bombycina* King) by using plant extract

18:00 - 19:00 Poster session with refreshment

WEDNESDAY 24. 9. 2025

Session 2, chair: Pavel Pavlenda

- 9:00 - 9:15 **Florian Irauschek et al:** From calamity to adaptation: insights from surviving Norway spruce under bark beetle and drought stress, presented by Marcela van Loo
- 9:15 - 9:30 **Pavína Máchová et al:** Control system to verify and identify the origin of forest reproductive material suitable for afforestation after a bark beetle outbreak; presented by Eva Pokorná
- 9:30 - 9:45 **Natalie Korolyova et al:** The Last Trees Standing: An interdisciplinary analysis of Norway spruce survival during bark beetle outbreaks
- 9:45 - 10:00 **Michael Stastny et al:** Ecosystem function of forest watersheds under insect disturbance
- 10:00 - 10:15 **Laura Harms et al:** Benefitting from damages? - How different treatments of disturbance sites affect forest biodiversity
- 10:15 - 10:30 **Radek Novotný et al:** Impact of forest dieback and salvage logging on carbon sequestration, nutrient balance and risk elements mobility

10:30 - 11:00 Coffeebreak

Session 3, chair: Sven Martens

- 11:00 - 11:15 **Antonín Martiník:** Forest regeneration (restoration) options in calamity areas - models
- 11:15 - 11:30 **Andrej Vertelj et al:** Forest Restoration After Natural Disturbances and Bark Beetle Infestations in Slovenia

11:30 - 11:45	Jan Łukaszewicz et al: Problems of regeneration and tending methods on large-scale areas after wind calamity in northern Poland; <u>presented by Tadeusz Zachara</u>
11:45 - 12:00	Reneema Hazarika: Substituting European Native Trees at Risk: Potential of Non-Native Tree Species under Climate Change
12:00 - 12:15	Monika Vejpustková et al: Larch as a key productive tree species in areas affected by bark beetle outbreaks
12:15 - 12:30	Andrej Gubka et al: Game as a significant damaging factor in young forests
12:30 - 12:50	Poster session appetizer III

12:50 - 14:15 Lunch

Session 4, chair: Vilém Jarský

14:15 - 14:30	Přemysl Mácha: The Social Limits of Sustainable Forestry: A Perspective from Czechia
14:30 - 14:45	Dalibor Šafařík: Development Strategy of the State Enterprise Lesy České republiky, s.p. for the Period 2025–2029; New Visions and Fulfillment of the Principles of Sustainable Forest Management
14:45 - 15:00	Sigrid Netherer et al: DECIDE for proactive forest management towards resilient forests in Styria and Lower Austria
15:00 - 15:15	Zuzana Sarvašová: Managing Forests for the Future: Challenges and Opportunities for Private Forest Owners in Ecosystem Service Provision
15:15 - 15:30	Jakub Linda et al: Trajectories of sustainable use and supply of biomass in Slovakia for the period 2025 – 2050
15:30 - 15:50	Poster session appetizer III

15:50 - 16:20 Coffebreak

16:20 - 16:45 IUFRO Business Meeting

16:45 - 18:00 Poster session

18:30 Departure for Social Dinner

19:30 - 21:00 Social Dinner

THURSDAY 25. 9. 2025

EXCURSION

8:30	Departure from Průhonice
9:30 - 11:30	Želivka: Experimental catchment and ICP Forests level II plot
13:00 - 15:30	Nové Veselí: Reforestation of clearcuts
16:00 - 17:45	Zelená hora: Pilgrimage Church of St. John of Nepomuk (UNESCO World Heritage site)
18:00	Excursion Dinner
cca 21:30	return to Průhonice

Details will be provided in the Excursion guide you will receive at the conference registration

No: Poster session - appetizer I:

- 1 **Agnis Šmits et al:** Outbreak Dynamics and Management of *Ips typographus* in Latvian Spruce Forests; presented by Līva Legdina
- 2 **Olli-Pekka Tikkanen et al:** *Ips typographus* L. in the north: from curiosity to the most threatening insect pest of boreal coniferous forests of NW Europe
- 3 **John Alexander Pulgarín Díaz et al:** Drivers of European spruce bark beetle (*Ips typographus*) damage risk in Finnish forests and insights for its management
- 4 **Hyeon Suk Jo et al:** A Short Review on the Species and Damage of Bark and Ambrosia Beetles (*Coleoptera: Scolytinae*) Distributed in Korea
- 5 **Juraj Galko et al:** *Taphrorychus bicolor* in Slovakia: A New Challenge for Beech Forest
- 6 **Magdalena Kacprzyk et al:** Diversity of target and non-target beetles and associated nematodes in monitoring of the pine sawyer beetle *Monochamus galloprovincialis* (*Coleoptera, Cerambycidae*) in Scots pine and Maritime pine stands - a case study from Poland and Portugal; presented by: Luis Bonifacio
- 7 **Johanna Tuviala et al:** Bark beetle outbreak in Koli National Park, eastern Finland, and environmental factors affecting it
- 8 **Simon Kärvelo et al:** Spruce bark beetles and forest conservation in Sweden
- 9 **Jaroslav Strádal et al:** Selection of ester-forming and -hydrolysing enzymes putatively involved in pheromone production in *Ips typographus* (Linnaeus, 1758)

No: Poster session - appetizer II:

- 10 **Mikko Pelto-Arvo et al:** Occurrence and overwintering of *Ips typographus*, associated species and natural enemies in southeastern Finland – implications for forestry
- 11 **Maartje J Klapwijk:** Spruce bark beetle activity in sub-optimal habitat
- 12 **Anna Jirošová et al:** Forest Edge Formation Alters Microclimate and Volatile Cues but Does Not Immediately Increase Susceptibility to European Spruce Bark Beetle
- 13 **Slavomír Rell et al:** Biological control strategies for bark beetle population management
- 14 **Dragos Cocos et al:** Colonization of non-native lodgepole pine by *Ips typographus* in Sweden: A Rare but Noteworthy Event
- 15 **Iuliana Vasian et al:** Synthetic Approach to the Aggregation Pheromone of *Ips duplicatus* (Sahlberg) (*Coleoptera: Curculionidae, Scolytinae*); presented by Monica Gorgan
- 16 **Iuliana Vasian et al:** Preliminary Field Evaluation of Pheromone Lures for the Monitoring of *Lymantria dispar* (L.) (*Lepidoptera: Erebidae*)
- 17 **Eun Jung Ahn et al:** Morphology of prothoracic depressions and associated microbial symbionts in the oak ambrosia beetle, *Platypus koryoensis*
- 18 **Štefania Tötös et al:** Development of an optimal method for detection and monitoring of *Lamprodila festiva*, an invasive pest of ornamental *Cupressaceae* species

No: Poster session - appetizer III:

- 19 **Sven Hofmann et al:** New approaches towards digital bark beetle monitoring
- 20 **Benjamin Schumacher et al:** Merging Copernicus Data into national forestry products
- 21 **Ivan Barka et al:** Remote sensing based monitoring of bark-beetle outbreak - a case study from central Slovakia
- 22 **Čepelka Ladislav et al:** SMARTbeetle: Using AI and Molecular Scent Profiling for Species-Specific and Eco-Friendly Spruce Bark Beetle (*Ips typographus*) Control
- 23 **Ruth Carter et al:** Using Machine learning to Improve *Ips typographus* Surveillance
- 24 **Joowon Park et al:** Assessment of the Efficiency of Pine Wilt Nematode Monitoring Using Unmanned Aerial Vehicles
- 25 **Ye Eun Park et al:** Morphological and molecular identification of *Inostemma seoulis* and *Platygaster matsutama*, parasitoid wasps of *Thecodiplosis japonensis*
- 26 **Magdalena Kacprzyk et al:** Ophiostomatalean fungi associated with the great spruce bark beetle (*Dendroctonus micans* Kugelann) (*Coleoptera: Curculionidae, Scolytinae*) in Poland and Czech Republic
- 27 **Dragoş Toma et al:** Phoretic mite communities associated with *Ips typographus* (Linnaeus, 1758) and *Ips duplicatus* (Sahlber, 1836) (*Coleoptera: Scolytinae*) in a Norway spruce stand; presented by Gabriela Isaia

No: Poster session - appetizer IV:

- 28 **Dragoş Toma et al:** The climate change and the evolution of *Lymantria monacha* population in Romania; presented by Gabriela Isaia
- 29 **Serban Chivulescu et al:** Forecasting Forest Management Scenarios for Climate Mitigation: Insights from the LTER Bucegi-Piatra Craiului Site, Romania
- 30 **Joyce M N Romeiro:** Projecting and Managing Bark Beetle Risk in Norway's Forests under Climate Change
- 31 **Elza Otaņķe et al:** From Background Species to Major Threat: *Ips acuminatus* Response to Forest Disturbance in a Changing Climate
- 32 **Zuzana Sitková et al:** Long-Term Dynamics of Forest Vegetation in the Tatra Mountains: Evidence from Permanent Plots
- 33 **Ondřej Špulák:** Soil and air microclimate in differently managed young silver birch stands compared to spruce growing on a former clear-cut area
- 34 **Kateřina Neudertová Hellebrandová et al:** The Impact of Clear-cuts on the Water Retention Capacity of a Small Forest Catchment During an Extreme Precipitation Event
- 35 **Fayaz Asad:** Revealing the climate variability in the Hindu Kush: a tree ring based temperature reconstruction
- 36 **Rebecca Hood-Nowotny et al:** Promoting adaptation to climate change and bark beetle attacks using a citizen-science transformative approach.

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To monitor or not to monitor – three decades of bark beetle monitoring in the Sopron Mountains

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Over the past three decades, Norway spruce (*Picea abies*) stands in the Sopron Mountains (West Hungary) have experienced significant bark beetle damage. Climate change has severely weakened the natural resistance of the trees especially because those stands are at lower elevations and outside of the native range of Norway spruce. From the 1990s onwards, increasingly severe bark beetle outbreaks have been recorded, with major damage peaks occurring in the '90s and after the turn of the millennium. The primary control method has been early detection and removal of infested trees, supported by systematic trapping of bark beetles. Since the 1990s, pheromone traps have become widely used, primarily for monitoring *Ips typographus* and *Pityogenes chalcographus* swarming patterns and mass trapping.

Continuous trapping of the beetles and forest management that takes into account the beetle swarming patterns (which areas are most at risk) made it possible to carry out forest transformation over a longer period of time rather than having to harvest the initially dominant spruce (25%) in the area within a few years. All this reduced the economic losses of the forest owner, and provided the opportunity to create and transform new forests with an appropriate tree species structure (diversity and resilience).

The Norway spruce forests of the Sopron Mountains are undergoing transformation under the pressure of climate change and bark beetle damage. Beetle trapping using pheromones or generic lures remains a valuable tool for monitoring and early warning both for native and introduced bark and ambrosia beetle species.

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Bark beetle outbreak in spruce forests of the Horehronie region following the 2022 drought

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A massive bark beetle outbreak occurred in the Horehronie region of central Slovakia following a severe drought during the 2022 growing season. Rapid spruce dieback was observed in several areas at once, affecting both commercial forests and national parks. In response, professional pest control strategies were proposed by the Forest Protection Service in Banská Štiavnica and formally implemented through state administrative decisions. This paper discusses the predisposing factors contributing to the outbreak, the role of secondary pests, and provides a prognosis for future forest development in the affected areas.

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Fig. 1: Clearcuts around previously healthy forest stand, which later died anyway.

Overview of the spruce bark beetle *Ips typographus* (L.) outbreaks in Poland during last 20 years – patterns and implications

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During las 20 years severe and extended *I. typographus* outbreaks affected Norway spruce stands in some Central-European countries, including Poland. *Picea abies* is not a main tree species in Poland (representing about 6,5%), and its distribution is not homogenous – one can distinguish some specific regions with spruce and a “spruceless belt” in the central part of the country area (Boratyńska, 1998), considered also as an area of its scattered distribution (Boratyński, 1998). Nevertheless, during last 20 years, some bark beetle outbreaks have affected the stands in all regions with spruce. The patterns and implications of those outbreaks differed between the regions, although the result was always the same – the total volume of processed spruce timber recorded as originating from the trees infested by bark beetles in Poland in this timespan reached over 17,5 million m³. This figure does not include the volume of killed trees in protected areas, left in the forest. The main aim of the presentation is to depict the outbreaks in individual areas of spruce distribution (Grodzki, Michalski 2013): north-western (Fig. 1), northern, north-eastern, south-western and south-eastern), define their origin and patterns, and indicate the implications for forests and forest management in the areas affected by the spruce decline caused by bark beetles.



Fig.1: Norway spruce stand killed by *I. typographus* in north-western Poland.

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Occurrence of forest damaging factors in Czechia

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The volume of salvage felling has decreased significantly year-on-year, from 5.9M m³ of timber in 2023 to 4.6M m³ in 2024. Abiotic influences caused 2.9M m³ of recorded damage in 2024. Wind again dominated, damaging 2.1M m³ of timber. Drought damage was recorded at 560K m³. Persistent yellowing of spruce was recorded on a total area of 20K ha. According to the records, 1.7M m³ of timber was damaged by biotic agents in 2024. Calamitous bark beetle infestations, especially *Ips typographus*, in spruce stands were still dominant. Over 1.4M m³ of spruce timber infested by bark beetle was recorded (Fig. 1). This represents a year-on-year decrease of almost 60%. Other tree species, especially conifers, are also increasingly infested by bark and wood boring insects. Defoliating insects were recorded again on minimal areas in 2024, mostly at the level of latency. Amongst sucking insects, the occurrence of the rapidly spreading invasive bug *Corythucha arcuata* should be mentioned, especially in southern Moravia. As regards other insects, the damage was mainly caused by *Hylobius abietis* adults on a total area of 2.4K ha of the youngest conifers. There was a year-on-year increase in damage to youngest broadleaves caused by small rodents. Problems with cloven-hoofed game damage in Czechia are still alarming. The incidence of fungal pathogens was very high in 2024. 195K m³ of timber were recorded due to root rot caused by *Armillaria* spp. Needle and leaf diseases were mainly caused by *Lophodermium* spp. on pines and *Microsphaera alphitoides* on oaks. Ash dieback caused by the fungal pathogen *Hymenoscyphus fraxineus* accompanied by wood-destroying fungi continues without any prospect of improving.

Note: The Forest Protection Service data covers approximately 70% of the total forest area in Czechia.

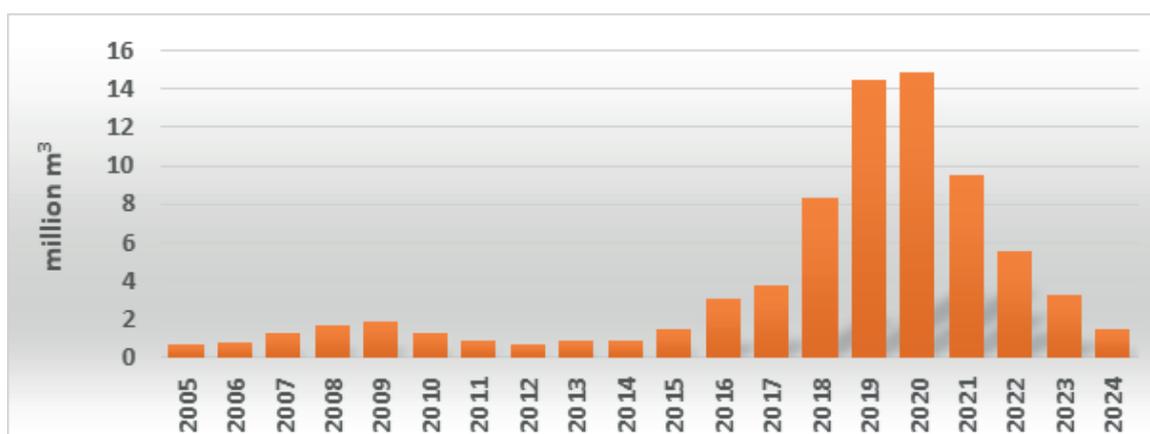


Fig. 1: Recorded volume of harvested spruce timber infested by bark beetles in Czechia since 2005 (values from ca 70% forest surface; data source: FPS FGMRI)

Acknowledgement:

The work was supported by the Forest Protection Service activity sponsored by the Ministry of Agriculture of the Czech Republic, by the National Agency for Agricultural Research, Project No. QK23020126 and institutional support MZE-RO0123.

Spruce bark beetle outbreaks – the dominant forest protection problem in Austria since 2015

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Since summer 2015, outbreaks of the European spruce bark beetle, *Ips typographus*, have been perceived as the dominant forest protection problem in Austria. Annual damage (as reported in the Documentation of Forest Damaging Factors) reached unprecedented levels, peaking at 5.2 million m³ in 2018, never dropping below 1.9 million m³ and exceeding abiotic damage by storm and snow in most of the last ten years. There have been two separate *I. typographus* outbreaks. The first concerned Norway spruce forests mostly at elevations below 600 m in the north of Austria and peaked in 2018. Damage returned to normal in 2022. Analysis of a 20-year time series showed that climatic water balance significantly influenced bark beetle damage in the area. The second outbreak affected mountainous Norway spruce forests in the Alps in the south of Austria. This outbreak started independently from the previous one. It was triggered by major storm and snow damage in preceding years (2018-2020) and supported by high temperatures. It peaked in 2023; attacks affected spruce from 700 m up to elevations above 1800 m. Damage significantly decreased in the outbreak area in 2024, remaining at high level. The population might reach the decline phase; the damage, however, in these mountain forests with their valuable protective function against natural hazards has already been enormous.

During both outbreaks, logistic problems (lack of labour, transport and storage capacities) became evident at times of very high attacks. Disturbance of timber market further worsened the situation. In the Alpine area, the steep terrain – if it was at all accessible – typically made cable yarding necessary, which hampered fast reactive measures. These focussed on early detection and timely removal of infested material. The protective function of the forest against natural hazards was always considered when prioritizing sanitation felling. A task force “Sanitation logging and forest protection in southern Austria”, installed by the Federal Ministry (BMLUK) in 2022, has been facilitating regular exchange of information and coordination among forest authorities, forest managers, logging companies, scientists and forest protection experts in the affected area. New tools for monitoring and planning management activities based on remote sensing and predisposition assessment have been made available.

Damage by *I. typographus* declined in Austria in 2024 but remains at very high levels (2.8 million m³). The decline is mostly due to the situation in the south of the country. An increase was noted at low elevation in the north as well as the south-east of Austria. High storm damage (3.8 million m³ in Austria in 2024) provided potentially suitable breeding material for bark beetles in many regions. Given the rising temperatures and elevated water stress due to climate change, the bark beetle outbreak risk remains high in the entire spruce forest area of Austria.

Hotter drought increases population levels and accelerates phenology of the European spruce bark beetle *Ips typographus*

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Bark beetle-induced tree mortality has increased strongly in Europe in recent years. Bark beetle populations are highly sensitive to temperature, and drought weakens tree defenses against beetle attacks. Yet, the compound effects of drought and heat (termed hotter drought) remain poorly quantified, even though climate change increases their joint occurrence. Here, we analyzed data from a regional-scale network of pheromone-baited *Ips typographus* traps (158 traps across 7 Mha in southeast Germany, with 67.5-million beetles caught between 2015 and 2021), contrasting the unprecedented hotter drought period of 2018-2020 with non-drought years. Our objectives were (i) to assess the effect of hotter drought on bark beetle population dynamics, (ii) to quantify changes in spatial patterns during hotter drought, and (iii) to investigate how well trap data can explain observed tree mortality. Bark beetle population levels were strongly driven by temperature and drought, with an annual increase of approximately 2,000 beetles per trap per °C under drought conditions (SPEI = -1). Furthermore, critical phenological thresholds were reached 7 and 4 days earlier for the timing of aggregation and peak swarming, respectively, per °C of temperature anomaly. In drought years, *I. typographus* population levels were autocorrelated across hundreds of kilometers. Trap data explained between 37% and 49% of observed bark beetle mortality, highlighting that pheromone trap networks are a useful tool for monitoring and managing forest risk. We conclude that hotter drought intensifies and extends mass outbreaks of the European spruce bark beetle, suggesting the emergence of novel patterns of disturbance.

Status of spruce bark beetle outbreaks in forests managed by the Romanian State Forest Fund for the last 10 years (2015–2024)

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Romanian forests occupy approximately 28% of the national territory, encompassing 6.93 million hectares. Coniferous species account for 1.88 million hectares, with *Picea abies* (Norway spruce) being the predominant resinous species, covering approximately 1.37 million hectares in pure and mixed stands. These forests are administered by various entities, with the Romanian National Forest Administration (RNP) managing around 50% of the total area. The primary biotic stressor affecting spruce forests is bark beetles, specifically *Ips typographus* and *Ips duplicatus*, which proliferate in the presence of significant quantities of wind-blown trees and/or drought. Over the last 10 years, 10.56 million m³ of wind-blown trees have been recorded in RNP-managed forests (min. 0.379 million m³ in 2021 and max. 2.24 million m³ in 2020). Of this volume approx. 12.7% was infested by bark beetles (1.345 million m³, with a min. of 0.081 million m³ in 2015 and a max. of 0.281 million m³ in 2020). Bark beetles also infested another approx. 2.01 million m³ standing spruce trees (min. 0.103 million m³ in 2020 and max. 0.391 million m³ in 2022) (Fig. 1). In the last ten years, there has been no bark beetle calamity in Romania. Still, bark beetle attacks are a significant problem, mainly due to poor management in such situations, amid an intensification of drought periods, especially after 2019 (Ioniță et al. 2025).

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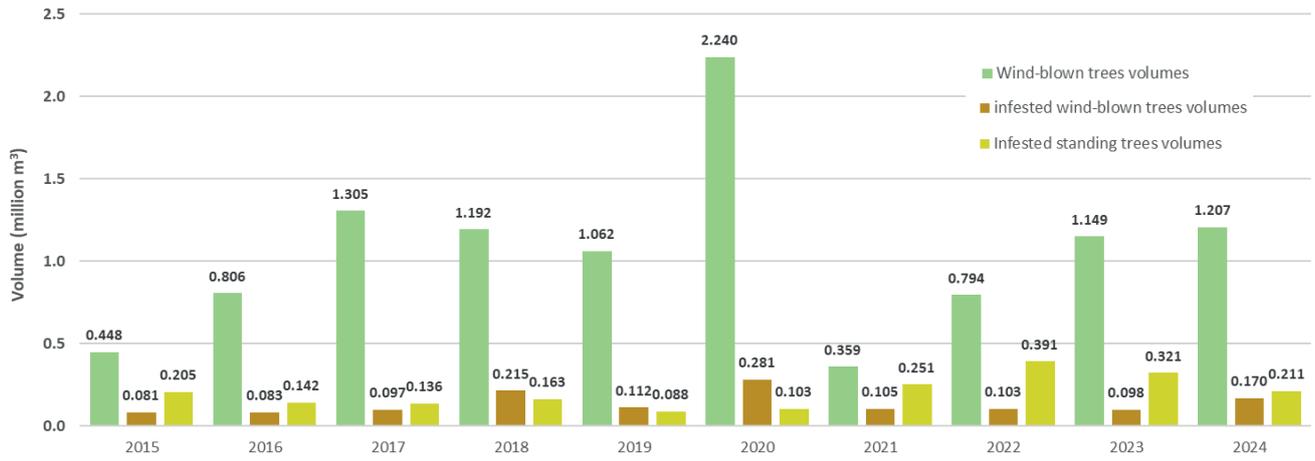


Fig.1: Evolution of wind-blown trees volumes and bark beetle-infested trees volumes between 2015 and 2024, in Romanian spruce forests managed by RNP.

The bark beetle situation in Slovenia: A 1995–2024 overview

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The bark beetle (*Ips typographus*) infestations in Slovenia have emerged as a significant environmental and economic concern, particularly since the early 2000s. These outbreaks have been fuelled by a combination of factors, including storm damage to trees, rising temperatures, and prolonged droughts, reaching their peaks between 2015 and 2019. The logging due to bark beetles was 2.0 million m³ in the period from 1995 to 2004, 4.0 million m³ from 2005 to 2014, and 11.5 million m³ from 2015 to 2024. The infestations have impacted spruce stands across Slovenia, from lowland areas to the upper tree line. Although sanitary logging is the primary control method, its effectiveness has been hampered by the large scale of damage and the logistical challenges of removing large quantities of damaged and infected wood from the forest in a short period of time.

While immediate measures focus on actively reducing the infestation, the long-term solution necessitates the adaptation of forest management practices to mitigate the impacts of climate change, and enhance the resilience of forest ecosystems. In the short term, continuous monitoring and control efforts will remain essential, but long-term forest management strategies will aim to prioritize ecological stability and sustainability to diminish the likelihood of future outbreaks.

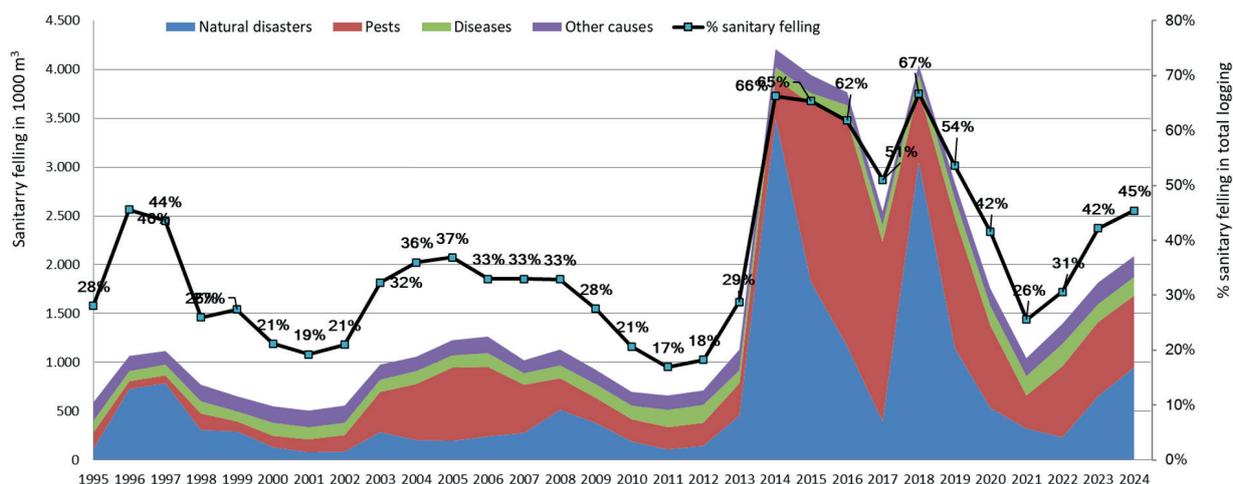


Fig.1: Sanitary felling due to natural disasters, pests, diseases, and other causes: annual trends from 1995 to 2024 and its share in total logging from 1995 to 2024.

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Modelling effects of environmental drivers of spruce bark beetle outbreaks in Switzerland

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In this project, our objectives were to further develop a tool to simulate bark beetle phenology, and include a new model of European spruce bark beetle (*Ips typographus*) infestation dynamics including the following variables: drought stress, the annual number of beetle generations, the stand-level spruce share, current and prior storm influences, local forest management, and nitrogen deposition. We carried out a comprehensive statistical analysis of bark beetle infestation dynamics using a 37-year time series of sanitation felling in Switzerland. Our analyses indicate that the foremost predictor of infested wood volume is the volume of salvaged timber in the previous year. More thorough harvest of infested wood in the previous year results in a net decrease in infested wood. Net increases are associated with elevated numbers of bark beetle generations per year, drought stress, as well as the occurrence and intensity of storms. Higher spruce density had a weak positive effect, and nitrogen deposition had a non-significant direct effect, with some indirect effects. We found evidence of moderate negative density dependence whereby large infestations tend to shrink and small infestations tend to grow. We found limited ability to isolate the impacts of windthrown timber on bark beetle outbreak dynamics, which hindered us from fully integrating storm impacts in our decision tool. We were able to estimate the impacts of a small set of storms with record-setting intensities, and we provide some guidelines for forest managers in the event of windthrow at local or regional scales.

Bark beetles in boreal forests: Calm before the storm?

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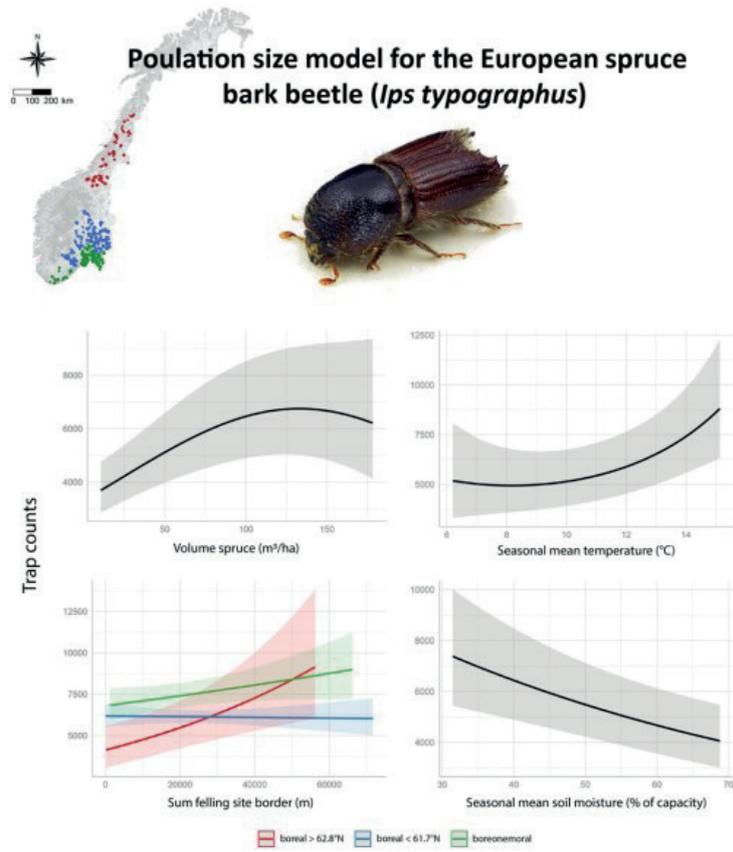
²⁾ Norwegian Institute for Nature Research (NINA), Norway

The European spruce bark beetle (*Ips typographus*) is a notorious tree-killer in Central Europe but has had more limited impact in Europe's northern boreal forests, with only sporadic bursts of tree-killing. We analysed trapping data from the Norwegian bark beetle monitoring, using a 17-year period with no bark beetle outbreaks. This allowed us to examine environmental factors that are important for driving bark beetle numbers towards the outbreak threshold. By identifying these factors and mechanisms under non-outbreak conditions we can better understand outbreak risks. Not surprisingly, the amount of spruce in the landscape was an important determinant of bark beetle numbers. We also observed that more newly exposed stand edge after clear-cutting is associated with higher beetle numbers, probably because trees along stand edges are weakened by the sudden exposure to sun and wind. Furthermore, we found both temperature and drought to be important, with beetle numbers being higher after hotter and dryer periods. Perhaps most interestingly, we observed a clear time delay in how some of these environmental factors influenced bark beetle numbers. Our analyses show that there is typically a 3-year delay from a disturbance, such as the exposure of a new stand edge, until bark beetle numbers peak. Similarly, a severe drought is expected to cause high bark beetle numbers three years later. Due to the time delay described above we can use current environmental data and predict bark beetle numbers three years into the future. This useful feature can be used to direct logging activities to high-risk areas with high beetle populations.

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Spatial prediction of future population size

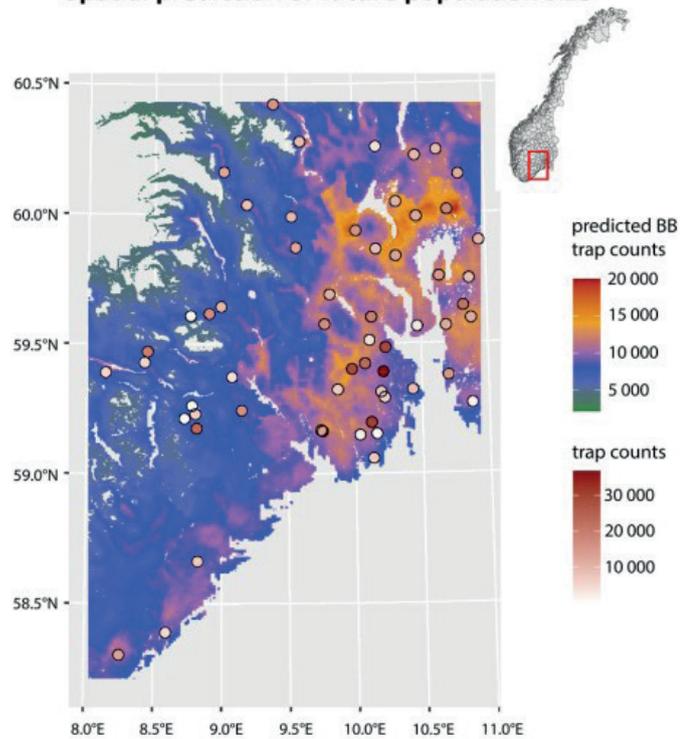


Fig.1: Summary of the study.

Do sanitary selective cuttings improve the health of *Ips typographus* infested spruce stands?

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This study evaluates the impact of sanitary selective cuttings in Norway spruce (*Picea abies* (L.) H. Karst.) stands on the infestation dynamics of the eight-toothed spruce bark beetle (*Ips typographus* L.), in relation to various stand parameters including harvesting time, stand age, species composition, and soil type. Using multispectral drone photogrammetry, 182 stands were mapped between August 15 and August 30, 2024. It was assumed that all visibly dead spruces post-cutting represented trees infested by the first beetle generation in 2023 or 2024. The results indicate that older spruce stands exhibit a significantly higher risk of post-cutting bark beetle infestation. Risk was also elevated when cuttings occurred during the beetles' active flight period, in stands with higher admixture of other tree species, and on wet soils compared to drained sites. Furthermore, sanitary cuttings following bark beetle damage posed greater infestation risk than those following windthrows. Regional differences in infestation levels corresponded with variations in local bark beetle population densities. These findings highlight the importance of stand characteristics and timing when planning sanitary interventions to mitigate bark beetle spread.

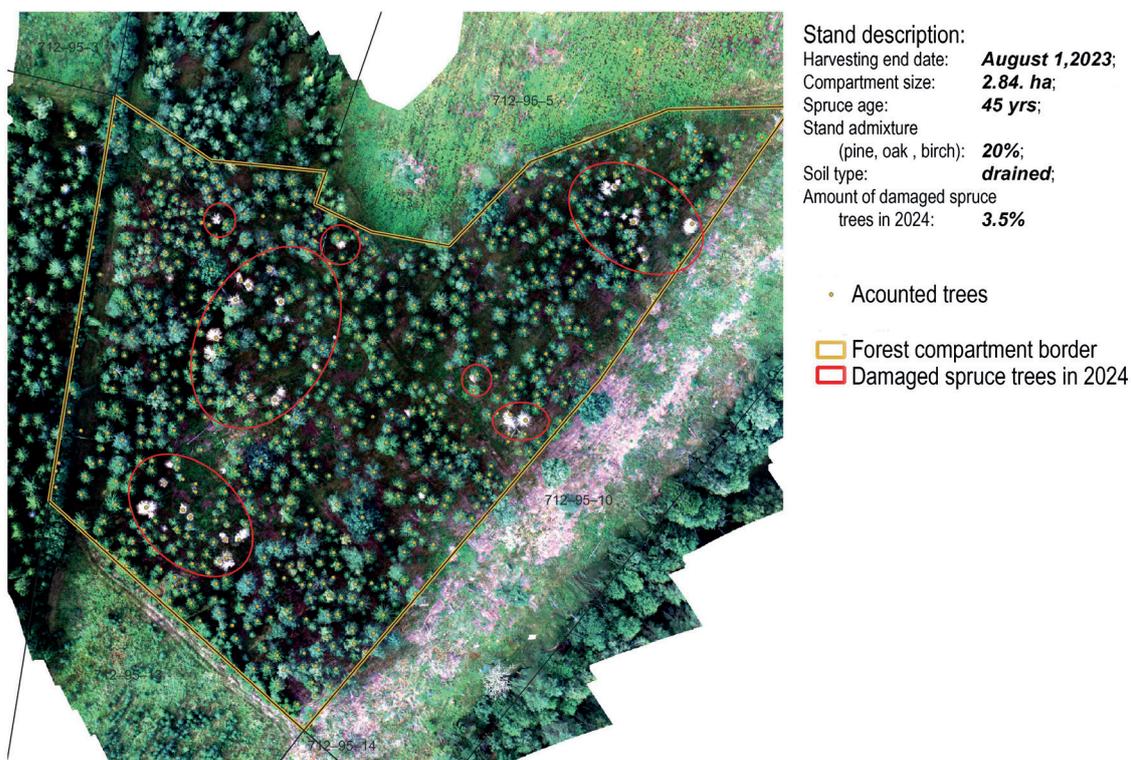


Fig.1: Example of multispectral drone photogrammetry.

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Tree mortality in Finnish forests: linking bark beetle infestations and fungal infections under warming climate

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The abundance of trees killed by bark beetles (Coleoptera: Curculionidae, Scolytinae) has increased in Finland. The underlying cause is the warm and dry summers, which have stressed the trees. Small outbreaks of the spruce bark beetle (*Ips typographus*) are most typical, and are often accompanied by *Pityogenes chalcographus* and *Polygraphus poligraphus*. Recently, *Ips duplicatus* has also caused minor spruce mortality.

In recent years, Scots pines (*Pinus sylvestris*) have also experienced sudden die-offs in Finland. *Ips acuminatus*, a bark beetle not typically found in southern Finland, caused the death of individual trees or small groups of pines in 2013 (Puukko 1981, Siitonen 2014). Similar mortality recurred in 2019, following the warm and dry summer of 2018. Deaths of mature *P. sylvestris* in multiple locations along the Finnish coast were observed. Ninety percent of the studied *I. acuminatus* infestations in coastal regions tested positive for Diplodia tip blight (see Terhonen et al. 2025). The fungus, *Diplodia sapinea*, is spreading unnoticed due to its asymptomatic endophytic life stage and is emerging as a pathogen at its northern range limits. It may also cause problems in forest nurseries and kill seedlings at forest regeneration sites.

Bark beetles, which are attracted by host volatiles, may also detect compounds released by fungi in host trees. Therefore, we aim to investigate whether there is a causal relationship between the beetle and the fungus, or whether both are simply favoured by drought and/or heat stress in pine trees. *I. acuminatus* infestations have also been detected in central Finland, where their connection to *D. sapinea* appears to be lacking. Other pathogens, such as the root rot fungus (*Heterobasidion* sp.), have co-occurred with *I. acuminatus* infestations. Root rot may contribute to drought stress and lower the defensive capacity of trees. It has recently been linked to *I. typographus* infestations (Wahlman et al. 2025).

The sudden deaths of Scots pine have raised concerns about whether we are witnessing an early warning signal for future. The ability of *I. acuminatus* to attack and kill healthy, vigorous trees has been demonstrated.

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Novel methodology for detecting and modelling bark beetle-induced forest disturbances in Finland

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The severity of bark beetle infestations is elevating in the boreal forests, but the outbreak risk can be decreased by timely detection and proactive management measures. We analyzed bark beetle (*Ips typographus* L.) infestation intensity of Norway spruces (*Picea abies* L.), assessed the relationship between damage and stand characteristics, and the impact of an outbreak on spruce volume in managed and conserved areas in southeastern Finland. Symptoms were visually observed at the stem level (entrance-exit holes, resinous flows, bark damage) and crown level (defoliation, discoloration). Tree-wise damage indices were based on the scoring of the symptoms. Damage indices served as ground-truth for forest monitoring by remote sensing. Further, we developed and assessed a tree-based methodology using multi-temporal, multispectral Uncrewed Aerial Systems (UAS) images to track changes by *I. typographus*. Our method included four steps: 1) individual tree detection using structure-from-motion point clouds, 2) tree species classification, 3) classification of spruces as healthy, declined, or dead, and 4) change detection, identifying fallen/removed trees and degradation in spruce health. The uncertainty estimation showed the overall accuracies ranging from 0.58 to 0.91 for individual tree detection, 0.84 for species classification, and 0.83–0.96 for health status classification. Change analysis were visualized by tree health status maps, where dead, living, fallen and removed trees, and outbreak clusters were indicated between years. The conserved areas were more damaged than the managed areas. Stand volume decreased over eight years by 80% in conserved areas and 40% in managed areas, indicating successful control in managed stands. These methods serve stakeholders by precise monitoring, timely risk assessment, and evaluating management strategies.

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Impacts of forest stand and landscape variables on the formation of *Ips typographus* damage hotspots in Finland

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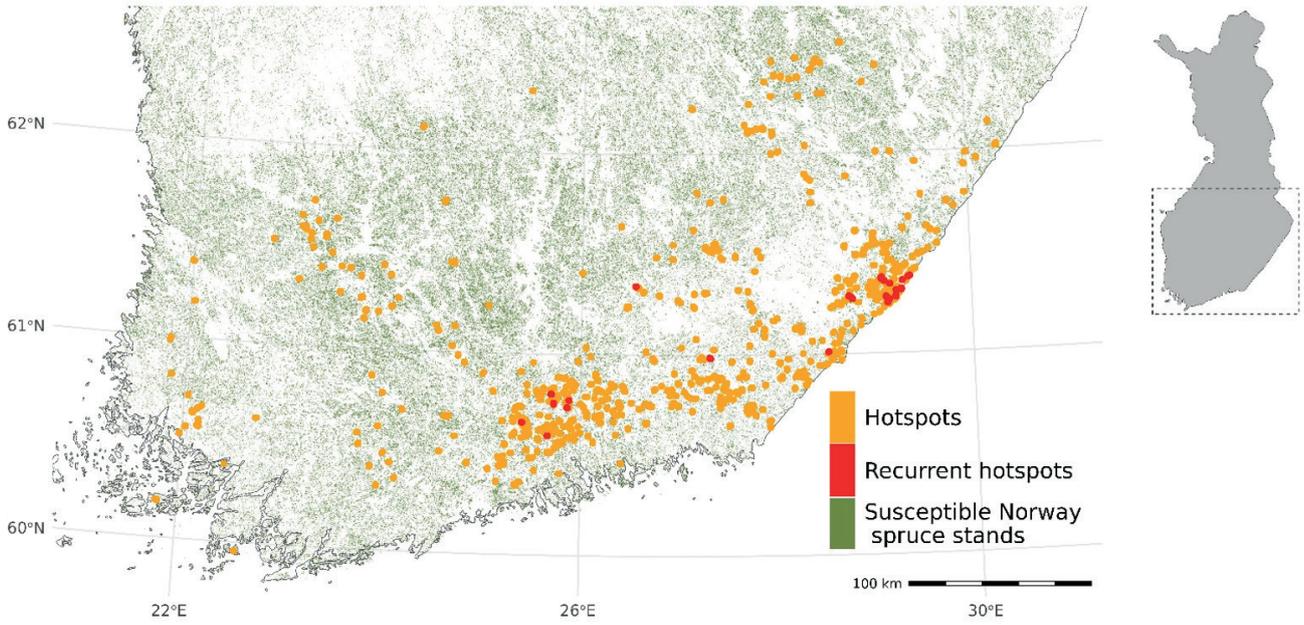
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Climate change is projected to amplify European spruce bark beetle (*Ips typographus*; SBB) damage in Norway spruce (*Picea abies*), particularly in Finland, where Norway spruce plays a key role both ecologically and economically. Gaining deeper insight into the ways stand- and landscape-level characteristics shape the emergence of SBB damage hotspots could enhance the scientific foundation for sustainable forest management decisions. We investigated how stand- and landscape-level variables contribute to the emergence of SBB damage hotspots across southern Finland from 2012 to 2020, using salvage logging due to SBB as an indicator of SBB damage. Spatial clustering of damage was evaluated with global Moran's I, while local Moran's I was used to pinpoint hotspots. Damaged stands were categorised based on whether they did not form hotspots, formed hotspots or recurrent hotspots. To assess how forest stand and landscape variables shaped both the likelihood of an area in becoming a hotspot and the chance of a hotspot in recurring, we applied logistic regression and forest stand level information. Although SBB-damaged stands exhibited weak global spatial autocorrelation, still hotspots emerged. Hotspots initially clustered in southeastern Finland and later in the southwest. Hotspot formation correlated with stand age and proximity to previously damaged stands, while the formation of recurrent hotspots correlated with stand development class and proximity to previously damaged stands. Rapid detection and removal of infested trees remain essential for limiting the spread of new hotspots. Over the longer term, the creation of spruce-dominated landscapes in areas prone to SBB damage should be minimized. Our results offer practical insights to support risk-aware forest management and policy decisions at both regional and national scales.

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Susceptible Norway spruce stands for 2021. Hotspots and recurrent hotspots of *Ips typographus* damage during 2012–2020.

Research innovations in the face of unprecedented long-distance dispersal – managing *Ips typographus* in the UK

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Since the first finding of *Ips typographus* breeding in Britain in 2018, multiple research projects have helped clarify Britain's policy on eradicating *Ips typographus* despite multiple waves of introductions via natural dispersal from the continent (Blake *et al.* 2024). Research projects on phenology (Webb, Blake & Gilligan 2024), the susceptibility of our main forestry conifer Sitka spruce (Inward *et al.* 2025), improved surveillance techniques, and proving long-distance dispersal from the continent (Blake *et al.* 2024; Inward *et al.* 2024) have led to the position that *Ips typographus* can be eradicated, and our long-term policy now focusses on creating a *cordon sanitaire* in the south east of England to stop *Ips* moving into spruce-rich areas in Wales, Scotland and northern England. Our research now focusses on improving sample processing via object ID and machine learning, designing internet-of-things connected traps for faster detection, citizen science trapping, predictions of dispersal via atmospheric modelling, further research into spruce defences, and the parasitoid fauna associated with *Ips typographus*. These research innovations have been able to put Britain on a better footing for dealing with novel insect pests.

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Fig.1: Sitka and Norway spruce killed by *Ips typographus* in the UK.

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Recent local outbreak of *Ips* bark beetles in Korea: emerging threat or limited impact?

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Bark beetles are known as one of the most destructive insect pests in forests, capable of inflicting significant economic damage on trees. In 2010, sudden outbreaks of two *Ips* bark beetle species were observed in planted coniferous forests located in Yeongyang and Inje, Korea. In Yeongyang, it had been planted with Korean white pine (*Pinus koraiensis* Sieb. & Zucc.) in 1983 meanwhile the Japanese larch (*Larix leptolepis* (Sieb. et Zucc.) Gordon) plantation was located in Inje, Gangwon-do. The bark beetles that caused noticeable infestations in these forests were the engraver beetle (*Ips acuminatus*) in Korean white pine, and the large larch bark beetle (*I. subelongatus*) in Japanese larch. Approximately 10 hectares of Korean pine forest was affected by *I. acuminatus* outbreak, resulting in the mortality of more than 1,000 trees. Meanwhile, *I. subelongatus* caused the death of about 50 Japanese larch trees. Although large-scale outbreaks of species *I. acuminatus* have not been observed since 2010, ongoing larch mortality associated with species *I. subelongatus* has been documented. These findings highlight the need for continuous monitoring to detect early signs of bark beetle activity and to implement timely management strategies.



Fig.1: Korean white pine forest infested by *I. acuminatus* in 2010.

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Sub-fossil bark beetle remains as indicator of past outbreaks

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Bark beetle outbreaks have increased in frequency and magnitude over the past decades and have become more associated with periods of drought than windstorms, as was the case historically. Extensive monitoring projects, studies about the phenology of bark beetle species, and modelling studies have improved our understanding of the current status quo and the ability to predict future outbreaks. Recommended methods for future mitigation of outbreaks are often related to adaptive management to improve the forests' resilience to droughts and other extreme events. The effect of this management change, however, is uncertain over a longer period. Paleoecology, the subfield of ecology that uses fossil records to reconstruct past environments, can be used to reconstruct former baseline stages of forest structure and composition, including the forest fauna. Our study (Schafstall et al., 2021) is the first where subfossil bark beetle remains from a sediment core were used to reconstruct past outbreaks. Several cores were extracted from a small peat bog at the foothills of the High Tatra Mountains (980 m a.s.l.) in Slovakia, near Tatranská Lomnica, and correlated by geochemistry. A master sediment core was radiocarbon dated and shows that peat formation at the site started around 600 AD. The sediment from the other cores was pooled and divided into 18 bulk samples that covered between 50–100 years each. Pollen, charcoal particles, and well-preserved beetle remains were used to reconstruct changes in the vegetation, fire events and bark beetle outbreaks. The conifer bark beetle record shows three peaks that could indicate outbreaks, and a shift in the dominant species. This shift from dominant species *Polygraphus poligraphus* to *Ips typographus* and associated species could be correlated to changes in tree composition, in particular the disappearance of fir and beech trees. Our study highlights how subfossil beetle remains can reveal long-term patterns in forest insect outbreaks and vegetation change, offering valuable historical context for modern forest management. By extending the baseline beyond recent records, such insights can inform resilience strategies against future climate-driven disturbances. Currently, pilot studies using sedimentary ancient DNA are underway in other European localities to replicate this type of research.

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Recent detections of non-native ambrosia beetles and their fungal associates in Switzerland

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Ambrosia beetles are highly successful as invaders because they are often transported internationally with wood packaging and other wood products and because their inbreeding mating system facilitates establishment of invading populations. In 2022, two independent insect surveys in canton Ticino (southern Switzerland) using bottle traps baited with ethanol, and unbaited Polytrap intercept traps revealed the widespread occurrence of several non-native ambrosia beetles. *Anisandrus maiche* was found to be widespread and very abundant mainly in southern Ticino. This species is native to east Asia and has previously been found as a non-native invasive species in the United States, Canada, western Russia, Ukraine and, in 2021, in northern Italy and subsequently also in Slovenia. Three other ambrosia beetle species were detected in Ticino. Limited surveys in other parts of Switzerland suggest that none of these species has been present elsewhere in the country so far. These and several other ambrosia beetle species were also detected in adjacent countries (in Italy, France and Germany), indicating a wider pattern of recent invasions of ambrosia beetles. Here, we present the results of several surveys documenting the occurrence and known distribution of non-native ambrosia beetles in Switzerland and adjacent countries in Central Europe, along with information on the known host plants and impacts as well as the fungi associated with these beetles. Knowledge of pathways enabling invasions of ambrosia beetles and options for their management will be discussed.

First finding in Ireland of *Pseudips mexicanus* - a non-European bark beetle

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Forest cover in Ireland is currently estimated to be 11.6% (808,848 ha) of the total land area, a considerable increase from less than 2% forest cover in the early twentieth century. Many European coniferous bark beetle species are absent from the island of Ireland. For example, there are no *Ips* species present. Ireland is recognised as a Protected Zone under the EU Plant Health Regulation (EU 2016/2031) for six coniferous bark beetle species present in other parts of the EU. Their absence in Ireland is demonstrated through annual surveys over the last three decades. In the course of official Protected Zone bark beetle surveys in 2023 by the Department of Agriculture Food and the Marine, *Pseudips mexicanus*, a non-European Scolytinae species was detected in traps in Co. Clare. All non-European bark beetles are regulated as Union Quarantine Pests under the EU Plant Health Regulation. Accordingly regulatory measures are in place in Ireland including the implementation of a demarcated area with movement restrictions on host material and ongoing surveillance. No damage or breeding population has been detected in Ireland. A Pest Risk Analysis is underway by the European and Mediterranean Plant Protection Organisation (EPPO).



Fig.1: *Pseudips mexicanus*.

Photo: Robyn Earl, Department of Agriculture, Food and the Marine, Ireland.

Phytotron-based assay to investigate induced molecular defense response of *Picea abies* against *Ips typographus*

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Norway spruce (*Picea abies* [L.] H. Karst.) is a cornerstone species of European montane and boreal forests, providing important ecosystem services such as timber production, water regulation, soil stabilization, and biodiversity maintenance. However, the survival of these forests is increasingly threatened by bark beetle outbreaks, especially from the Eurasian spruce bark beetle (*Ips typographus* (L.)), whose attacks have become more frequent and severe due to climate change-related stressors such as drought and windthrow events. These outbreaks lead to widespread forest mortality and cause severe economic and ecological losses across Central Europe. The bark beetle colonizes mature spruce trees by penetrating the outer bark (a constitutive defense) to access nutrient-rich tissues, often introducing symbiotic fungi that facilitate the host's infection. Although mass attacks can quickly overwhelm trees, successful resistance depends on the tree's ability to mount an effective defense response (an induced defense).

While field studies have contributed to our understanding of these interactions, their inherent unpredictability, environmental variability, and logistical demands can limit controlled experimentation and their reproducibility. In addition, large-scale field trials can be labor-intensive and restricted by the availability of suitable experimental sites and beetle rearing facilities. To address these limitations, we developed a controlled, scalable laboratory-based assay simulating early-stage bark beetle attacks. Bark beetle protein extracts were applied to Norway spruce seedling stems in the phytotron under controlled conditions. This method serves as a reproducible infection system that mimics insect-associated biotic stress without requiring live beetles or the use of mature trees. Following exposure (2 and 48 hours post inoculation), RNA-Seq analysis of treated tissues revealed up to 550 differentially expressed genes involved in key defense processes, including plant-pathogen interactions, MAPK signaling cascades, hormone-mediated responses, and secondary metabolite biosynthesis. Impor-

tantly, the defense signatures observed in seedlings mirrored to a significant extent those previously identified in clonal adult trees under controlled beetle attack.

This work supports the concept of a conserved molecular defense strategy in *P. abies*, potentially shaped by its long-standing co-evolution with *I. typographus* since the postglacial recolonization. Our phytotron-based approach offers a powerful tool to study spruce defense mechanisms systematically, facilitating high-throughput screening of genetic variation in resistance traits among different seed sources. The optimization and application of this technique can ultimately contribute to targeted breeding programs aimed at enhancing forest resilience against escalating bark beetle pressures under changing climatic conditions.

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Challenges and improvement strategies for using semiochemicals to protect spruce stands

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The use of semiochemicals for the protection of spruce stands remains limited across Europe. Traditionally, pheromone traps have been employed primarily for monitoring bark beetle (*Ips typographus*) populations. However, recent findings – particularly from the EXTEMIT-K research project – demonstrate new possibilities for applying semiochemicals in practical forest protection. Generally, semiochemical-based methods have shown limited effectiveness in spruce monocultures situated at lower elevations. In contrast, they can be significantly more effective in natural or semi-natural spruce stands. One example is the application of pheromone trap barriers as part of an integrated protection strategy (including timely sanitary felling), which proved effective in northern Slovakia during the late 1990s. Earlier experiments with anti-attractants yielded only limited success. However, a newly improved anti-attractant mixture (Jakuš et al., 2024) has demonstrated promising results, even in low-elevation spruce monocultures. These findings also highlight that anti-attractants may be effective as a standalone treatment, without the concurrent use of pheromone traps. Positive results have also been observed under the ecological conditions of the southern Alps. Nonetheless, the combination of anti-attractants with pheromone traps – i.e. the „push-pull“ system – has not proven effective. This suggests that push-pull strategies may only be efficient when implemented with a high density of pheromone traps. Further research is necessary to optimize these systems. An additional approach to enhancing the effectiveness of semiochemical applications involves combining anti-attractants for *Ips typographus* with attractants for its natural predator, *Thanasimus formicarius* (Korolyova et al., 2024). This strategy offers a promising avenue for future forest protection methods.

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The nematode diversity in *Ips typographus* during an ongoing outbreak in South Tyrol

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The spruce bark beetle *Ips typographus* (L.) is a major forest pest in Europe. Rising temperatures and prolonged dry periods put its host, the Norway spruce *Picea abies* (L.), under stress. This allows the beetles to successfully attack healthy trees and proliferate rapidly leading to significant economic losses and ecological disturbances every year. The Southern Alps experienced only minor damage by *I. typographus* prior to 2018. Then several years of wind break, snow damage and drought caused heavy disturbances, which led to a massive and ongoing bark beetle outbreak in South Tyrol and Eastern Tyrol. Natural antagonists that co-occur with the beetle are one important factor in controlling the beetle population. A variety of organisms including bacteria and fungi are associated with the spruce bark beetle. However, even if nematodes are described to be commonly found in bark beetles, their diversity and effect on the beetle are currently understudied. In our project we study the nematode community of *I. typographus* during the current outbreak in South Tyrol by performing metabarcoding of whole beetles. We aimed to determine which nematode species are living on and within the beetle and to identify potential antagonists and symbionts. We used DNA from adult beetles that were collected in South Tyrol across several years and at two different altitudes. Two genes (18S, 28S) were amplified and sequenced with a metabarcoding approach. The comparison of sampling years and altitudes allowed us to characterize the core nematode community and determine its stability. The nematode sequences mostly derived from five species of four different genera comprising parasitic and phoretic taxa. One species, *Micoletzkyia buetschlii*, was present in almost all beetles, other species appeared only in a few samples. Both, sampling year and altitude, seemed to affect the presence of nematode species. Two species were found more often in earlier years, while two other species were common more recently. This might indicate a shift in species within ecological groups. As some nematode species might have negative consequences for the host, a deeper understanding of the associated nematodes and their dynamic is important to understand their role in the outbreaking dynamics of *I. typographus*.

Sustainable management of leaf miner (*Phytomyza* spp.) infesting som plant (*Machilus bombycina* King) by using plant extract

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Rearing of muga silk worm (*Antheraea assama* West wood) is done on som plant (*Machilus bombycina* King). Nutritional value of leaves of som plant plays an important role in the larval growth and silk production. Rearing becomes difficult due to attack of large number of insect-pests on som plant. Leaf miner (*Phytomyza* spp.) (Diptera: Agromyzidae) is a major pest and very harmful to som plant leaves. From observation it is found that leaf miner was found active throughout the year on som plant leaves. Higher population level was maintained during 27th standard week to 34th standard week that is during 1st week of July to last week of August, with highest population (20.42 larvae/5 leaves) was recorded on 32nd standard week that is on the 2nd week of August. Leaf miner population had a significant positive correlation with temperature and relative humidity. This indicates that activity of leaf miner increases with the rise of temperature and relative humidity. A mixed formulation of imidacloprid (a chemical insecticide at low dose) with azadiraction (a plant based insecticide) was found most effective against leaf miner recording highest control (79.24%), closely followed by recommended dose of imidacloprid (76.25% control) and mixed formulation imidacloprid+polygonum (73.74% control). Plant based insecticides / extracts gave higher control when it is mixed with other formulations. Lower dose of imidacloprid mixing with azadiractin/polygonam/spilanthes extracts will be environmentally sound and eco-friendly, and it is recommended for leaf miner control to promote organic farming.

Key words: Muga rearing, silk production, bio-pesticides, eco-friendly, organic farming

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From calamity to adaptation: insights from surviving Norway spruce under bark beetle and drought stress

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In recent years, unprecedented bark beetle outbreaks have caused severe damage in Norway spruce forests across Austria, largely driven by climate change and increasing drought events. Our research aimed to improve the long-term resilience of spruce populations by identifying, conserving and studying individual trees ("plus trees") that survived extensive bark beetle damage under extreme drought conditions in 2018. These survivors were hypothesized to possess genetic adaptations for stress tolerance.

Selected plus trees were propagated through grafting and seed collection to establish clone archives and seedling trials. Drought response of the progeny was assessed in two experiments: a growth-based drought tolerance test and an RNA-sequencing analysis under controlled drought conditions. While overall growth performance of plus tree progeny did not exceed standard provenances under drought, transcriptomic data revealed that progeny classified as drought-tolerant exhibited lower activation of stress-related genes, suggesting inherent resilience mechanisms.

The study highlights the complexity of drought adaptation in spruce and demonstrates that targeted selection within field-identified plus trees can enhance drought tolerance traits for future breeding programs. These findings provide a scientific foundation for climate-resilient forestry in Central Europe.

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Control system to verify and identify the origin of forest reproductive material suitable for afforestation after a bark beetle outbreak

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The impacts of the bark beetle outbreak in previous years continuously reflected consequences in forestry and forest management in the Czech Republic with significant loss of forest stands. One of the more appropriate strategies is to afforest these areas with a suitable forest reproductive material (FRM) with a declared origin of the seeds, nursery seedlings and nursery transplanted plants. The Czech Republic, as a member of the EU, has the obligation to create a functioning control system for the determination of FRM origin. For this purpose, genetic analyses using nuclear microsatellites were developed and optimized for several forest tree species, e.g. Norway spruce, Scots pine, European beech (Máchová et al. 2021, Máchová et al. 2022a, 2022 b.) and for *Quercus* spp. the optimization of DNA analysis procedures is in the process. Monitoring procedures of the identity of FRM was carried out during three and four years from seed collection to transplanted plants. Optimally polymorphic microsatellite markers with sufficient informative values were analyzed using PCR reactions, followed by fragment analysis on a genetic analyzer. Genetic data were evaluated with the GenAEx 6.503 program (Fig. 1). Subsequently, the genetic structure was evaluated using the Bayesian clustering method implemented in the software STRUCTURE 2.3.4. According to the obtained results, we confirmed the declared origin of individual certified units of FRM in selected forest tree species. Developed optimized methodological procedures could be used in the state control system to verify the declared origin of FRM and subsequently, this verified FRM could be used for afforestation after a bark beetle outbreak.

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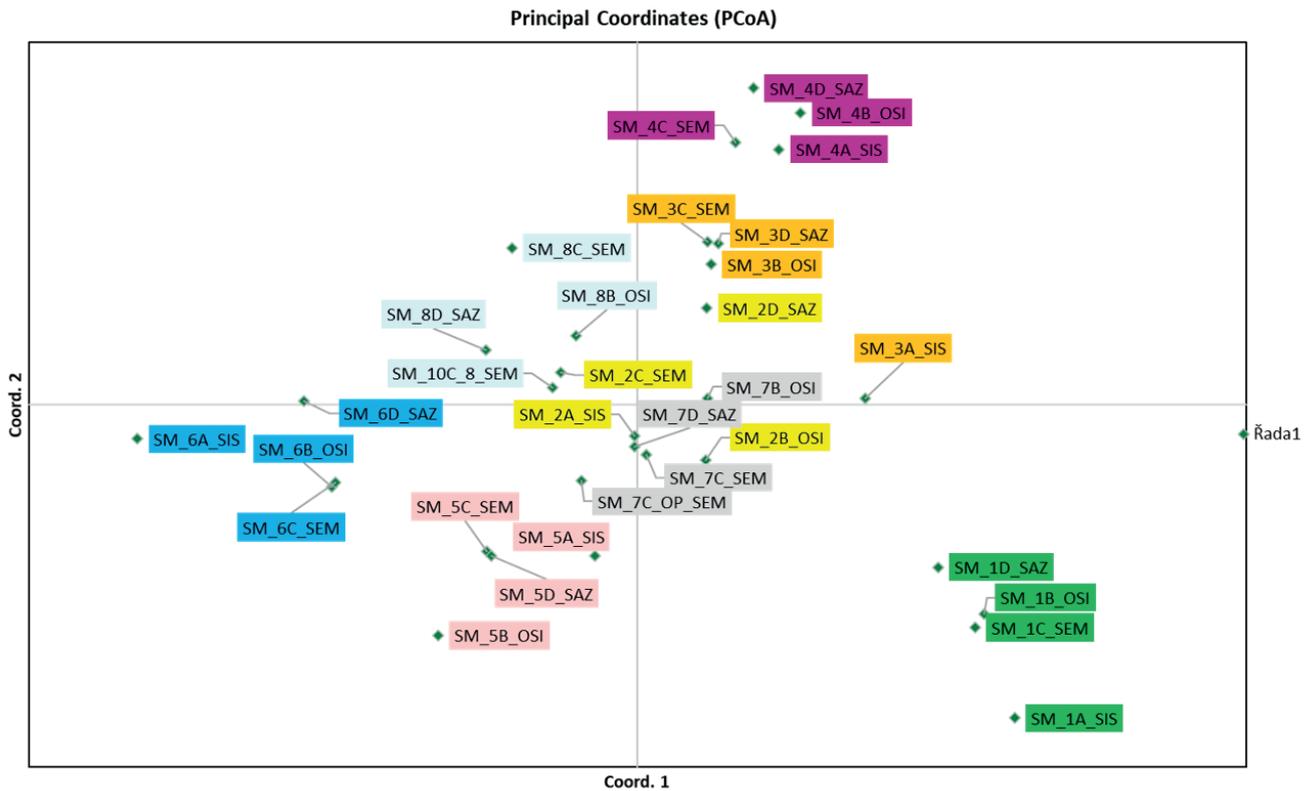


Fig.1: Result of Principal coordinates analysis in Norway spruce for eight selected sources of forest reproductive material. Individual colours represent each testing sample set of different origins.

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This work was supported by the Ministry of Agriculture of the Czech Republic, institutional support MZE-RO0123 and a grant project no. QL24020127 „Control of conformity and verification of the origin of reproductive material of forest trees using DNA analyses“.

The Last Trees Standing: An interdisciplinary analysis of Norway spruce survival during bark beetle outbreaks

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Climate change is intensifying bark beetle outbreaks, posing a major threat to the survival of *Picea abies*. Despite widespread mortality, fewer than 1% of individuals – termed “Last Trees Standing” (LTS) – persist through such disturbances (Fig. 1). Using a multidisciplinary approach combining dendroecology, analytical chemistry, remote sensing, and genomics, we investigated factors underpinning LTS survival during a prolonged *Ips typographus* outbreak in Central Europe. The spatial clustering of LTS individuals suggests non-random survival processes. Larger-diameter trees were more vulnerable, likely due to growth–defence trade-offs or interactions with beetle aggregation behaviour. Competition further reduced survival, whereas trees with larger crowns, superior photosynthetic capacity, and greater carbon reserves exhibited increased resistance. Prolonged water limitation exacerbated vulnerability. Dendroecological analysis revealed slower long-term radial growth in LTS, indicating a trade-off between growth and defence. Genomic analyses identified 12 SNPs markers linked to survival, including genes associated with stress responses such as methylation, growth suppression, and cellular regulation. Of 56 terpenes analysed, neoabietic acid was the strongest survival predictor, with survival probability increasing non-linearly up to a threshold concentration. Methyl jasmonate inoculation increased most terpene levels 2- to 13-fold; LTS trees had higher α -terpinolene and γ -terpinene, while reference trees showed more sabinene hydrate, methyl dehydroabietate, and dehydroabietal. LTS individuals also had significantly higher sucrose concentrations, with survival probability rising non-linearly with sucrose levels. Conversely, reference trees exhibited greater soluble starch concentrations, associated with decreased survival probability. Mechanical wounding experiment showed that elevated catechin production enhanced survival. Proximity to beetle populations and crown condition influenced defensive capacities, with defoliation and sun exposure reducing survival. These findings provide crucial insights for informing adaptive forest management strategies under a changing climate.

Acknowledgement:

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Fig.1: Bark beetle-disturbed forest area in Šumava National Park, Czechia (above), and examples of “Last Trees Standing” (bottom).

Ecosystem function of forest watersheds under insect disturbance

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Insect outbreaks are an integral component of the natural disturbance regime of forests, but our understanding of their broader impacts on ecological functioning of forest ecosystems has been overshadowed by the historical focus on timber supply. Canopy loss and tree mortality resulting from insect outbreaks can alter a range of ecosystem variables, from soil nutrient cycling to stream hydrology and aquatic food webs. These potentially long-term and large-scale ecosystem consequences should inform both insect pest and forest management decisions. We report on responses of forest watersheds to defoliation and tree mortality resulting from an ongoing outbreak of spruce budworm (*Choristoneura fumiferana*) in the Gaspésie region of Quebec, Canada. Drawing from a landscape-scale manipulative experiment, we discuss our findings and the methodology of linking insect damage data with ecosystem responses to insect disturbance. In the context of pest risk assessment and control strategies, we also draw parallels between this defoliator and another prominent outbreaking insect in western North America, the mountain pine beetle (*Dendroctonus ponderosae*). In the face of climate change and other stressors on forest systems, we propose that ecosystem impacts of insect disturbances need to be viewed against their normal range of variation, with universal implications for forest pest management.

Benefitting from damages? How different treatments of disturbance sites affect forest biodiversity

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The years 2018 to 2020 were characterized by extreme drought, facilitating large-scale bark beetle outbreaks in Central European spruce-dominated forests. This in turn generated large amounts of standing deadwood and increased salvage logging activities. Deadwood and light availability play a pivotal role for forest biodiversity, but are typically scarce in commercial forests. Disturbance sites provide both elements, albeit to varying extents depending on post-disturbance management decisions, making them potentially valuable for forest biodiversity conservation.

To examine the responses of photophilous and saproxylic communities to post-disturbance management and identify winners and losers under different scenarios, we compared three treatments: a) logged and cleared stands (CC), b) recently disturbed forest stands with retained deadwood (DR), and c) regularly managed, undisturbed control sites (CN).

45 sites of 1 ha, arranged in 15 triplets (CC, DR, CN) with similar site conditions, were selected in mixed mountain forests of the Black Forest, Baden-Württemberg, Germany. Data was collected on forest structure, vascular plants and mosses, birds, butterflies, bats, saproxylic beetles and other insects.

First results revealed that both post-disturbance treatments (CC and DR) benefited photophilous groups like vascular plants and butterflies, with stronger effects in CC sites. Logged sites negatively affected the species richness of saproxylic beetles, while woodpecker abundance significantly increased on DR sites. Further analysis will focus on treatment effects on Red-Listed species to better understand how the treatment of forest disturbance sites can aid conservation efforts.

Impact of forest dieback and salvage logging on carbon sequestration, nutrient balance and risk elements mobility – project overview

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The aim of the three-year project was to evaluate changes in forest soils on clearcuts after forest dieback and salvage logging compared to undisturbed stands of Norway spruce (*Picea abies*). Field work was focused on the ICP Forests Level I plots that were salvage logged after the last bark beetle outbreak during the period 2018–2022. The project aimed to evaluate (i) the rate of decomposition of organic matter, (ii) biochemical changes in the topsoil and (iii) chemical changes in the soil profile down to 80 cm.

The studied sites experienced significant changes in air and soil temperature, along with slight alterations in the quality of organic matter. However, changes in forest soil chemistry were not as pronounced as it was expected. Moreover, processes that may be considered negative or even risky for the soil and forest ecosystem appear to be temporary. The soil surface becomes covered by the gradually developed herbaceous layer and natural regeneration of pioneer tree species, thereby reducing temperature and moisture fluctuations. This suggests that processes threatening forest soil conditions can be gradually mitigated or even eliminated through active management balancing natural and artificial regeneration according to the forest owner's goals and capabilities.

Main results could be summarised as follows:

- Topsoil pH increased significantly following spruce forest dieback.
- Contents of water-extractable organic carbon (DOC) indicated accelerated mineralization of organic matter on clearcuts.
- Also, a parallel teabag experiment showed the higher rate of decomposition on clearcuts, as compared to the undisturbed control.
- However, significant differences in the quality of organic matter between the clearcut and a control stand were found only in the upper organic (FH) layer.
- No significant differences were found in the contents of potentially toxic elements in the soil (aqua-regia extracted As, Cd, Cu, Pb and Zn) between the clearcuts and a control treatment (undisturbed stand). And the distributions of risk elements in the soil profiles did not differ depending on the management of logging residues (chipping vs. cleaning) within the clearcuts.

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- Changes in soil organic carbon (SOC) stock after spruce forest dieback with or without salvage logging showed a fast temporal dynamic.
- Litter-layer C stock initially increased on dead-standing plots, but decreased on salvaged plots.
- As topsoil C stock remained 30% higher on salvage-logged plots than on dead-standing ones, this suggested a vertical redistribution of litter C and harvesting debris into the topsoil layers.
- Salvage-logging did not result in an immediate major penalty to soil C stocks, but in a shift between soil layers.

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Forest regeneration (restoration) options in calamity areas – models

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The aim of this paper is to present a methodology that discusses models of postcalamity forest regeneration. This methodology deals with the adaptation of forest ecosystems in the process of post-calamity forest regeneration. The aim of the methodology is to identify, specify, evaluate and quantify restoration models in terms of adaptive capacity. In total, there are 4 basic and 1 superstructure model: extensive; continuous cover; passive; plantation; adaptive. The adaptive potential of the models was assessed for the following adaptive principles: exploiting natural processes; increasing species richness; increasing structural diversity; maintaining and increasing genetic variability of species; increasing individual tree resilience and maintaining low stand stock. In terms of adaptive capacity, the continuous cover model performs best and should thus be used preferentially in post-calamity regeneration. The extensive and passive models can be used as secondary models. The plantation model can be used only marginally in justified cases. The specific models, their application and their contribution to a given site will be based on the habitat conditions, the condition of the surrounding vegetation, the extent of the calamity clearings, the availability of labour and expertise, and so on.

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Forest Restoration After Natural Disturbances and Bark Beetle Infestations in Slovenia

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Slovenia has encountered significant challenges in forest management as a result of extreme natural events, such as severe storms and subsequent bark beetle infestations. Thus, in the last decade 25 mio m³ salvage logging was realized annually representing almost half of yearly timber removal. These calamities have caused extensive damage to forested areas, creating an urgent need for effective forest restoration. The environmental ramifications of these events are profound, leading to substantial tree loss and soil degradation as well as reduced provision of ecosystem services.

In response to this destructive impact, Slovenia has acknowledged the critical importance of restoring damaged forests. While the country traditionally emphasizes natural regeneration and forest restoration, the scale of devastation wrought by storms and pests has made active reforestation measures (e.g. planting seedlings and sowing seeds) a crucial element of the recovery strategy. Therefore, in the period from 2015 to 2024, 4,800 hectares of damaged forest with 32 different tree species were restored.

For areas experiencing large-scale damage, a detailed restoration plan is developed. This plan serves as the foundation for securing funding to support the proposed restoration activities. It outlines the necessary steps for rehabilitating the forests, including assessing the extent of the damage, selecting appropriate tree species for replanting, and establishing a monitoring system to track recovery progress.

In conclusion, the restoration of Slovenia's forests in the wake of extreme weather events and bark beetle infestations is guided by comprehensive legal frameworks and strategic planning. By incorporating both natural regeneration and active planting initiatives, Slovenia aims to revitalize its forest ecosystems, ensuring their sustainability and resilience for future generations. Through the engagement of forest owners and various stakeholders, the country seeks to cultivate a collective commitment to restoring its forests and mitigating the impacts of future disturbances.

Problems of regeneration and tending methods on large-scale areas after wind calamity in northern Poland

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The hurricane which passed over the northern part of Poland in the night 11th/12th of August 2017 destroyed the forest ecosystems on area of more than 40 thousands hectare. It was the greatest wind damaged in the history of our forestry. The most affected were forest districts belonged to Regional Direction of State Forests in Toruń (18 425 ha). The goal of the project, started in 2022, is to answer the question how to regenerate successfully the post-windthrow areas and to disperse the risk connected to such large-scale regeneration. The series of experimental plots were established to test different soil preparation and planting methods, age of seedlings, their type (container or bareroot) in a case different tree species. In older plantations (already established), the effect of different methods of tending cuts on their growth and development is being studied.

In 2024 in the Rytel Forest District (RDLP Toruń) on two post-disaster areas and for comparison in a neighbouring pine stand with oak admixture, microclimate measurements were taken by measuring air temperature at a height of 10 cm using HOBO automatic measuring sensors. The measurements were taken from April 26 to October 8, 2024, at an interval of 0.5 hours. The great differences between these plots were stated in a case of early morning air temperature especially in spring time, which brings frost damage to oak and other broadleaved seedlings. It harmonizes with first findings concerning the inhibited growth of admixture species in new established plantations. It must be concluded that artificial regeneration process should respect rules of natural succession, giving priority to pioneer species in the first phase of restoration.

Acknowledgement:

This work is supported by the project of the General Direction of State Forests (grant No BLP-476)



Fig.1: Five-year-old pine plantation with an admixture of oak on post-windthrow area (Forest District Rytel)

Substituting European native trees at risk: Potential of non-native tree species under climate change

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Climate change is profoundly altering forest ecosystems, threatening biodiversity and essential ecosystem services. In Europe, where forests span over 200 million hectares, rising temperatures and climate-induced disturbances are reducing the climatic suitability of many native tree species. As these species retreat from parts of their current ranges, non-native tree species (NNTs) are drawing increasing attention for their potential role in future forest management. While NNTs have historically supported biodiversity and timber production, their use under changing climate conditions remains controversial due to ecological and regulatory concerns.

This study provides a comprehensive assessment of the potential range shifts of 15 NNTs and 13 key native species in Europe using available projections of potential distribution from species distribution models. Except for *Pinus contorta*, all NNTs are projected to gain climatically suitable distribution areas in the future. Species such as *Juglans nigra*, *Robinia pseudoacacia*, *Pseudotsuga menziesii*, *Fraxinus pennsylvanica*, *Acacia dealbata*, *Pinus radiata*, and *Pinus strobus* are expected to retain much of their historical range while expanding further (Fig.1). Coniferous NNTs will likely contract in southern and southeastern Europe but expand northward and eastward. Broadleaved NNTs like *Acacia dealbata*, *Acer negundo*, *Robinia pseudoacacia*, and *Fraxinus pennsylvanica* are expected to maintain their southern ranges and extend into central and northern regions. Meanwhile, NNTs such as *Abies grandis*, *Pinus contorta*, *Picea sitchensis*, and *Thuja plicata* are predicted to remain confined to the Atlantic margins of Europe.

Historically, native species have had a larger potential range (~2.39 million km²) compared to non-native tree (NNT) species (~0.53 million km²). However, this pattern is projected to reverse under future climate scenarios, with NNTs gaining a larger share of climatically suitable areas as native species lose 14–21% of their historic range. Most native species, except a few such as *Fagus sylvatica*, *Quercus robur*, *Pinus sylvestris*, *Quercus pubescens*, and *Pinus halepensis*, are expected to experience range losses. In contrast, several NNTs, including *Acacia dealbata*, *Acer negundo*, *Pinus radiata*, *Fraxinus pennsylvanica*, and *Robinia pseudoacacia*, are projected to expand their climatically suitable areas. Some widely planted NNTs like *Pseudotsuga menziesii* and *Quercus rubra* may lose their highest suitability zones. Overall, NNTs are expected to outperform native species in Southwest, Southeast, and Atlantic Europe, while natives will remain more dominant in Central and Northern Europe (Fig. 2).

These findings highlight the growing importance of NNTs in future forest planning, emphasizing the need for careful, site-specific strategies that balance ecological risks with potential benefits.

Acknowledgement:

The work was supported by the EU-COST action [NNEXT](#) Interreg Alpine Space project [ALPTREES](#).

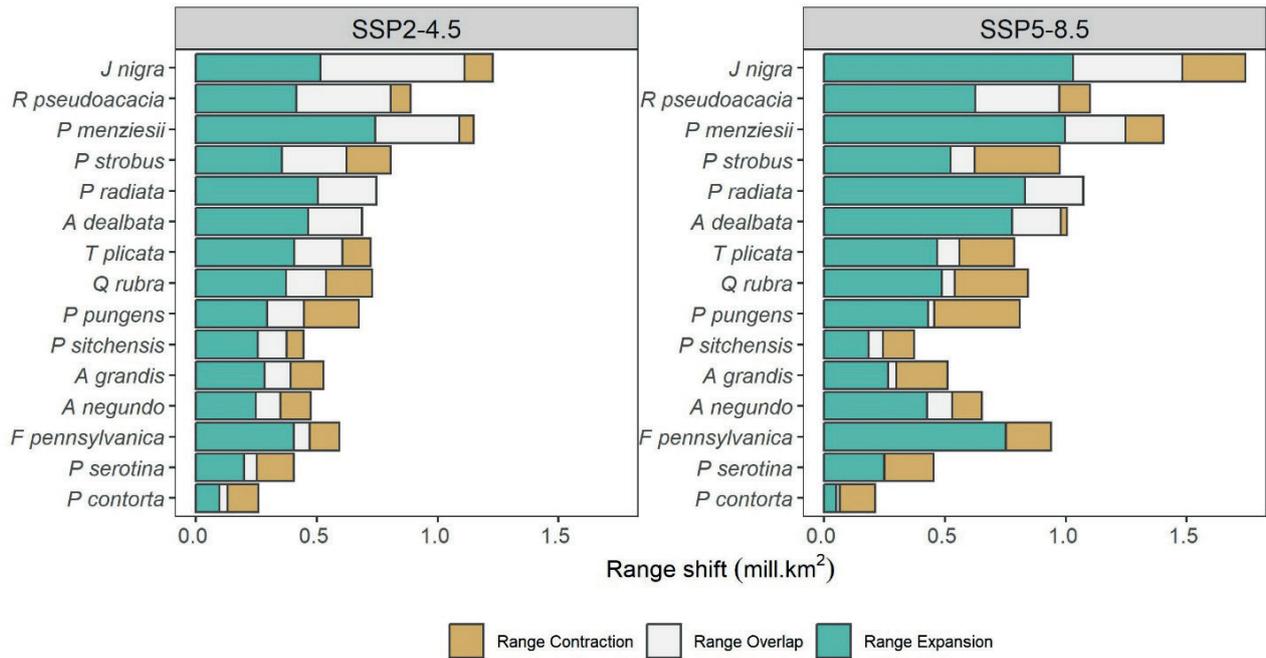


Fig. 1: Range shift of the 15 target NNT species in Europe. The range shift was estimated by an ensemble SDM model with occurrence data from both native and non-native ranges of each target species. Range shift (contraction, overlap, and expansion) refers to changes in potential species range between the historic period (1961–1990) and the future time frame 2061–2080 under two climate change scenarios SSP2 and SSP5.

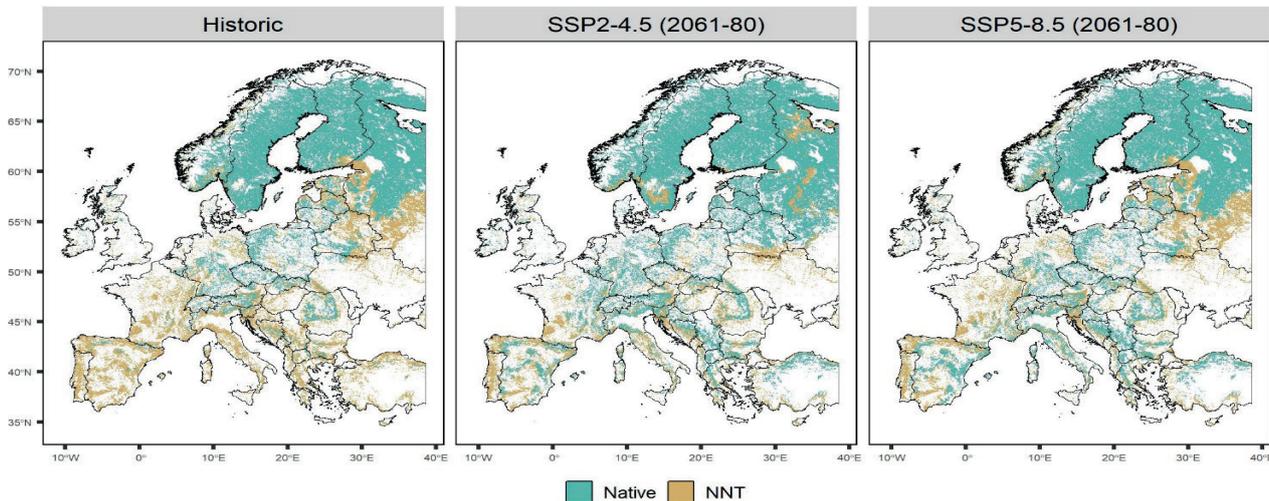


Fig. 2: Potential climate suitability depicting forested grid cells with either native or NNT species predicted to have the highest climatic suitability in historic climate and two future time frames under SSP2-4.5 and SSP5-8.5 scenarios.

Larch as a key productive tree species in areas affected by bark beetle outbreaks

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In areas affected by the large-scale decline of spruce stands due to bark beetle outbreaks, larch is becoming a key commercial tree species. As a result of spruce removal, larch now grows in open stands or as individual reserve trees. The aim of the study was to determine how larch growth develops after release and what production can be expected from mature trees when extending the rotation period to an older age (150 to 200 years).

Larch growth was studied in the region of northern Moravia, where the decline of spruce stands began as early as in the 1990s. This allowed for the analysis of larch growth response more than 20 years after release. Growth was examined using full stem analysis on 30 sample trees – 18 released trees and 12 growing in closed-canopy stands. Additionally, increment cores were collected from 200 trees (120 released and 80 in closed-canopy conditions). The growth development determined from stem and tree-ring analyses was complemented by an assessment of growth trends based on data from the Czech National Forest Inventory (NFI).

Tree-ring and stem analyses showed that larch does not respond to release by an increase in increment (light-induced growth), nor is there a decline in growth due to increased exposure to abiotic stress factors. Larches are capable of vigorous growth even at an advanced age. In most of the analyzed sample trees, aged 80–140 years, the curves of current and mean annual volume increment are diverging, indicating that the trees have not yet reached quantitative felling maturity, which is defined by the point of intersection of these two curves. Thus, larch has the potential for intensive growth even at an older age.

The analysis of NFI data reveals that larch has high productive potential especially at lower elevations and on nutrient-rich sites, where the current volume increment peaks at 108 years and then declines very slowly. As a result, the intersection point of current and mean annual increment curves – and therefore the felling maturity – is reached only at 202 years. In contrast, on sites belonging to the ilimerized edaphic category, the current volume increment peaks already at 40 years and then decreases rapidly, with felling maturity reached around the age of 70.

In the northern Moravia region, where nutrient-rich sites prevail, larch is among the economically valuable tree species with high productive potential up to the age of 200 years. In the coming years, larch will make a significant contribution to ensuring a positive economic balance of forest management in this area.

Acknowledgement:

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Game as a significant damaging factor in young forests

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Due to climate change and other contributing factors, there has been a significant increase in the population density of ungulates in Slovakia. This mainly concerns red deer (*Cervus elaphus*) – over 68,000 individuals hunted in 2024, fallow deer (*Dama dama*) – 36,000 hunted, and roe deer (*Capreolus capreolus*) – 26,000 hunted. High population densities of ungulates are associated with damage to young forest stands.

From databases compiled during the preparation of forest management plans, we extracted data about game damage in forest stands up to 10 years old. As of 2023, there were 110,607 forest stands in Slovakia under 10 years of age, covering a total area of approximately 231,724 hectares.

Results show that in almost 22% of these stands, at least one tree species is being damaged by game. Nearly 6% of the reduced area (stand area decreased by tree density) of all young stands is damaged by game. However, the extent of the damage varies across regions – some districts report damage in nearly 50% of the stands, while others report less than 5%.

Among tree species, occurring in at least 1,000 young forest stands, the most frequently damaged by game are sycamore maple (*Acer pseudoplatanus*), rowan (*Sorbus aucuparia*), European ash (*Fraxinus excelsior*), and silver fir (*Abies alba*). More than 30% of the stands and over 12% of the reduced area containing these species are affected by game damage.

This situation has a significant impact on forest ecosystems and on the objectives related to forest management and nature conservation.

Acknowledgement:

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The social limits of sustainable forestry: A perspective from Czechia

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The adaptation of Czech forests to climate change and changing societal expectations brings about a host of challenges: biological, technological, economic, legislative, and political, to name just a few. Another significant, yet seriously understudied, dimension of forestry transformation is the social one. Foresters on the one hand and local communities and the general public on the other play a crucial role in the formulation and implementation of climate change adaptation policies. Consequently, they have to be an integral part of any thinkable adaptation strategy aspiring to success. However, in spite of growing research, we still do not know enough about the social aspects of the transformation of Czech forests and the forestry sector or how this process is perceived and accepted by the foresters themselves. In this paper, I will present the preliminary results of ethnographic research in several forest enterprises in Czechia. My research involving formal and informal interviews as well as participant observation focuses on forest practitioners ranging from top forest managers to forest workers who plant and cut trees. The goal of the research is to identify the social limits of environmentally and socially sustainable forestry.



Fig.1: People are the „conditio sine qua non“ of sustainable production forests.

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Development strategy of the state enterprise Lesy České republiky, s.p., for the period 2025–2029; new visions and fulfillment of the principles of sustainable forest management

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After the subsiding of the largest bark beetle calamity of the early 21st century, there has been an intensive discussion within professional circles – also in connection with climate change adaptation – about a new substantive definition of the principles of sustainable forest management. A key element must be a differentiated approach, diversity in silvicultural practices, and recognition of the importance of the productive function of forests.

As the largest forest manager in the Czech Republic and a key component of the entire forest management sector and related industries, the state enterprise Lesy České republiky commits in its new development strategy to the principles of sustainable forest management. This commitment aligns with the conclusions of the EU Council on the new EU Forest Strategy to 2030, and aims to make maximum use of natural processes to cultivate spatially and species-diverse stable forest stands with rich tree species composition. This includes the use of natural regeneration, water retention in the landscape, its efficient use, and variability in silvicultural methods – thus contributing to the mitigation of climate change impacts.

Lesy ČR is striving to optimize two opposing tendencies:

1. Maintaining the economic prosperity of the enterprise and transferring ownership rent to the founder's fund.
2. Intensifying support for the non-productive functions of forests as a legitimate public interest.

DECIDE for proactive forest management towards resilient forests in Styria and Lower Austria

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The maintenance of vital forests and their essential ecosystem services in montane environments is threatened by the ongoing changes in climate regimes in conjunction with various abiotic and biotic disturbance factors. Forest management strategies aiming at the preservation and promotion of resilient forests and the reduction of damage risks are therefore essential, but often prevented by lacking knowledge about the main factors driving forest vulnerabilities. The Austrian DECIDE project has focused on the development and testing of a decision-support tool to inform different stakeholders in forestry (forest owner, managers, forestry consultants) about pro-active management options to promote resilient forests less susceptible to the major abiotic and biotic disturbance agents.

The DECIDE tool is conceptualised for conifer-dominated forests with a high share of either Norway spruce, European larch, European silver fir, or pine species. Predisposition assessment systems (PAS) have been updated or newly developed for storm, snow, fire, several bark beetle species (*Ips typographus*, *Ips cembrae*, pine bark beetles), ungulates (peeling of forest trees by red deer, browsing by ruminant ungulates), and wood decaying fungi. Based on high-resolution remote sensing and climate data, damage susceptibilities of forests in the Austrian model regions of Styria and Lower Austria are modelled. Within the tool, users choose main management goals, such as climate-adapted, economically used forest for timber production or protected forest for carbon and water storage. Stand characteristics not available from remote sensing can additionally be defined with the help of pictograms. Best forest management recommendations for a 10-year period adapted to the respective

goals and modelled predisposition are then provided for a forest area selected by the user. Stand susceptibilities and management options are visualised in tables and graphs.

The development of the DECIDE tool has been accompanied and supported by stakeholder workshops for identifying main management goals, testing the tool, and informing users how to interpret the recommendations. The tool will be freely accessible and all background information provided in a manual to ensure optimal transfer of scientific knowledge into practice.

Acknowledgement:

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Managing forests for the future: challenges and opportunities for private forest owners in ecosystem service provision

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The current social and environmental threats to forests management has exposed the vulnerability of Central European forests to climate change and raised urgent questions about the sustainability of current forest management practices, especially in non state forest sector especially in the non-state forest sector, which accounts for half of Slovakia's forest area. Amid growing uncertainty about how to ensure long-term forest productivity, ecosystem stability, and the delivery of social benefits, a key challenge for non-state forest owners is the limited access to information on forest ecosystem services (ES) and alternative management approaches that align with evolving public expectations and climate-related risks. In response to these challenges, a new methodology for assessing and optimizing the provision of forest ecosystem services has been developed. This approach supports multi-criteria decision-making and functionally integrated forest management by balancing ecological, economic, and social objectives. To explore its applicability in the non-state forest sector, a questionnaire survey was conducted among 65 private forest owners in the Banská Bystrica region. The survey examined owners' preferences for ecosystem services, their willingness to adapt management practices, their perception of the methodology's practical value, and their interest in developing alternative forest management plans. The results indicate that forest owners are increasingly aware of the need to respond to social and environmental pressures on forests management and recognize the potential value of new tools to support decision-making. However, the findings also underscore the need for targeted support, practical guidance, and collaborative mechanisms to facilitate the adoption of such methodologies among private forest owners. This research contributes to the broader discussion on forest policy and governance strategies that promote adaptive, informed, and socially responsible forest management in times of ecological uncertainty.

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Trajectories of sustainable use and supply of biomass in Slovakia for the period 2025–2050

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This study investigates the structure, utilization, and circulation of woody biomass in Slovakia, focusing on the period 2025–2035. It is based on detailed sectoral analysis and wood flow tracking, with special emphasis on energy applications and their sustainability. Biomass accounted for 58% of all renewable energy production in Slovakia in 2023, with significant consumption in households, industry, and the energy sector. Forest growth and harvesting dynamics were modelled using a forest biodynamic simulation model (SIBYLA) under several scenarios reflecting varying harvesting intensities, spatial limitations (e.g. protected areas), and policy trajectories aligned with the National Energy and Climate Plan (NECP) and new Renewable energy directive RED III. These scenarios assess the sustainability of biomass supply while considering forest structure, increment potential, and forest age distribution.

Approximately 59% of total wood in circulation is used for energy purposes, of which 45% originates from secondary flows in the wood-processing industry. Direct flows from forests, such as firewood, chips, and logging residues, make up roughly 32% of the energy wood supply. Most energy biomass is of lower quality (grades V and VI or below-industrial standard residues), and in many cases not officially recorded in harvesting statistics.

Households remain major consumers of biomass, predominantly firewood and pellets. However, improper storage and combustion practices are widespread: 44% of households do not dry firewood adequately, contributing to local air pollution through elevated PM_{2.5} emissions. In the industrial and energy sectors, most electricity from biomass is generated in high-efficiency combined heat and power (CHP) installations, often using by-products such as black liquor, bark, or wood chips.

Economic factors strongly influence biomass allocation. High-grade timber is prioritized for material use, while lower-grade wood is diverted to energy. In the absence of sufficient local demand and due to high transport costs, wood may be downgraded to fuel use even when higher-value applications are technically feasible.

The study concludes with recommendations to enhance biomass flow monitoring, support efficient and sustainable energy use (particularly in CHP systems), reduce inefficient residential combustion, and ensure that biomass deployment remains compatible with climate targets, air quality standards, and biodiversity protection. Modeling outcomes suggest that biomass can play a stable role in Slovakia's energy transition, but only under scenarios with balanced forest management and robust environmental safeguards.

Poster session

Outbreak dynamics and management of *Ips typographus* in Latvian spruce forests

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In recent years, Latvia has experienced the most severe outbreak of the spruce bark beetle (*Ips typographus* L.) on record, with population levels peaking in 2022. Since then, a gradual decline has been observed. In 2024, approximately 3% of mature and over-mature Norway spruce (*Picea abies* (L.) H. Karst.) stands were infested. Additionally, there is a clear trend toward earlier onset of beetle flight activity, likely influenced by changing climatic conditions. To improve early detection and monitoring of infested stands, remote sensing data are being explored. An evaluation is conducted of the reliability and practical applicability of such data for identifying affected forest areas.

Pheromone traps are widely used for bark beetle control in Latvia, though their effectiveness remains debated. The regional-scale impact of pheromone trap density on bark beetle populations was investigated. Results from a two-year monitoring period indicate a statistically significant negative correlation between trap concentration and beetle population density, suggesting pheromone traps can contribute to population management when deployed at appropriate scales.

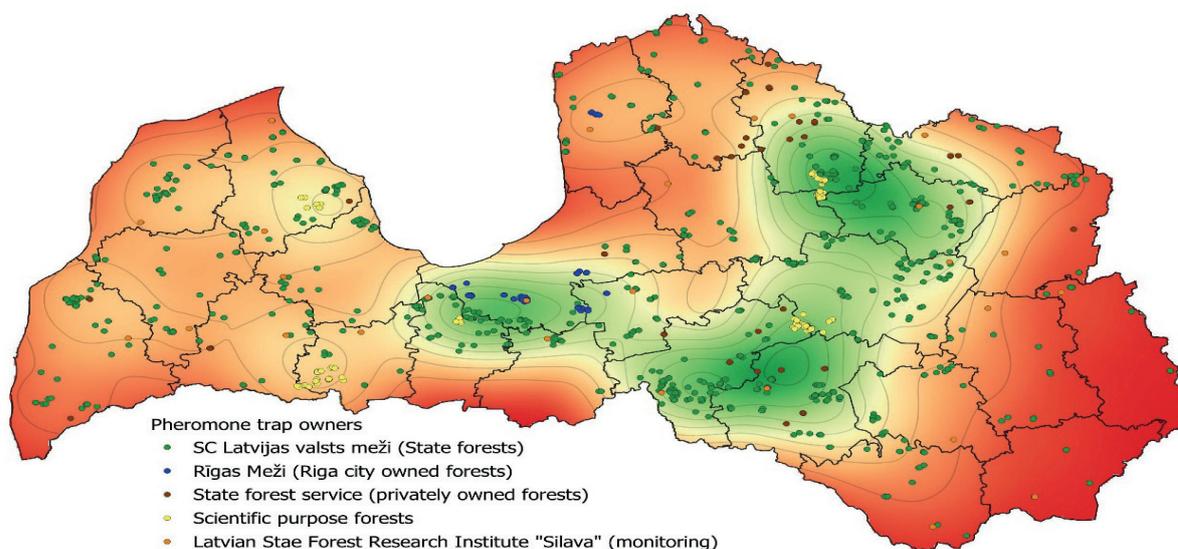


Fig.1: Concentration of clear-cuts with pheromone traps in 2024.

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Ips typographus L. in the north: from curiosity to the most threatening insect pest of boreal coniferous forests of NW Europe

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Before 2010, pine sawflies (Diprionidae) caused more damage in Finnish forests and posed greater challenges to forest managers than bark beetles. At that time, the risk of *Ips typographus* (L.) damaging living Norway spruce (*Picea abies* Karst) trees was low. However, the situation began to change when *I. typographus* attacks killed standing trees surrounding gaps created by major winter storms in 2003–2005 in southern Finland. This was followed by a brief latent period. In 2013, there was a sudden increase in reported salvage logging due to *I. typographus* attacks. This surge was further driven by devastating storms and unusually hot summers – a new phenomenon in Finland. After the 2013 peak, the annual frequency of salvage logging due to *I. typographus* outbreaks (counted from June 1 to May 31 of the following year) declined from 1,800 to 100–200 cases. However, in the early 2020s, the number of salvage logging reports began to rise again. By 2022–2023, there were approximately 1,700 reports annually (Fig. 1).

The main driver of this resurgence in *Ips typographus* damage is the increasing cumulative thermal sum during the growing season, which enhances beetle reproduction and increases drought stress in spruce. Although the frequency of *I. typographus* damage has risen significantly in southern Finland since 2010, the overall risk remains relatively low. Even in the peak year of 2022, the probability of damage in a susceptible Norway spruce stand was low (ranged from 0 to 0.125). However, detailed nationwide statistics on the timing, extent, and wood volume of bark beetle damage in Finland, are still lacking.

Under the moderate climate change projection (RCP4.5 scenario), conditions for *I. typographus* outbreaks are expected to become more favorable. Recently, high temperature sums and summer droughts have been more frequent in southern Sweden – where severe *I. typographus* outbreaks have occurred – than in Finland. However, warm and dry summers, similar to those experienced in the Swedish outbreak epicenter, are already common in the Baltic countries. With a warming climate, southern Finland is expected to experience temperatures comparable to southern Sweden within the next 20 years. Furthermore, over the next 40 years, hydrothermal conditions in the Baltics and southern Finland are projected to resemble those during the recent Swedish epidemic, increasing the risk of outbreaks in these regions.

FORESTS' FUTURE 2025

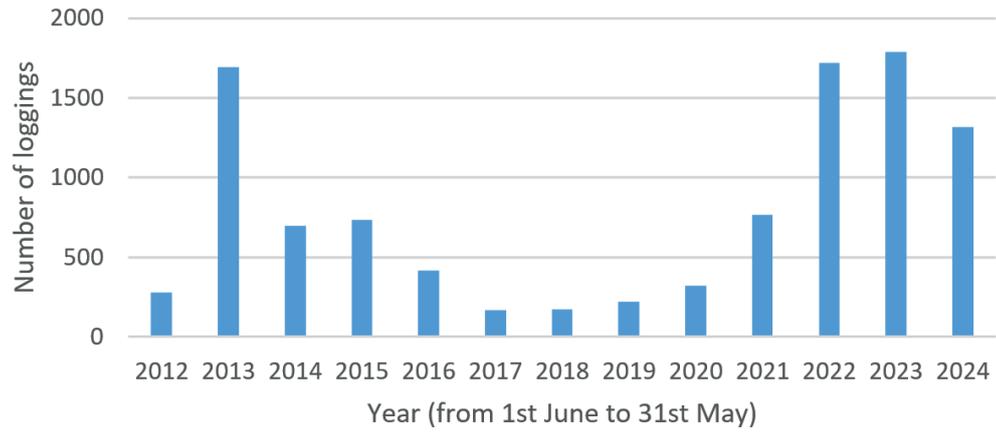


Fig.1: Annual number of salvage logging reports due to *Ips typographus* damage in Finland (Metsäkeskus, Open Data).

Drivers of European spruce bark beetle (*Ips typographus*) damage risk in Finnish forests and insights for its management

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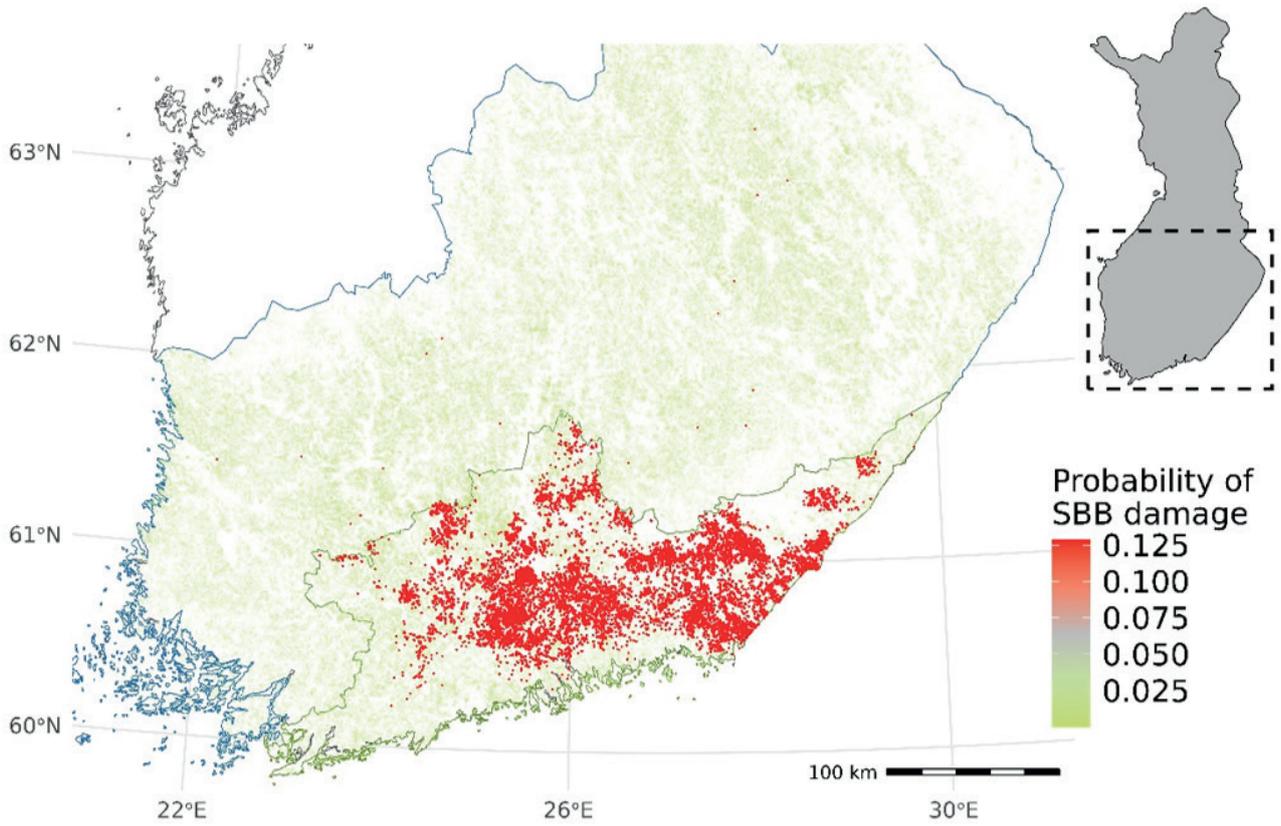
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While *Ips typographus* L. (SBB) has damaged Norway spruce (*Picea abies*) forests mainly in Central and Eastern Europe, conditions favouring the development of damage are spreading northward, including in Finland where Norway spruce is widely grown. Previous research reports that SBB risk stems from climate, forest stand properties, and landscape structure. Understanding the effects of these factors could support evidence-based forest management and policy. We studied the risk of salvage loggings due to SBB damage (as proxy for SBB damage) during 2020–2022, using logistic regression and information from Finnish forest and from the southern half of Finland. The study area, comprising 11.4 M ha of forestry land, with 1.919.485 Norway spruce stands, was dissected into north and south, where we developed two separated generalized linear mixed effect models using forest stand, landscape and climate variables. In general, the risk of SBB damage was low (whole area mean = 0.00034; southern area mean = 0.00058; northern area mean = 0.00012), though notable variability remains to be explained — particularly in the north. Our models show how forest stand, landscape, and climate attributes influence SBB damage risk, with each factor contributing differently by modelled area. Landscape variables had the strongest effect, followed by stand and climate variables. The top predictors were proximity to clear-cuts, D_{mean} , and number of hot days — highlighting the role of local conditions to increase the risk. Increasing the distance to clear-cuts sharply decreases the probability of SBB damage, with higher risk at very short distances (<0.5 km). Given that proximity to clear-cuts was the strongest risk factor, salvage operations must be reconsidered.

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FORESTS' FUTURE 2025



Estimated probability of salvage loggings due to SBB damage, based on 2022 data. The top 1% of stands with higher probabilities are highlighted in red.

A short review on the species and damage of bark and ambrosia beetles (Coleoptera: Scolytinae) distributed in Korea

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Since the first record of 51 species in 1929, approximately 169 species of Scolytine beetles, belonging to the bark and ambrosia beetles (Coleoptera: Scolytinae), have been documented in Korea. In the past, these beetles were primarily recognized as pests of stone fruit trees and received relatively little attention in forests compared to other major insect pests like lepidopteran insects. In Korean forest pest studies, Scolytine beetles were occasionally mentioned as pests of both coniferous and broadleaf trees, but in-depth studies have been limited. A review of published research (1980-2024) reveals that out of the 169 species historically recorded in Korea, 49 species have been consistently observed in the field, indicating their continuous presence. Species found frequently include *Hylastes plumbeus*, *Hypothenemus eruditus*, *Ambrosiodmus rubricollis*, *Ambrosiophilus atratus*, *Xyleborinus saxeseni*, and *Xylosandrus germanus*. On the other hand, species with high field abundance (i.e., trap catches) include *X. saxeseni*, *Cnestus mutilatus*, *X. germanus*, *X. crassiusculus*, *Cyclorhipidion bodoanum*, and *Euwallacea validus*. Recently, concerns have grown over the potential for sudden outbreaks of Scolytine beetles due to climate change. For example, in 2024, a severe outbreak occurred in the protected natural forest of Mt. Sanbongsan on Jeju Island, where approximately 380 *Castanopsis sieboldii* trees were killed. This incident has highlighted the need for proactive monitoring, outbreak prediction, and integrated pest management strategies to prevent large-scale forest damage in the future.

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Taphrorychus bicolor in Slovakia: a new challenge for beech forest

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European beech (*Fagus sylvatica*), a keystone tree species in Central European forests, faces increasing pressure due to climate change, particularly recurrent droughts. Weakened trees become more susceptible to biotic threats. This poster presents the results of an assessment of the bark beetle *Taphrorychus bicolor*, previously considered a secondary pest, which currently exhibits changed (or overlooked) behaviour in Slovakia by attacking living beech trees. We analyse the infestation mechanisms, the role of environmental stressors, and the potential for secondary infections that exacerbate tree decline. Drawing on field data and extensive research experience in Central Europe, we outline practical monitoring strategies and propose essential forest management measures to mitigate the impact of this possible emerging pest.



Fig.1: Infestation mechanism of living beech trees by *Taphrorychus bicolor* in Slovakia

Acknowledgement:

The work was supported by the Slovak Research and Development Agency (APVV-22-0545).

Diversity of target and non-target beetles and associated nematodes in monitoring of the pine sawyer beetle *Monochamus galloprovincialis* (Coleoptera, Cerambycidae) in Scots pine and Maritime pine stands - a case study from Poland and Portugal

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Biotechnical methods that use chemical lures to attract harmful forest insects are an important component of prevention and management efforts of integrated forest protection (Sukovata and Skrzecz, 2022). Moreover, due to the ongoing climate change, globalization of trade of wood and wood commodities, the pressure from native and non-native pests is increasing on forests (Schafstall et al., 2024). In Europe, one of the challenges of today's strategy is to protect pine stands against the quarantine pinewood nematode *Bursaphelenchus xylophilus* (Steiner et Bühner, 1934) Nickle, by monitoring its vector, the pine sawyer beetle *Monochamus galloprovincialis* (Oliv.) (Coleoptera, Cerambycidae), using different pheromone traps (Álvarez et al., 2015; Sousa et al., 2015; Jactel et al., 2019; Sukovata et al., 2022), baited with Galloprotect-2D lure (SEDQ, Spain). The lure includes the specific pheromone for *M. galloprovincialis* but also pine volatiles and bark beetles' pheromones (Pajares et al., 2010). As a result, many other bark- and wood boring beetles (Coleoptera, Curculionidae, Scolytinae) and longhorn beetles (Coleoptera, Cerambycidae) are also caught in traps (Rodrigues et al., 2015; Sousa et al., 2015; Allison et al, 2024).

In the spring and summer of 2024 the occurrence of *M. galloprovincialis*, bark- and wood boring beetles in Scots pine (Poland: Włoszczowa, Knyszyn) and Maritime pine (Portugal: Samora Correia; Tróia) stands were

studied, using various pheromone traps: white panel with 50 cm length, white panel with 100 cm length, black twelve-elements multifunnel, black six-elements multifunnel, and white six-elements multifunnel, all baited with Galloprotect 2D-Plus lure. Furthermore, insects caught in traps were surveyed for the presence of nematodes. The ecological role of nematodes in forest ecosystems was also discussed. The insects were identified through a morphological characters, whereas for nematodes identification used a combination of morphological characteristics and molecular analysis.

In Portugal, 6290 coleoptera insect species were captured in total, represented by eight families, Alleculidae-one species, Buprestidae-four species, Cerambycidae-five species, Cleridae-one species, Colidiidae-two species, Curculionidae-eight species, Histeridae-one species, Trogositidae-one species). The most abundant species were *Hylurgus ligniperda* (F.), *Orthotomicus erosus* (Wollaston), *Spondylis buprestoides* (L.) and *M. galloprovincialis*. Relevant number of bark beetles' predators (468 specimens) was also captured, belonging to Trogositidae (*Temnoscheila caerulea* (Olivier)), Coliididae (*Aulonium ruficorne* (Olivier)), Cleridae (*Thanasimus formicarius* (Zett.) and Histeridae families.

In Poland, 4742 specimens of beetles were caught, from 12 families (Buprestoidae-three species, Carabidae-three species, Cerambycidae-seven species, Chrysomelidae-two species, Cleridae-one species, Curculionidae-nine species, Elateridae-nine species, Geotrupidae-one species, Hydrophilidae-one species, Scarabaeidae-one species, Silphidae-two species, Tenebrionidae-three species). The species of highest frequency were *S. buprestoides* and *Hylaster ater* Erich. *Monochamus galloprovincialis* occurred sporadically. It was found that the type of pheromone trap had no significant effect on the number of insects species and specimens captured in Scots pine stands. In opposite, in Maritime pine stands insects composition and numbers varied significantly between types of pheromone traps, revealing the black 6 funnel trap as the most effective to capture *M. galloprovincialis*. At the same time, the highest diversity of insects was found on black 12-element multifunnel trap.

Nematodes survey of insects (302 samples): *Acanthocinus griseus* (Fabr.), *Arhopalus fesus* (Mulsant), *A. syriacus* (Reitter), *H. ligniperda*, *Ips sexdentatus* (Börner), *M. galloprovincialis*, *O. erosus*, and *S. buprestoides*, caught in Portugal, revealed 36,4% of analysed samples to carry nematodes, while in case of Polish beetles (75 samples): *Arhopalus rustricus* (L.) *I. sexdentatus*, *M. galloprovincialis*, *Rhagium inquisitor* (L.), and *S. buprestoides*, 89% of them carried nematodes. Considering all locations in both countries, 28 different nematode taxa were confirmed, with the prevalence of free-living bacterivores (12 species) and mycophagous (9 species), followed by facultative entomopathogenic (5 species), and two parasitic plant nematodes: *Neotylenchus* sp. and *B. xylophilus*, detected only in *M. galloprovincialis* specimens from Portugal.

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Acknowledgement:

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Bark beetle outbreak in Koli National Park, eastern Finland, and environmental factors affecting it

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Koli National Park (NP) has experienced substantial spruce mortality caused by the European spruce bark beetle (SBB) (*Ips typographus*) since 2018. The outbreak was triggered by snow damage, followed by a hot and dry summer. SBB, but also the spruce wood engraver (*Pityogenes chalcographus*) and the Polygraphus spp. bark beetles bred in the snow-damaged and drought-stressed spruces, and eventually in the healthy spruces. Snow damage occurred again a few years later, sustaining the outbreak. Koli NP belongs to the hill zone of eastern Finland, where forested, gentle-sloped hills are common, distinguishing it from the rest of the Finnish SBB distribution range that is mostly lowland. Due to its unique topography, Koli NP is the southernmost site in Finland, where heavy crown snow-load appears. Koli NP is a non-intervention zone. These factors make Koli hills unique and topical research site. This study aims to identify environmental factors affecting the SBB outbreak in Koli NP.

Using field data (Fig. 1a) and open data, it will be observed how the SBB infestation rate is affected by environmental factors (temperature, soil moisture, soil characteristics, nutrient availability and elevation) and how it varies in diverse and steep topography. Based on the first field observations, SBB attack symptoms increase with elevation and on the eastern slopes, warm temperature and low water availability. Resin flow seems to be decreased with low water availability as water deficiency disrupts resin production, compromising spruce defence. Melting snow seems to play an important role in water availability and can compensate for low precipitation during early summer. Understanding the factors that predispose forests to SBB outbreaks makes early intervention easier and benefits forest management practitioners.

Acknowledgement:

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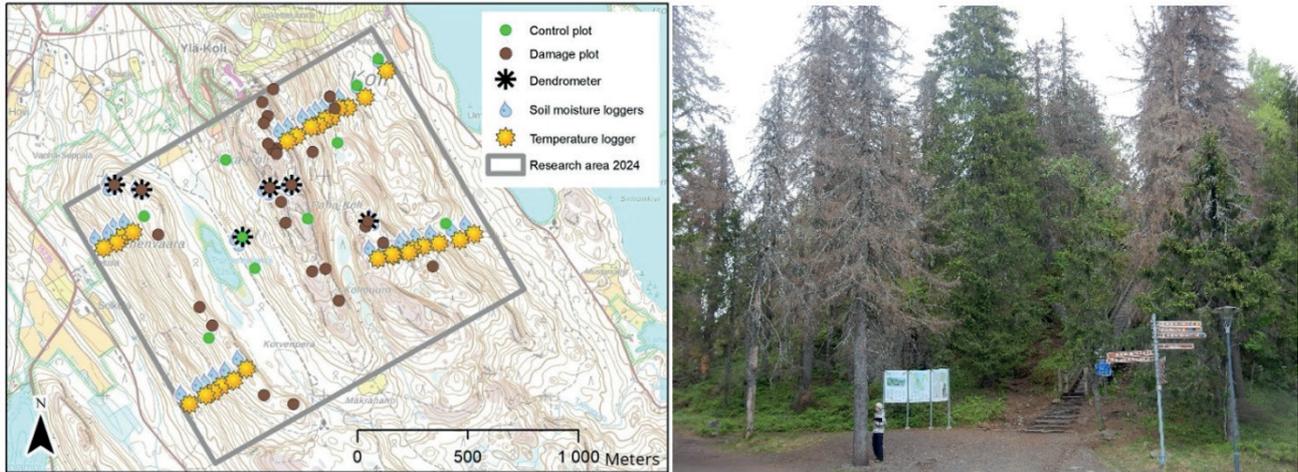


Fig. 1: a. Field measurement setup in Koli NP for monitoring the SBB outbreak development and environmental factors predisposing spruces to SBB. b. Spruce mortality in Koli NP. Photo: Päivi Lyytikäinen-Saarenmaa.

Spruce bark beetles and forest conservation in Sweden

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The drought of 2018 triggered the largest and most destructive spruce bark beetle (*Ips typographus*) outbreaks ever recorded in Europe. During this and previous outbreaks, intensive debates have arisen concerning forest management in conservation areas. Among foresters, there is a strong concern that conservation areas may act as sources of bark beetles and increase infestations in the surrounding managed forests.

In this presentation, I will synthesize the findings of my research in Sweden, spanning from detailed tree-level data to stand- and landscape-scale effects. At the tree level, we found no differences in attack densities or reproductive success when comparing bark samples from conservation areas with those from managed forests (Kärvemo et al. 2025). Instead, variations in forest conditions and the abundance of natural enemies played more important roles.

At stand and landscape scales, conservation areas were associated with the occurrence and size of infestations, but only under specific conditions. Other factors – such as soil moisture, the presence of clear-cuts, outbreak trigger, and spatial scale – proved to be equally or even more important (Kärvemo et al. 2023; Baker 2025). However, the lack of pest management in conservation areas may in some specific cases increase infestation risks (Fig 1).

These findings highlight the complexity of bark beetle dynamics in and nearby conservation areas and emphasize the need for context-specific strategies when managing forests under both production and conservation goals.

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FORESTS' FUTURE 2025

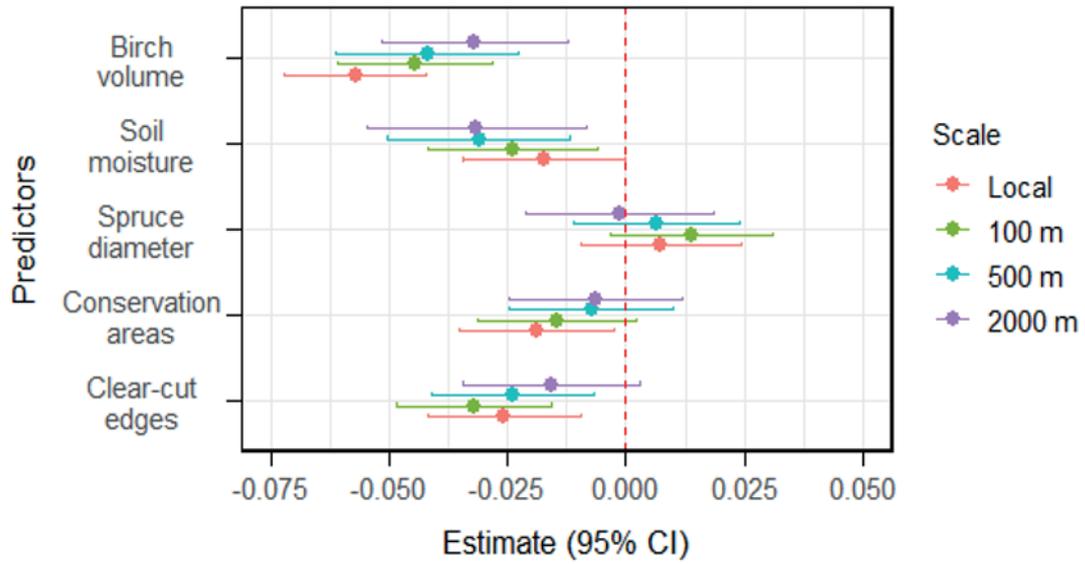


Fig.1: Occurrence of large infestation patches and influence of different forest structures and at different spatial scale.

Selection of ester-forming and -hydrolysing enzymes putatively involved in pheromone production in *Ips typographus* (Linnaeus, 1758)

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The aggregation pheromone of the European spruce bark beetle *Ips typographus* (Linnaeus, 1758), a critical factor in the coordination of the beetle's mass attacks, comprises key components including 2-methyl-3-buten-2-ol, ipsdienol, and *cis*-verbenol. The latter is notably synthesized from the tree host precursor α -pinene via a hydroxylation as part of the detoxification process. Recent advancements, such as high-quality transcriptomic analysis of *Ips typographus*, have led to the proposition of a second, alternative *cis*-verbenol biosynthetic pathway. This pathway involves a novel mechanism for the storage and release of *cis*-verbenol from fatty acid ester conjugates, potentially mediated by as-yet-unidentified ester-forming and -hydrolysing enzymes. This discovery could help elucidate how pioneer beetles can emit *cis*-verbenol independently of the host-derived α -pinene. Despite these advances, the specific genes responsible for coding these enzymes remain unknown.

To address this knowledge gap, we have sequenced larval, pupal and adult stages of *I. typographus*. In the obtained transcriptome, through local alignment and phylogenetic analysis, all homologous sequences to previously characterized enzymes of similar function have been selected. Next, differential gene expression analyses were conducted. This approach allowed us to select seven carboxylesterases and one lipase. Finally, we confirmed stage- and sex-specific expression patterns of these genes by quantitative RT-PCR. This work yields a shortlist of candidate enzymes and establishes a solid foundation for their future functional characterization. Correct identification of genes involved in pheromone biosynthesis opens the door to use of novel molecular methods for pest management such as RNAi-mediated silencing to disrupt bark beetle aggregational abilities.

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Occurrence and overwintering of *Ips typographus*, associated species and natural enemies in southeastern Finland – implications for forestry

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Natural enemies of *Ips typographus* (L.) may provide regulative service in the control of outbreaks. This would require more knowledge about the impacts that current forest management practices have on these species. Most of the sanitary logging operations are performed before the winter, jeopardizing species that prefer to overwinter in the trees. Species composition and overwintering were studied using trapping logs and emergence traps in southeastern Finland. Spruce bark beetle individuals were released into Norway spruce logs, which were then transported to forest and exposed to local predators at the end of May. Logs were re-caged in August, and all the emerging insects were collected from August over the winter to the following June. Only 21.2% of *I. typographus* individuals but 98.5% of the *P. chalcographus* remained in the trapping logs over the winter. Several enemies and associated species (e.g. *Thanasimus formicarius*, *Quedius plagiatus*) abandoned logs before winter. Small staphylinid beetles with unclear feeding habits (*Placusa*, *Leptusa*, *Phloeonomus* spp.) overwintered in large numbers in the logs. Predatory histrid beetle *Plegaderus vulneratus* overwintered exclusively as a larva in the logs. Results suggest that salvage loggings and sanitation cuttings, if performed too late after the swarming of *I. typographus*, have only limited impact on the overwintering population of the beetle. In contrast, impact on enemies overwintering in the infested trees may be more drastic. This study also highlights that species previously considered as significant enemies of *I. typographus* (e.g. *Thanasimus* ant beetles) are significant not only because their effectiveness as a predator, but also due to overwintering outside the trees being beneficial for the current forestry.

Acknowledgement:

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FORESTS' FUTURE 2025

Table 1: Insects emerging from the logs. Timesets are Early Autumn (23.8.-17.9.) Late Autumn (17.9.-27.10.) and Spring (27.10.-6.6.). Results of Dunn's test ($p < 0.05$) are marked in superfix.

Species/Genus	Emerged individuals			Overwinter
	Late summer	Autumn	Spring	%
Bark beetles				
<i>Ips typographus</i>	2003 ^a	2872 ^b	1309 ^a	21.2
<i>Pityogenes chalcographus</i>	10 ^a	3 ^a	912 ^b	98.5
Natural enemies				
<i>Plegaderus vulneratus</i>	149 ^a	122 ^a	36 ^b	11,7
<i>Thanasimus formicarius</i>	15 ^a	2 ^b	1 ^b	5.6
<i>Quedius plagiatus</i>	23 ^a	5 ^b	0 ^c	0
<i>Phloeonomus spp.</i>	330 ^a	494 ^a	597 ^a	42.0
<i>Placusa</i>	12 ^a	1 ^b	78 ^c	85.7
<i>Leptusa</i>	25 ^{ab}	21 ^a	67 ^b	59.2

Spruce bark beetle activity in sub-optimal habitat

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Spruce bark beetle (*Ips typographus*) has a strong preference for Norway spruce (*Picea abies*). Population densities and damage levels are strongly determined by the volume of spruce in the landscape. Mixing their host trees with non-host trees at the stand level and increasing variation at the landscape level is therefore a good approach to working towards lower population levels at landscape levels, potentially keeping the population under outbreak threshold. Activity of spruce bark beetle was measured in two different forest habitats using baited funnel-traps and un-baited window traps. In addition, in order to understand better the aggregation behaviour of spruce bark beetle in sub-optimal habitat an experiment was used to assess the relationship with male colonisation density, using inoculated bolts, and attraction of conspecifics in different habitats. The results indicate that the spruce bark beetles have higher flight activity in monoculture spruce stands based on both baited and un-baited traps. Pure spruce habitat is most attractive to searching beetles as the results show higher additional attacks in bolts inoculated with males, and there is no difference between bolts with different inoculation densities. We conclude that both activity and colonisation rates are highest in pure spruce stands but not completely absent in other habitats.

Acknowledgements:

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Forest edge formation alters microclimate and volatile cues but does not immediately increase susceptibility to European spruce bark beetle

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Natural disturbances driven by climate change, along with logging activities, are accelerating forest fragmentation and increasing stand vulnerability. The formation of forest edges rapidly alters local microclimates, notably by exposing previously shaded trees to direct sunlight. It is widely hypothesized that such edge trees may act as focal points for European spruce bark beetle (*Ips typographus*) infestation, particularly during outbreak conditions.

This study investigated how newly established forest edges created at the beginning of the growing season affect microclimate (air and bark temperatures, soil moisture), tree physiology (sap and resin flow, bark chemical defences), and beetle attraction through volatile organic compounds (VOCs). Beetle host acceptance was tested using both limited-choice and non-choice field bioassays.

Edge trees exhibited significantly higher bark surface temperatures and increased resin and sap flow compared to interior trees. Soil moisture remained high throughout the season, declining only in August. While phloem monoterpene concentrations were similar across edge and interior trees, VOC emissions were elevated at the forest edge during May and June, likely influenced by fresh logging debris. These changes coincided with heightened beetle activity in bioassays shortly after edge formation. However, the defensive effect of increased resin flow could not be conclusively assessed, as bark boring occurred in both edge and interior trees, predominantly later in the season.

In conclusion, freshly created forest edges do not appear to be more immediately susceptible to beetle attack, but their altered microclimate and enhanced olfactory cues may promote beetle swarming. Infestation risk is likely modulated by beetle population density and the timing of disturbance and harvesting events.

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Biological control strategies for bark beetle population management

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There is a growing trend toward reducing pesticide use and replacing them with environmentally friendly alternatives, such as entomopathogenic fungi. This poster presents a biological control strategy developed by the Forest Protection Service, Slovakia, designed to suppress bark beetle outbreaks. The system features a patent-pending spherical fungal carrier (patent no. 20764176.2) and a pheromone-based applicator (Community design no. 015023460-0001), which together attract and infect beetles with the entomopathogenic fungus *Beauveria bassiana*. We evaluated the virulence of commercial and indigenous strains of *B. bassiana* against several beetle species, including *Ips typographus*, *I. duplicatus*, and *Hylobius abietis*. Our results indicate that infection success varies depending on the fungal strain and the duration the carriers are exposed to environmental factors, with efficacy decreasing over time. Integrating *B. bassiana*-infected carriers into pheromone traps shows strong potential as an eco-friendly method for bark beetle management, although ongoing refinement of the system is still necessary.



Fig.1: Entomopathogenic fungi carrier, methods of its installation for different pests, and pests infested by fungus.

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Colonization of non-native lodgepole pine by *Ips typographus* in Sweden: A rare but noteworthy event

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This study documents the first known natural attack and successful colonization of non-native lodgepole pine (*Pinus contorta*, Douglas) by the Eurasian spruce bark beetle *Ips typographus* (L.) in Sweden. Although *P. contorta* is widely planted across approximately 6,000 km² in Sweden, it has not previously been reported as a viable host for *I. typographus*. In this case, the attack occurred in the absence of nearby infested Norway spruce (*Picea abies*, L. Karst), suggesting that lodgepole pine can act as a direct target under certain stress conditions. The killed trees exhibited high beetle colonization densities (mean 329 maternal galleries/m²) and extensive blue-stain fungal infection, but extremely low reproductive success (0.01 daughters per mother), indicating that the lodgepole pines may act as a demographic sink for the beetle. Tree stress, likely due to poor site conditions and severe droughts in 2018 and 2023, appeared to have reduced resin-based defences. Despite lodgepole pine's chemical and anatomical differences from the traditional spruce host, *I. typographus* produced aggregation pheromones and was able to complete development in a subset of trees. The bark beetle's natural enemy community, including generalist predators and parasitoids, was similar to that found in the spruce. These findings highlight the potential for *I. typographus* to expand its host range under climatic stress and emphasize the need for monitoring non-native conifers in European forestry systems.

Keywords:

bark beetle, blue-stain fungi, drought stress, *Pinus contorta*, reproductive success, spruce bark beetle

Synthetic approach to the aggregation pheromone of *Ips duplicatus* (Sahlberg) (Coleoptera: Curculionidae, Scolytinae)

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This study describes the synthesis of E-myrcenol, a key component of the aggregation pheromone of *Ips duplicatus*. An efficient and reproducible method was developed, based on controlled oxidation of beta-myrcen followed by a reduction reaction of E-myrcenal. The process was optimized to achieve high yield, meeting the standards required for pheromone trap applications. As a result of this optimization, the technology was successfully scaled up to the micropilot level, confirming its feasibility for semi-industrial production. This step represents significant progress toward the sustainable and cost-effective production of E-myrcenol for use in ecological monitoring and control programs targeting *Ips duplicatus*.

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Fig.1: The completed maternal and larval galleries of a heavy infestation. Foto M-L Duduman

Preliminary field evaluation of pheromone lures for the monitoring of *lymantria dispar* (L.) (Lepidoptera: Erebidae)

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Lymantria dispar, also known as the gypsy moth, is a major defoliating pest affecting a wide range of deciduous and fruit trees. Pheromone-based monitoring and control methods have become increasingly important in integrated pest management (IPM) strategies due to their selectivity and environmental safety. This study focuses on testing synthetic sex pheromones to evaluate their effectiveness in attracting *Lymantria dispar* males. Various pheromone mixtures were evaluated under field conditions to determine their attractiveness. The results contribute to the optimization of pheromone-based tools for early detection and sustainable control of *Lymantria dispar* populations.

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Acknowledgement:

This work was supported by "Babes-Bolyai" University, "Raluca Ripan" Institute for Research in Chemistry, Pheromone Production Center. This research received no external funding.



Fig.1: Pheromone traps used in this experiment. Foto: Cosmin Paraschivoiu

Morphology of prothoracic depressions and associated microbial symbionts in the oak ambrosia beetle, *Platypus koryoensis*

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Platypus koryoensis, the oak ambrosia beetle, has been identified as the primary vector of oak wilt disease in South Korea. The disease has spread nationwide since its first outbreak in 2004. Infected trees exhibit numerous entry holes and harbor the ambrosia fungus *Raffaelea quercus-mongolicae*, the primary causal agent. The beetle possesses prothoracic depressions that function as mycangia (Fig. 1a, b). The sexual dimorphism of the prothoracic depressions in *P. koryoensis* was examined using field-emission scanning electron microscopy (FE-SEM) and energy-dispersive X-ray spectroscopy. Female adults had (i) small cavities, (ii) large cavities, and (iii) mycangia, whereas male adults had only (i) small cavities and (ii) large cavities (Fig. 1c, d). These depressions frequently contained cavity-filling fungal masses (Fig. 1e). In male cavities, crystalline structures composed of calcium, silicon, and potassium were observed (Fig. 1f). Serial block-face scanning electron microscopy (SBF-SEM) analysis revealed that small cavities typically contained a single fungal cell, whereas large cavities and mycangia contained diverse microbial cells, including both fungi and bacteria (Fig. 1g). These findings provide a morphological basis for a deeper understanding of the symbiotic associations between *P. koryoensis* and its microbial symbionts.

Acknowledgement:

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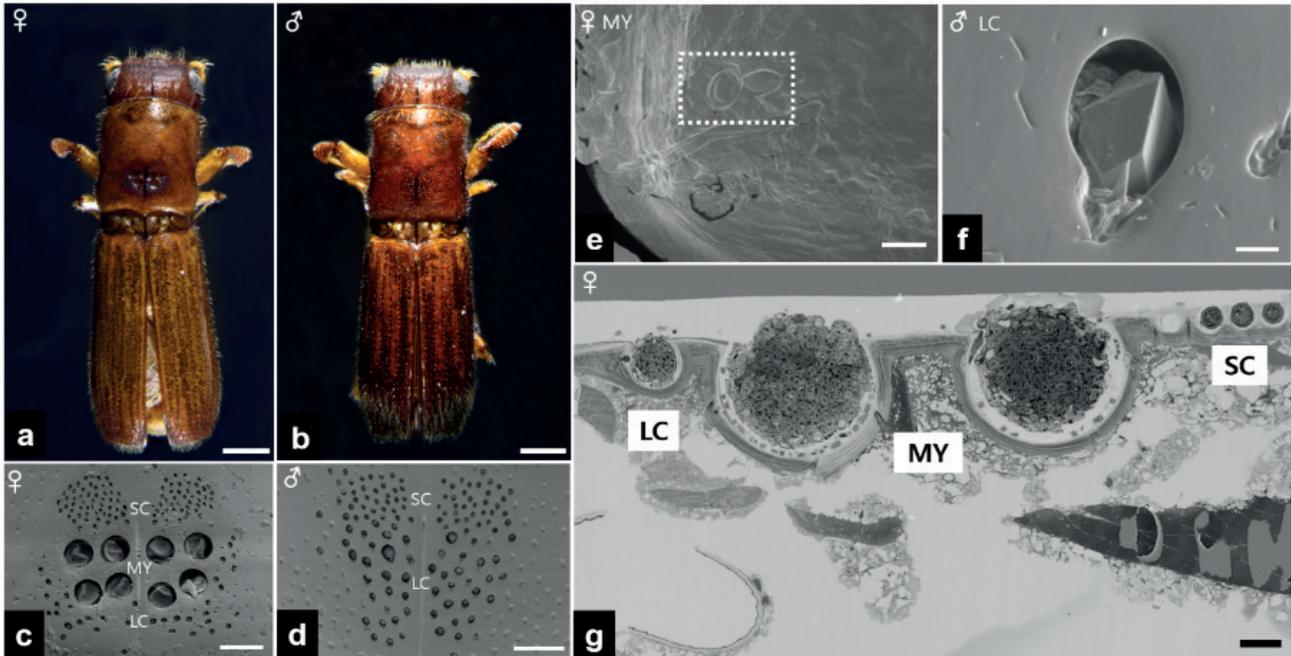


Fig. 1: Morphological and microbial features of prothoracic depressions in *P. koryoensis*. (a) Female adult. (b) Male adult. Scale bars = 500 μm. (c) FESEM image of prothoracic depressions in a female adult. (d) FESEM image of prothoracic depressions in a male adult. Scale bars = 100 μm. (e) FESEM image of a mycangium in a female adult showing fungal spores. (f) FESEM image of prothoracic depressions with crystalline structures in a male adult. Scale bars = 5 μm. (g) SBF-SEM image of prothoracic depressions in a female adult. LC, large cavities; MY, mycangia; SC, small cavities.

Development of an optimal method for detection and monitoring of *Lamprodila festiva*, an invasive pest of ornamental Cupressaceae species

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In the last years *Lamprodila festiva* (Linnaeus, 1767), naturally common in Mediterranean countries, reached Central and Eastern Europe, causing considerable damage to ornamental Cupressaceae species in many urban and nurseries. Its presence in Romania was reported for the first time in 1950s-1960s in Mehedinți County and the first report of the insect in urban areas occurred in 2014 in two nurseries near Bucharest (Nitzu et al. 2016). The literature data have shown that Buprestidae species are attracted to specific visual and olfactory cues and the combination of the visual and olfactory attractants can increase captures of Buprestidae species (Domingue et al. 2011).

In order to develop an optimal method for detection and monitoring of *Lamprodila festiva*, yellow and green colors were used for the visual stimuli. For the olfactory cues, chemical compounds were selected based on Bozsik et al. (2022), who analyzed *Lamprodila festiva* antennae responses to various host volatiles emitted by *Thuja occidentalis*. The colored sticky panels measured 210 x 297 mm and were coated with adhesive on both sides. The sachet lures were loaded with 1,2 ml of a mixture of (-)-β-pinene, (-)-α-pinene, (-)-limonene, (+)-limonene, terpinen-4-ol, and (-)-fenchone in proportion of 2:1:1:1:1:2. The average release rate was 52 mg/day for 21 days and was determined by measuring weight loss at room temperature (22 °C). The four variants used were grouped in pairs per replicate: yellow unbaited with green unbaited and yellow baited with green baited. A total number of 1325 adults of *Lamprodila festiva* were captured on the sticky panels and the most active flight period of the insect was observed between May 31 and July 3. The green unbaited traps were found to be the most effective in detecting *Lamprodila festiva* adults. The study also revealed that males prefer the green color traps and the female the yellow traps. The addition of host volatile attractants did not increased the capture levels, the baited traps recording fewer captures.

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New approaches towards digital bark beetle monitoring

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For about three decades, the Forest Research Institute Baden-Württemberg (FVA) in Freiburg has operated a bark beetle monitoring program utilizing conventional pheromone traps, checked weekly to inform forest owners about the current situation. The resulting extensive dataset has provided valuable insights into beetle phenology and swarming patterns, offering a rough estimate of infestation risk. However, conventional monitoring has several limitations, including significant operational costs, and reduced spatial and temporal resolution as well as timeliness of the data.

To address these challenges and enhance bark beetle management, we have developed and implemented an automatic pheromone trap within our monitoring network. This system continuously records and transmits high-resolution data on swarming intensity of *Ips typographus*, *Pityogenes chalcographus*, and *Pityokteines curvidens* associated with relevant climatic parameters. The resulting data of the recent three years have further

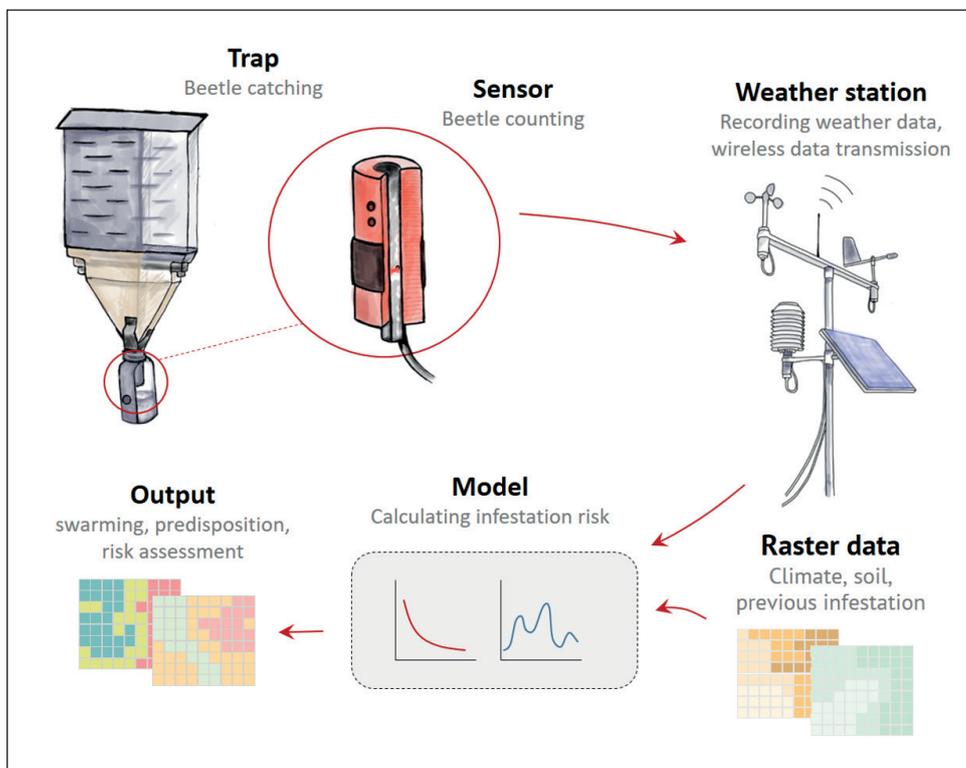


Fig.1: Workflow of the implemented digital risk management tool

enabled the calibration of swarming models using temperature, global radiation, day of year, and pheromone release as predictors, which facilitates area-wide predictions based on climate raster data.

While these models cannot quantify absolute trap catches without further site-specific data, they provide robust predictions for the relative intensity at the stand level. The integration of such models into digital risk assessment tools that include additional predisposing factors (e.g. stand composition, drought, previous infestation) marks a significant step towards the digitalization of pest monitoring, to ultimately accelerate management reactions.

We want to discuss our progress in monitoring to showcase a possible transition to a modern risk assessment of pest insects, as this technology will complement or even supersede conventional monitoring approaches. The method comes with multiple advantages like saving operational costs for monitoring and offering practitioners timely and reliable risk assessment for their specific forest stands.

Merging Copernicus Data into national forestry products

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In recent years, Austria's forests have been subject to several large-scale disturbances induced by both biotic and abiotic drivers. Since climate change increases temperatures, period of droughts and extreme weather events in Central Europe, the pressure on forests is likely to remain high in the coming years. To quantify the damage caused by biotic and abiotic disturbances a monitoring system needs to be developed. Tackling three facets of damaged forests, the FASE team aims to develop such a system based on satellite-based remote sensing methods. The first aspect is using a machine learning approach to distinguish regular harvests, including final cutting, thinning and building forest roads, from other anomalies, such as salvage logging after storms and bark beetle infestations. The model is trained on expert labelled sites of forest cover anomalies with additional input layers on the topography. The second topic of the project is quantifying the volume stock change after such a disturbance. For this, a Random Forest was trained on based on Sentinel-2 bands and the Digital Surface Model (DSM).

While storms and bark beetle outbreaks represent a sharp decrease in forest vigour, also gradual declines can occur due to fungal infections and other slow progressing diseases. Therefore, FASE is developing an algorithm to observe these declines in tree vigour, specifically focusing on *Diplodia* dieback on black pines (*Pinus nigra*). For this, the already existing BFW anomaly detection model was refined to detect gradual anomalies in forest cover.

The preliminary results demonstrate that the general distinction between single drivers of anomalies in forest cover can be done reliably (Balanced Overall Accuracy: 0.8). However, in practice, mixed patterns such as pest outbreaks after a storm are common. For these mixed patterns the accuracy declines but remains useful (F1 Score: 0.64). The performance of the Random Forest model for quantifying stock changes in forests predominantly based on two dimensional parameters is not satisfactory which is also supported by current literature (¹). Detecting *Diplodia* dieback specifically is challenging as black pines often suffer from a decrease in vigour caused by several factors such as bark- and woodboring insects, *Viscum sp.*, and wounds from resin harvest. Additionally, the occurrence of vigorous deciduous trees can mask the signature of struggling black pines in remote sensing data.

This poster presentation will give an overview into these three newly developed monitoring efforts for existing and emerging threats to Austrian forests. We will give an insight to the application of these methods and future developments specifically in monitoring slow tree vigour decrease in alpine regions, and the further development in classifying forest cover anomalies including additional datasets such as wind warnings and climate parameters. Since the model for quantifying growing stock volume is based on Sentinel-2 parameters (2D) it may be available on very short time intervals, however the missing 3D information leads currently to

poor results. As suggested by Jiang et al (2023)² this can be optimised by including information from Airborne Laser scanning.

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Remote sensing based monitoring of bark-beetle outbreak - a case study from central Slovakia

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Following an intensive summer drought in 2022 (Turňa et al. 2023), a bark beetle outbreak began in commercial Norway spruce forests in central part of Slovakia (Fig. 1). In order to monitor development and to evaluate expected effects of this disturbance on forest ecosystems, remote sensing (RS) products have been utilised on an area of 21,900 ha. Using Sentinel 2 and Landsat scenes, combined with terrestrial data, we developed time series of spatial layers with affected forest stands. A normalized difference water index (NDWI, Gao 1996), combined with field observations, were the main RS-based features in the identification of bark beetle outbreak. Each layer in the time series identified newly affected forest stands. This time series (evaluated period was 2021–2025), with an employment of forestry data sources, allowed us to estimate a loss of growing stocks as well as carbon stocks in living biomass due to the selective logging. Produced outputs were successfully utilised for the preparation of the strategy of forest revitalisation in affected area.

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Fig.1: Initial phase of disturbance, which was already present in the central part of the affected region in 2022, was has been strongly accelerated by intensive drought.

SMARTbeetle: Using AI and molecular scent profiling for species-specific and eco-friendly spruce bark beetle (*Ips typographus*) control

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The SMARTbeetle project has two main objectives:

- to develop more effective and specific attractants for monitoring and control spruce bark beetle using modern biological and information technologies and to verify their effectiveness in the field
- to create a universal methodology for the development of odorous attractants effective against olfactory-oriented pests using the spruce bark beetle model

Bark beetle outbreaks represent a constant threat to spruce stands, which may further grow due to climate change. In the last few years, large-scale deforestation has occurred across much of Central Europe, which has disrupted all forest functions.

The goal of the SMARTbeetle project chooses to improve the effectiveness of lure attractants in pheromone traps. The combination of modern biological methods and artificial intelligence (AI) allows the design of an entire mixture of substances optimized for a specific species (the spruce bark beetle). This should significantly increase the efficiency of trapping while minimizing the risks of affecting non-target species. This measure will stop or slow down population growth of the bark beetle and contribute to a lower use of pesticides. In the conditions of ongoing climate change, this means more time to transform forests into a form more suited to current environmental conditions.

Another important contribution of the project will be the method of attractant development. It will be a universal and publicly available methodology that can be used for the development of other attractants – specific mixtures of substances effective on any organism that navigates by smell (incl. invasive species).

The SMARTbeetle project objectives require specific knowledge in several areas. Therefore, a seven-member consortium was formed, covering all specializations necessary to meet the project objectives. Most of the necessary methods have already been mastered by the consortium and will be adapted to bark beetles. The most promising attractants will be verified in field tests.

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A number of forest owners, managers, state administration and forestry companies have expressed interest in the project. It is therefore perceived as a promising contribution to solving the large-scale forest dieback.

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Using machine learning to improve *Ips typographus* surveillance

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Ips typographus, the eight-toothed spruce bark beetle, is a major quarantine pest of spruce trees and has been the focus of extensive eradication efforts in England since 2018 (Blake et al. 2024). Extensive monitoring efforts, including pheromone trapping, are used for the eradication of *I. typographus* from Great Britain. Surveillance can be highly expensive and time-consuming, but technological advances could reduce these costs. It is also currently difficult to collect daily or hourly data, which is needed to improve understanding of local and long-distance dispersal of the pest and to inform outbreak response (Webb et al., 2024). We developed a prototype Remote *Ips* Trap (RIT) to capture time-dependent data remotely. Alongside this, a machine learning algorithm was trained to distinguish *Ips* from other species and leaf debris. The aim is for the RIT to reduce the lag time between beetle capture and identification and be more cost-effective, as it may reduce staff costs and enable a more rapid response. While it is reducing sampling and processing efforts, further development is required for field use.

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Fig.1: Remote *Ips* trap



Fig. 2: Predictions from *Ips* model

Assessment of the efficiency of pine wilt nematode monitoring using unmanned aerial vehicles

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Pine wilt nematode (PWN) was first reported in Busan, South Korea, in 1988 and has since spread rapidly across the region. To prevent further expansion, an effective and efficient PWN monitoring approach is required. Although satellite imagery offers broad spatial coverage, its low temporal resolution may limit the timely identification of PWN outbreaks. In addition, ground-based monitoring methods, such as field surveys that rely heavily on human resources, often yield suboptimal results due to their time-consuming nature and high costs. In response to these challenges, unmanned aerial vehicles (UAVs) have emerged as a promising solution, significantly enhancing the efficiency of PWN monitoring. The UAV-based monitoring process consists of flight planning, image acquisition, orthophoto generation, and image analysis stages. This study evaluates the efficiency of UAV-based monitoring by comparing the operation of a single drone with the manpower and time required to survey a standard area of 300 ha. The results showed that, based on an 8-h workday, 0.93 special technicians, 1.27 senior technicians, and 0.75 intermediate technicians were required to complete the survey, whereas only one fixed-wing UAV was needed for the same area. Overall, the UAV-based approach was found to be approximately 10.8 times more efficient than conventional field surveys, particularly in cases where no item-selection process was conducted during the preliminary and/or advanced technician stages (at a labor cost of 0.02 person/ha). In the future, integrating artificial intelligence into UAV design and image analysis is expected to further improve the efficiency of PWN monitoring, enabling faster detection and supporting more effective decision-making.

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Table 1: Manpower requirements by task type for PWN monitoring using UAVs

Step	Description	Unit	Engineer level(person/day)		
			Expert	Senior	Intermediate
Preparation	Data collection, permits and approvals, field survey, flight planning	300 ha/session	0.13	0.26	0.26
Image acquisition	Setup, delay time, movement, image acquisition, data verification, data organization	300 ha/session	0.61	0.61	0.23
Orthophoto generation	Preparation, image production, quality evaluation	300 ha/session	0.06	0.15	0.04
Orthophoto analysis	Preparation, image analysis, thematic map creation	300 ha/session	0.13	0.25	0.22
Total			0.93	1.27	0.75

Morphological and molecular identification of *Inostemma seoulis* and *Platygaster matsutama*, parasitoid wasps of *Thecodiplosis japonensis*

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The pine needle gall midge (PNGM, *Thecodiplosis japonensis*) is regarded as a significant forest pest to pine trees in Korea. Larval feeding disrupts the development of pine needles, which gradually wilt and eventually cause the death of the host tree. Biological control strategies for PNGM include the use of parasitoid wasps, with four species identified to date: *Inostemma seoulis*, *Platygaster matsutama*, *I. hockpari*, and *I. matsutama*. These species parasitize PNGM during its larval stage. To utilize parasitoid wasps effectively, a thorough understanding of their ecology is essential. However, existing ecological studies are outdated – having been conducted over 20 years ago – and may not reflect current field conditions. Moreover, traditional morphological identification of adult wasps is challenging due to their minute size and limited interspecific variation. Despite their ecological relevance, genetic information on these parasitoids remains scarce. In addition, multiparasitism has also been reported, but is difficult to confirm at the larval stage without prolonged rearing to adulthood for identification. Therefore, in this study, we morphologically identified two dominant parasitoid species in Korea, *I. seoulis* and *P. matsutama*, and obtained their cytochrome c oxidase subunit I gene sequences. These data establish a molecular framework for species-level identification, enabling more rapid and accurate classification. Our findings lay the groundwork for future studies on the seasonal and annual population dynamics of parasitoid wasps in PNGM-infested forests.

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Ophiostomatalean fungi associated with the great spruce bark beetle (*Dendroctonus micans* Kugelann) (Coleoptera: Curculionidae, Scolytinae) in Poland and Czech Republic

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The great European spruce bark beetle, *Dendroctonus micans* (Kugelann) (Coleoptera: Curculionidae, Scolytinae) is a cambiofagous insect pest native to Europe and Asia (Lukášová and Holuša, 2011; Mayer et al., 2015), listed as a protected zone quarantine pest in Annex IIB of Council Directive 2000/29/EC for Greece, Ireland and the United Kingdom (Jeger et al., 2017). In Central Europe *D. micans* attacks apparently healthy trees, mainly at the bottom part and root neck with large root inflows of Norway spruce (*P. abies* (L.) H. Karst) and North American blue spruce (*Picea pungens* Engelm.) (Lukášová et al., 2014), although trees weakened by drought, snow, harvest operations, root pathogenic fungi infestation are also vulnerable (Vakula et al., 2016). *Dendroctonus micans* is extremely resistant to the defensive monoterpenes of conifers (Everaerts et al., 1988), therefore trees infested by the species can live for several years (Pfeffer 1955).

Dendroctonus beetles live in close symbiosis with various microbes, including ophiostomatoid fungi. The ophiostomatoid fungi are represented by economically important tree pathogens or wood-staining fungi and are one of the most common fungal groups associated with bark beetles (Kirisits 2004). Research on the association between ophiostomatoid fungi and *D. micans* in Europe is very limited, with only two reports from France (Lieutier et al., 1992) and Lithuania (Menkis et al. 2017). We have no information about fungal associates of *D. micans* in Central Europe. Therefore, the objective of this study was to elucidate the diversity of ophiostomatoid fungi associated with *D. micans* on Norway spruce in Poland and on blue spruce in Czech Republic.

The fungi were identified through a combination of morphological characteristics and molecular analyses. A total of 1444 strains of ophiostomatalean fungi were isolated from 335 beetle individuals and 225 galleries collected from infested trees in 2011 and 2022 in Poland (Radziki, Ołdrzychowice Kłodzkie) and Czech Republic (Nové Město na Moravě, Malý Háj). The multi-locus phylogenetic analyses of the six-loci, ITS, LSU, CAL, ACT, TUB2 and TEF1, revealed that 68 representative isolates belonged to seven genera: *Ceratocystiopsis* (one species), *Graphilbum* (one species), *Grosmannia* (three species), *Leptographium* (three species), *Masuyamyces* (one species), *Ophiostoma* (two species), and *Sporothrix* (four species). Phylogenetic analyses separated these isolates into 15 distinct taxa, 12 of which were previously described species and three represented novel species. One taxon, *Leptographium granulatum* has already been formally described (Crous et al., 2023).

The abundance of a particular fungal species varied between four study areas. Only *Ophiostoma piceae* was found in all locations. *Grosmannia penicillata*, *L. granulatum*, *O. piceae* and *Sprotothrix pseudoabietina* were commonly isolated species from beetles and galleries. The remaining species were rarely isolated.

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Phoretic mite communities associated with *Ips typographus* (Linnaeus, 1758) and *Ips duplicatus* (Sahlber, 1836) (Coleoptera: Scolytinae) in a Norway spruce stand

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In Romania, the spruce (*Picea abies* (L.) H. Karst) is the second most widespread tree species. The most destructive and aggressive pest of Norway spruce is the European spruce bark beetle, *Ips typographus* (Linnaeus, C., 1758). Recently, *Ips duplicatus* (Sahlberg 1836), another bark beetle species of conifers, has expanded its range being considered an invasive species in Europe and it is now present in the majority of Norway spruce stands outside of the natural range. Tree dieback in outbreak areas is not only the result of bark beetle attacks but also of pathogenic fungi with which the beetles associate and introduce into the wood. Numerous studies have shown that, in addition to pathogenic fungi, bark beetle populations are closely linked to other organisms such as nematodes or mites. Mite species, due to their lack of specialized legs for traveling long distances, use bark beetles for dispersal through a phenomenon called phoresy. Phoresy does not involve parasitic relationships, although it can become antagonistic to host species over time. In this study, we aim to determine and analyze the following aspects: (i) specie of phoretic mites associated with *Ips typographus* and *Ips duplicatus*; (ii) the attachment preference of phoretic mite species; (iii) the dynamic of the phoresy; (iv) comparative analysis of phoretic mite populations.

The research was carried out in an 80-year-old spruce stand near Râşnov, Braşov county, located at an altitude of 715 m, at the lower limit of the spruce range. *Ips duplicatus* has been reported in this area since 2011. Bark beetles were collected using six intercept traps (wing type), three baited with a commercial pheromone AtraTYP specific to *Ips typographus* and three baited with a commercial pheromone AtraDUP specific to *Ips duplicatus*, both produced by the Raluca Ripan Institute of Chemistry, Romania. The traps were set up on May 2, 2023, at 10–12 m from the forest edge, and bark beetles were collected every 7–11 days throughout the entire growing season, with the last collection in mid-September. The collected beetles were stored in a freezer at a temperature of -5 °C to prevent the detachment of phoretic mites from their hosts. A sample of 50 specimens was retained for the analysis of phoretic mites. To determine the attachment preference of the phoretic mites to their

hosts, the bodies of the bark beetles were subdivided into several parts: head, thorax, abdomen, first, second and third pair of legs, elytral declivity, and under elytra. In the case of *I. typographus*, a phoresy rate of 49.3% and for *I. duplicatus*, only 20.6% was obtained. Both *I. typographus* males (50.71%) and *I. duplicatus* males (23.38%) were more phoresed than females (47.95%; 17.86%), but there were no significant differences. Regarding the dynamics of phoresy rates over time, significant fluctuations were observed for both *I. typographus* and *I. duplicatus*. The distribution of mites on the host bodies varied depending on the mite species and the abundance of mites on the hosts. Among the 9 species of phoretic mites identified in this study, 3 are reported for the first time in Romania: *Dendrolaelaps disetus*, *Elattoma* sp., and *Paraleius leontonychus*. The maximum phoresy for both bark beetle species was reached at the beginning of the flight of the hibernating generation, indicating this as the most important moment for the dissemination of mites into new habitats. The most abundant species on the bodies of *Ips typographus* beetles was *Dendrolaelaps quadrisetus*, which accounted for over half of the entire population. In the case of *Ips duplicatus*, the population was dominated by specimens of *Dendrolaelaps quadrisetus* and *Elattoma* sp., with the latter being the only species exhibiting this behavior in host selection.

Keywords:

phoretic mites, Norway spruce, *Ips typographus*, *Ips duplicatus*

The climate change and the evolution of *Lymantria monacha* population in Romania

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Norway spruce (*Picea abies* L.) H.Karst.) is one of the most important species in boreal and subalpine coniferous forests, both ecologically and economically, with a wide distribution in Europe. In some parts of Europe, the number of forest defoliator outbreaks has increased, partly due to the planting of coniferous species outside their natural range, but also due to the constant raise in temperatures. *Lymantria monacha* L. is considered the most important defoliator of coniferous forests in Europe. In Romania, *Lymantria monacha* has caused damage mainly in spruce stands in the Eastern Carpathians, the highest damage being recorded between 1955–1964, in the Broşteni-Borsec Forest Districts, on an area of 60,420 hectares. In order to know the evolution of the pest in the future, it is necessary to analyze the relationship between the population of *Lymantria monacha* and climate change in recent decades in Romania.

In this study, potential evapotranspiration was used as an indicator of climate change, because insect populations are influenced by the same climatic parameters that are used to calculate evapotranspiration. The area chosen for this study is the Eastern Carpathians area because it is the most prone to defoliator gradation and based on the population levels reached in the past. This area has been divided into 3 transects: the first transect is located on the eastern side and comprises the weather stations Poiana Stampei, Topliţa, Joseni and Târgu Secuiesc (583–924 m), the second transect is located on the upper part of the Eastern Carpathians and comprises the weather stations Călimani, Ceahlău, Lăcăuţi and Penteleu (1632–2023 m), and the last transect is located on the western slope of the Eastern Carpathians and includes the weather stations Rădăuţi, Piatra Neamţ and Târgu Ocna (190–390 m). Potential evapotranspiration data was downloaded from the TerraClimate database that uses climate-assisted interpolation, combining weather rules with a spatial resolution of about 4 km. It also provides a monthly climate balance and climate water balance data for global land areas from 1958 to 2019, free of charge. As for the population level of the defoliator, the data reported by each forest district were used, the number of captured male butterflies of *Lymantria monacha* was averaged. Regarding the relationship between evapotranspiration and the average evapotranspiration from May to September of each year was calculated, because the evolution of defoliating insects is influenced by weather conditions in the growing season. Subsequently, analyzes were performed using both dot charts to show relationship between potential evapotranspiration in the growing season and the average number of male butterflies captured. Finally, a comparative analysis of the evolving trend of vegetation season evapotranspiration and the trend of the number of male butterflies caught in pheromone traps using combined linear graphs and the mobile trend line was performed for a period of 10 years.

It was observed, for the multiannual averages, that the potential evapotranspiration for all the analyzed station, within the 3 transects, from 1991–2019 and 2001–2019 is significantly higher than the potential evapotranspiration from 1974–1990 and 1974–2000, respectively, but also higher than the multiannual averages (1974–2019), which represents a constant aridity of the climate in the analyzed transects. For the analysis with the adjustment curves given by the moving averages, it was noted that the trend of potential evapotranspiration is also increasing at all the 3 transects. In addition, most often, the level of potential evapotranspiration on the adjustment curve since 1993, at a station at a certain altitude, corresponds to the level of potential evapotranspiration in 2019 from a station located at a higher altitude. The analysis conducted with the help of the mobile average shows that in the majority of cases, the level of catches follows both the increasing trend of potential evapotranspiration and its fluctuations over time.

Keywords:

Lymantria monacha males/trap, spruce, Eastern Carpathians, potential evapotranspiration

Forecasting forest management scenarios for climate mitigation: Insights from the LTER Bucegi-Piatra Craiului Site, Romania

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As the impacts of climate change intensify, addressing greenhouse gas emissions has become a critical global priority. Forests play a pivotal role in this effort, offering significant potential for carbon sequestration. This study explores the balance between maximizing carbon storage and maintaining economic sustainability in forest management, focusing on the LTER Bucegi-Piatra Craiului site in Romania's Southern Carpathians. Using the EFISCEN model, three 50-year forest evolution scenarios were developed – Business As Usual (BAU), Maximum Intensity Harvest (MAX), and No Harvest (MIN) – applied to two historical forest management regimes: conservation and production. These scenarios forecast changes in growing stock, carbon sequestration potential, and economic outcomes under varying harvest intensities. Results indicate that the MIN scenario achieves the highest carbon sink potential over the next 50 years, while the BAU scenario represents a balanced approach, combining substantial carbon sequestration (a 40% increase in growing stock, from 2.6 to 3.8 million m³) with sustainable annual revenues of EUR 3.7 million. Conversely, the MAX scenario temporarily boosts wood-related revenue by 35%, but results in reduced long-term profitability and ecological stability. This research emphasizes the importance of scenario-based decision support tools in forest management to address climate mitigation goals while ensuring socio-economic benefits for local communities. By integrating long-term ecological data and forecasting approaches, this study contributes to adaptive forest management strategies tailored for climate resilience and sustainability.

Keywords:

climate change mitigation, forest management scenarios, carbon sequestration, EFISCEN model, LTER Bucegi-Piatra Craiului, socio-economic forecasting, adaptive management

Projecting and managing bark beetle risk in Norway's forests under climate change

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Climate change is expected to intensify natural disturbances in boreal forests, including outbreaks of the European spruce bark beetle (*Ips typographus*), posing a threat to both forest productivity and carbon storage. To support adaptive forest management in Norway, we evaluated and applied a widely used bark beetle damage model (Seidl et al., 2009) under both current and future climate conditions.

For the evaluation of the model, our sensitivity analysis showed that the model produces plausible estimates across most of Norway's climatic and forest gradients. Key spruce-growing regions (Trøndelag, Innlandet, and Vestviken) currently face a low risk of severe damage. However, under future climate scenarios, annual damage volumes are projected to double by 2080, especially in areas where warmer temperatures may allow a second beetle generation. At the same time, model limitations in older stands and colder regions highlight the need for refinements better adapted to Norwegian conditions.

We then assessed how accounting for bark beetle risk in forest planning influences optimal rotation lengths and economic gains (NPV). Under current conditions, forest owners in southern Norway managing young, low-density spruce stands could already benefit economically from harvesting two to three years earlier than usual. In 50 years from now, the benefits of including bark beetle risk in forest planning become even more significant, and shortening the rotation length by four to five years could lead to an average economic gain of 861 NOK per hectare. However, reducing rotation length is not a one-size-fits-all solution, as it can lead to lower carbon storage and fewer large trees, which are vital for biodiversity, water regulation, and soil stability. Other adaptive strategies, such as shifting tree species composition toward more diverse and less vulnerable stands can reduce beetle risk and enhance ecosystem service provision.

These findings offer Norway's first national-scale projections of bark beetle risk under climate change and support the development of climate-smart forestry policies that sustain both carbon stocks and timber production.

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From background species to major threat: *Ips acuminatus* response to forest disturbance in a changing climate

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Sharp-toothed bark beetle *Ips acuminatus* (Gyllenhaal, 1827) is generally considered a secondary pest in temperate forests, yet under certain conditions it can develop outbreak-level populations. Its impact is usually limited to a few trees unless the entire stand is already weakened. However, climate change may elevate the risk of outbreaks by increasing the frequency and intensity of disturbances such as storms and forest fires, which weaken forest stands and create favorable conditions for colonization.

In Stiklu bog, located in the northwest region of Latvia, a forest fire occurred in July 2018, after which *Ips acuminatus* developed outbreak-level populations. This study investigates how the extent of damage and the time elapsed since disturbance to forest stands influence *I. acuminatus* tree colonization dynamics, including how soon after initial damage the beetle begins colonizing affected trees. In the first year after the forest fire, the emergence of first beetles and damage to trees were recorded. Three years after the disturbance and the peak of the *Ips acuminatus* population, a decline in the sharp-toothed bark beetle population was observed, which may be linked to changes in the population's sex ratio, natural self-regulation, and the presence of natural enemies. Methods used to assess *I. acuminatus* population distribution include trapping, bark sampling, debarking pine trees, and drone-based surveys.

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Long-term dynamics of forest Vegetation in the Tatra Mountains: Evidence from permanent plots

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A repeated typological survey of 35 permanent representative plots after several decades enabled the assessment of long-term changes in forest vegetation in the High Tatra Mountains. To evaluate these changes, the plots were classified into two groups. The first included vegetation on soils with lower pH, dominated by nutrient-poor, acid-tolerant species (hereafter referred to as *acidophilous* communities), while the second group comprised vegetation characterized by nutrient-demanding species (*eutrophic* communities).

Analysis of basic diversity metrics revealed that both acidophilous and eutrophic communities remained relatively stable over time, with only minor fluctuations in species richness. Nevertheless, notable shifts in species composition were detected, particularly for eutrophic communities. Their composition shifted towards more acidophilous character over the past decades.

Community changes of both groups are likely attributable to tree layer dynamics. In acidophilous communities, the cover of Norway spruce (*Picea abies*) and rowan (*Sorbus aucuparia*) increased, whereas in eutrophic communities, spruce declined and was replaced primarily by European beech (*Fagus sylvatica*) and sycamore maple (*Acer pseudoplatanus*). These tree species successfully regenerated, increasing their dominance in both the canopy and the herbaceous understorey.

Despite the overall increase in canopy cover, an expansion of species associated with canopy gaps and reduced stand density – such as *Epilobium angustifolium*, *Athyrium distentifolium*, *Rubus idaeus*, and *Calamagrostis villosa* – was observed, suggesting a shift toward greater structural heterogeneity. Over the decades, the mortality of individual trees followed by the positive growth response of younger individuals contributed to enhanced structural diversity, not only within the canopy but also in the herbaceous understorey.

Acknowledgement:

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Fig.1: Current conditions of the typological plot no. 416 (*Cembreto-Piceetum*), revisited in 2022 after 17 years. Previous typological surveys were conducted in 1957 and 2005. Remnants of original tree center markings at breast height ($d_{1,3}$) were detected only sporadically, mostly on broken stems or snags.

Soil and air microclimate in differently managed young silver birch stands compared to spruce growing on a former clear-cut area

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The increased occurrence of extreme weather events is a major cause of large-scale clearings of a calamity character in many regions. Such clearings represent a harsh growth environment difficult to overcome for many target tree species. Forest regeneration using preparatory tree species offers an adjustment of the microclimate and soil environment, which may be beneficial for the subsequent introduction of other tree species. This contribution aims to compare the development of soil moisture and soil and air temperature under young stands established by natural regeneration, specifically: (1) birch without thinning (12,600 per ha; Bi), (2) birch after an intensive thinning in favour of target trees (840 per ha; BiT), (3) birch-spruce mixture after moderate thinning (2,200 per ha; BiSp), and (4) planted spruce stand of the same age (1800 per ha; Sp).

The experiment is conducted on a former clear-cut area originated as a result of storm Kyrill in 2007. A large part of the area was naturally regenerated mostly by birch. The selected stand treatments (as listed in 1–4 above) were equipped with automatic devices for measuring soil moisture (depth approx. 5–15 cm), soil temperature (-10 cm), soil surface temperature (0 cm), and near-ground air temperature (10 cm), at a minimum of six replicates per treatment.

Budburst of deciduous tree stands, as well as sprouting and growth of ground vegetation, had a significant impact on the microclimate. Intensive thinning increased both near-ground air and soil temperatures, particularly during the growing season. In contrast, it increased soil moisture mainly during the dormant season (Fig. 1). During the growing season, the temperature regime was also influenced by stand density, with low impact of tree species composition. Stand density had a more pronounced effect on daily temperature maxima than minima. Compared to spruce stands, birch treatments exhibited higher minimum temperatures and lower maximum temperatures, apart from the intensively thinned treatment. The effect on soil moisture evolved over time, reflecting the development of forest stands.

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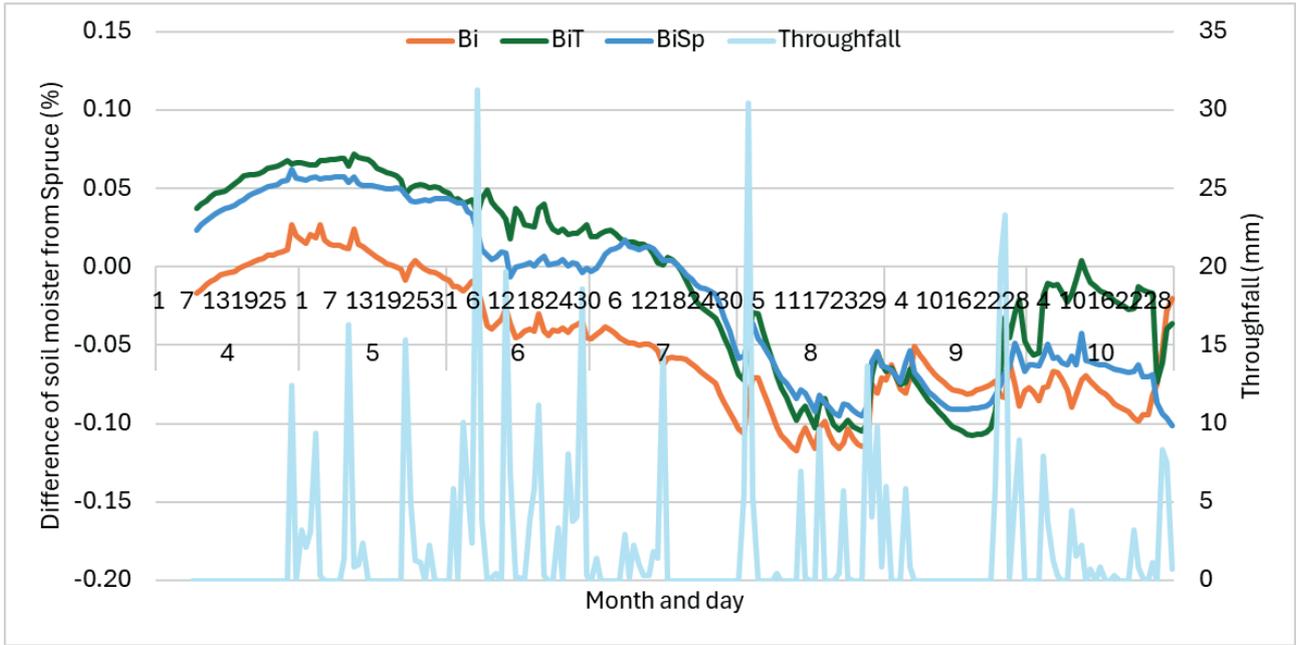


Fig. 1: Difference of other treatments from spruce in soil moisture presented with throughfall in 2020.

The impact of clear-cuts on the water retention capacity of a small forest catchment during an extreme precipitation event

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Since 2022, a forest-hydrological research project has been underway in the Jeseníky Mountains, focused on assessing the effects of forest cover loss in small mountainous catchments on their hydrological regime. The study encompasses three catchments with a total area of 1,097 hectares, where 79 hectares (7% of the study area) of clear-cuts have been created between 2016 and 2022 due to a bark beetle outbreak.

The research includes continuous monitoring of soil moisture and soil water potential across various site and forest stand conditions.

In September 2024, Central Europe, including the Czech Republic, experienced an extreme precipitation event that caused extreme floods resulting in significant damage to infrastructure, buildings and even human casualties. The monthly precipitation total for the Czech Republic reached 179 mm, representing 298% of the 1991–2020 normal. This marked the highest September precipitation on record and the second-highest monthly total since 1961. During the six-day period from 11 to 16 September, extreme rainfall was recorded especially in the Jeseníky Mountains, with 704.2 mm measured at the Švýčárna meteorological station.

This study analyses soil moisture dynamics at two locations, each comprising a spruce stand and an adjacent open area created by salvage logging of bark beetle-infested trees. The objective is to quantify changes in the water retention capacity of the affected catchments under the conditions of an extreme hydrometeorological event.

At the Devítková cesta site (elevation 670 m), soil moisture is monitored at: newly afforested clear-cut (DC_VP), 30-year-old spruce stand (DC_SM_30) and 90-year-old spruce stand (DC_SM_90). At the Medvědí cesta site (elevation 1,060 m), measurements are taken at: newly afforested clear-cut (MC_VP), and 60-year-old spruce stand (MC_SM_60). All measurements are conducted at soil depths of 10 cm, 30 cm, and 50 cm.

A comparison of pre-event minimum soil moisture values with post-event weekly averages showed that water saturation in the soil profile increased more significantly in forest stands than in open areas at both sites. This difference was especially pronounced at the Medvědí cesta site (Fig. 1). On the other hand, it does not seem that the current area of clear-cuts had a significant effect on lowering the water retention capacity of catchments during the extreme rainfall event.

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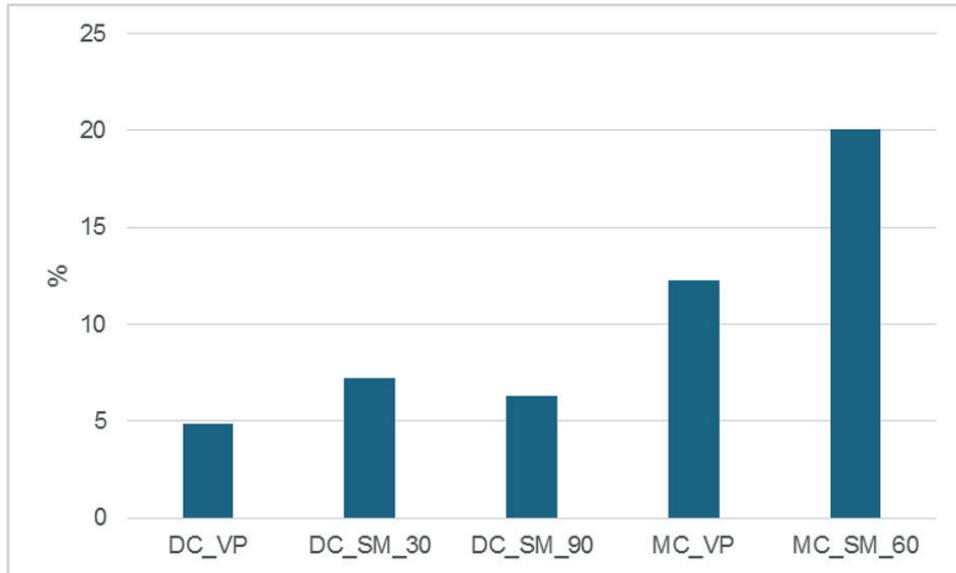


Fig.1: Difference in soil water saturation before and after an extreme rainfall period

Revealing the climate variability in the Hindu Kush: a tree rings based temperature reconstruction

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Annually resolved and absolutely dated proxy archives are necessary for contextualizing the rate and amplitude of anthropogenic climate change. High-resolution climate reconstructions are particularly important for remote regions where instrumental meteorological observations are limited in space and time. Here, we develop a robust, 260-year-long tree-ring width chronology from 32 Himalayan cedars (*Cedrus deodara* D. Don), which grew around 3000 m a.s.l. in the Kumrat Valley of the Hindu Kush region in northern Pakistan. This inverse relationship between radial tree growth and early spring temperatures, together with positive correlations against precipitation totals at the onset of the growing season, suggest that warming-induced drought is the most limiting factor of sub-alpine forest growth in the Kumrat Valley. We then use the inverse growth-temperature association to reconstruct March–April minimum temperatures from 1812 to 2018 CE. The reconstruction explains 40% of the instrumental record back to 1967, and exhibits the coldest and warmest spring conditions in 1815–1864 ($6.67 \pm 0.21^\circ\text{C}$) and 1918–1927 ($8.11 \pm 0.43^\circ\text{C}$), respectively. This pioneering study is indicative of the dendroclimatological potential in the Hindu Kush, where samples from living and relict trees of different species and elevational bands should be collected for advanced temperature and hydroclimate reconstructions.

Keywords:

tree rings, *Cedrus deodara*, dendroclimatology, temperature reconstruction, Hindu Kush region

Promoting adaptation to climate change and bark beetle attacks using a citizen-science transformative approach

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It is widely recognized in academic and policy circles that urgent adaptation to climate change is necessary in the forestry sector, but traditional wisdom and risk adverse attitudes may lead to catastrophic adaptation hysteresis. The general public easily perceives the link between forests and climate change, however one of the biggest threats to both our carbon stocks and our forests is bark beetle which has boomed in recent years due to climate change. This is a particular problem in Austria, as Norway spruce (*Picea abies*) covers more than 50% of forested land. With the predicted temperature increases and alterations in precipitation patterns, lowland forests and those forests currently in dry regions (e.g. Mühl-, Waldviertel) are already close to their upper temperature limit or to their lower precipitation limit. These forests are likely to experience drought and the cascading impacts of pest damage, specifically bark beetle attacks.

It has been stressed that targeted systematic research that integrates, evaluates forest management strategies and promotes stakeholder and community engagement are key to implementation of proactive land management for adaptation to future climate change impacts. In Adapt4K we want to address these issues directly by building-up the multi-actor and stakeholder organizational capacity to deal with future climate change in the forestry sector, and strengthen the adaptation capacity in the system by providing evidence-based solution options and by building lasting coalitions and interconnecting the various players in the county of Lower Austria (NÖ). We want to inspire and galvanize both the general public and the small-scale foresters to adapt to climate change by highlighting their site-specific vulnerability and that climate change is happening by involving them in the collection and analysis of data and the development of appropriate adaptation pathways. To achieve this, we are currently setting-up a network of Forest Living Labs in NÖ to be researched over a number of years to feed sufficient quality data into the wider research knowledge base.

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