GfÖ 2025

Book of Abstracts

54th GfÖ Annual Meeting

Würzburg, Germany, September 1-5 2025

"Ecological Systems Under Pressure: Challenges and Solutions"

Welcome to the GfÖ 2025

Welcome greetings by Christian Ammer

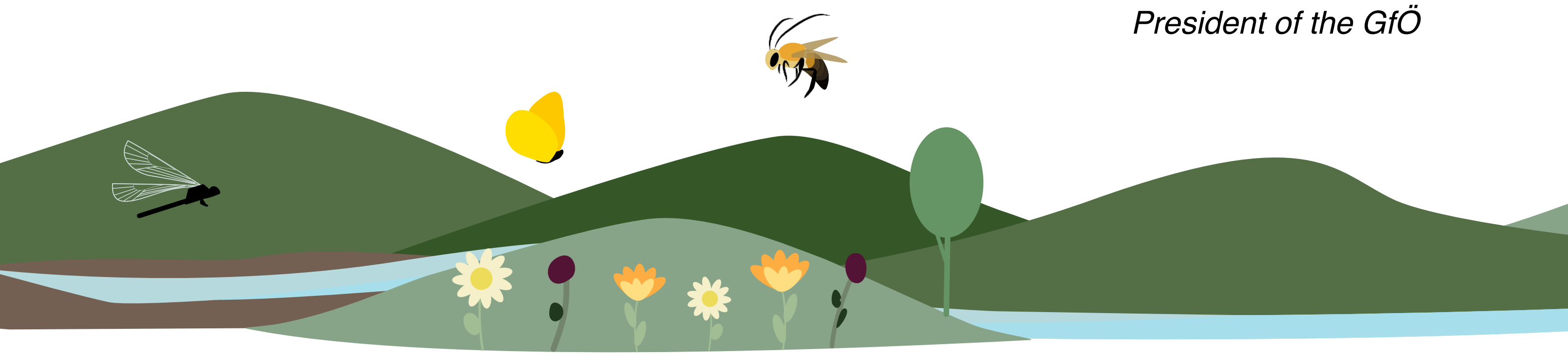
Welcome to the 54th conference of the Ecological Society of Germany, Austria and Switzerland in Würzburg. This is actually the first time that we meet in this old residence seat of the prince bishops and its renowned university. I am sure that all participants will agree at the end of the conference that it was high time we came here. Therefore, I would like to take the opportunity already now to thank the local organizing committee for all their hard work in putting together such a diverse program, which is also enriched by a colourful array of non-technical elements. I wish all participants new insights, good discussions, constructive feedback on their presentations, and time to get to know the diversity of methodological approaches and findings from areas of ecology beyond their own field.

This year's conference motto, ***"Ecological Systems Under Pressure: Challenges and Solutions"*** marks two important aspects: on the one hand the fact that human activities are causing an unprecedented level of change and, unfortunately, sometimes destruction of ecosystems, but on the other hand that this finding does not mean that there are no solutions to the climate and biodiversity crises. In this sense, we hope that the conference will also provide concrete impetus that will find its way into practice.

With the conference in Würzburg and after six years on the board, I will hand over the position of president of our society to my successor and bid you farewell in this role. However, I am confident that the conference in Würzburg will provide the new board with just as many new ideas and impulses as the conferences in previous years. I am also convinced that the conference in Würzburg will once again prove that it is the direct personal exchange with colleagues on site that leads to reflection on one's own points of view and own interpretations and at the same time is a source of inspiration for new ideas. With this in mind, I wish you and all of us informative and, if the depressing state of the world allows, happy days in Würzburg!

Christian Ammer

President of the GfÖ



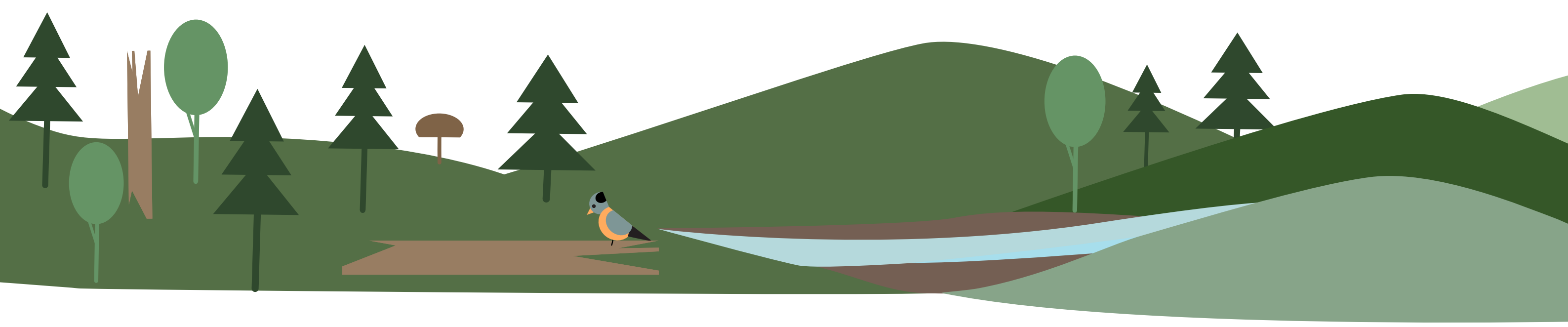
Welcome greetings by the team of JMU

Dear colleagues and friends, dear guests,

we would like to welcome you to the 54th Annual Meeting of the Ecological Society of Germany, Austria & Switzerland at the Julius-Maximilians-Universität Würzburg. In our university, several chairs focus on ecology from different perspectives and coordinate this annual meeting: the Chair of Animal Ecology and Tropical Biology, the Chair of Global Change Ecology, the Chair of Conservation Biology & Forest Ecology, and the Chair of Remote Sensing. The Local Organizing Committee thus covers a wide range of ecological topics, from organismic ecology to chemical ecology, from functional biodiversity research to conservation biology and remote sensing, in a wide range of habitats from forests to agricultural and urban environments, in the temperate zone and the tropics.

What unites us is our focus on current challenges in various ecosystems around the world and our passion to train young biologists and remote sensing students for positions not only in academia but also in conservation practice. Therefore, we chose the motto ***"Ecological Systems Under Pressure: Challenges and Solutions"*** for this conference. More than 400 contributions to the conference will create an interdisciplinary platform to discuss the major ecological challenges of our time and to stimulate exchange between the more than 600 participants of the academic ecological community, practitioners and multiplicators, to find solutions to environmental problems.

The conference venue in Würzburg and our diverse program will create a unique atmosphere for intensive scientific exchange in a wonderful city characterized by wine and science. This will start already at the first evening with a special icebreaker event. During the “Wilderness and Climate Show” you have the chance to meet the award-winning nature filmmaker Jan Haft and the Orchestras of Change. During the conference, you can take part in a wine-tasting session in the last remaining baroque wine cellar, a World Heritage site, constructed by Balthasar Neumann between 1720 and 1744 in the centre of Würzburg. Our program



guarantees top-class key notes, innovative workshops and many exciting talks and poster presentations. The latter will be organized this year in a special format, because not only will researchers present their newest findings, but also the young winemakers from Randersacker will present their wines during the poster session. The artistic research and dance performance “I don't hear Bugs in the City - A choreographic reminder of the small creatures among us”, will take a close look at the relationships between humans and insects in cities, as part of the interdisciplinary research project SLInBio on urban insect diversity. We hope you'll join us for a concluding night of partying at the traditional GfÖ-Club Night on Thursday evening, and that you'll still have enough resources on Friday to go on one of our excursions to beautiful habitats, experiments in forests, or explore the ancient culture of Würzburg.

Finally, we would like to thank the many people who have contributed to the successful organization of the meeting. First of all, we would like to mention Eveline Schneider, Steven Hill, Oliver Mitesser, Sabine Nooten, Mara Kuschke, Lars Landgraf, Sabine Oppmann, Julia Rothacher, Rabea Klümpers, Jochen Krauss, Fabienne Maihoff, Fabian Bötzl and Hanno Korten and Nicolas Willems for their indispensable help in organizing the meeting, together with KCS Heike Kuhlmann and the Event-Tech Team. We would also like to thank all other helpers for their support during the conference and the sponsors of our conference for their financial support. Many thanks to the keynote speakers for accepting our invitation as well as the chairs of the various sessions for covering stimulating topics. We are looking forward to inspiring lectures, talks, and poster sessions. We hope that this meeting will offer an inspiring atmosphere for fruitful discussions and interactions.

Jörg Müller & Nadja Simons

(Chair of Conservation Biology and Forest Ecology),

Christian Hof & Malte Jochum

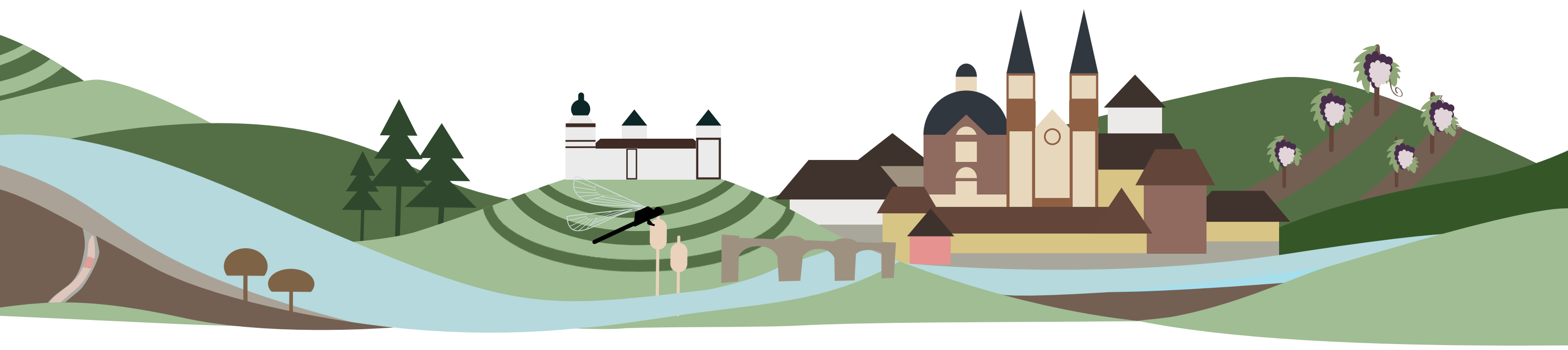
(Department of Global Change Ecology),

Ingolf Steffan-Dewenter & Thomas Schmitt

(Department of Animal Ecology and Tropical Biology),

Stefan Dech

(Department of Remote Sensing)



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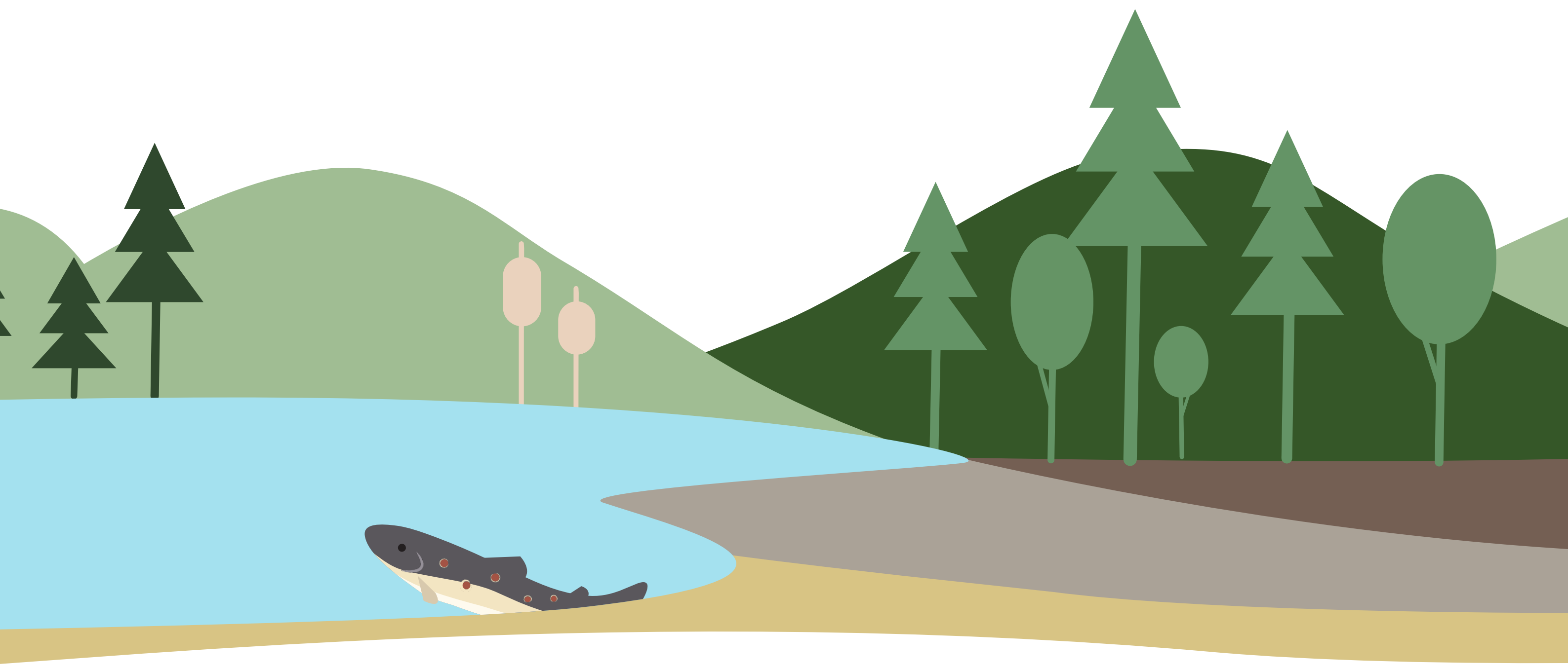
Macroecology and modelling

Keynotes



The flavours of iNEXT - quantification of biodiversity in the footprints of Alan Turing

Anne Chao[1], Pia Bradler[2],[3]

[1]National Tsing Hua University, Taiwan, Hsin-Chu, TW
[2]Institute of Ecology, Leuphana University, Lüneburg, DE
[3]Institute of General Ecology and Environmental Protection, TUD Dresden University of Technology, Tharandt, DE

Most ecological studies rely on sampling data. However, comparisons based solely on observed diversity can be misleading, as such values are typically sensitive to sampling effort and sample completeness. To enable meaningful comparisons across assemblages or spatial scales, sample (or data) standardization is essential. Within the Hill numbers framework—which encompasses species richness, Shannon diversity, and Simpson diversity—the iNEXT (interpolation and extrapolation) method offers a statistical approach for standardizing either sample size or sample completeness across datasets, for both abundance and incidence data.

An objective measure of sample completeness is sample coverage, defined as the proportion of individuals in the assemblage (including those from undetected species) that belong to the species detected in the sample. The concept of sample coverage was originally developed by Alan Turing during his cryptographic work during WWII. Sample coverage can be accurately estimated from sampling data. The integration of sample-size- and coverage-based rarefaction and extrapolation represents a unified standardization for quantifying and comparing species diversity across multiple assemblages.

The sample-size-based rarefaction and extrapolation curve can be used to assess whether data are sufficient for accurate asymptotic estimation. For non-asymptotic estimation, rarefaction and extrapolation standardized by sample coverage are better able to judge the magnitude of the differences in diversity among assemblages compared to size-based approaches. The iNEXT method has been extended to various contexts, including iNEXT.3D (for taxonomic, phylogenetic, and functional diversity), iNEXT.beta3D (for beta diversity), iNEXT.link (for network data), and iNEXT.meta (for synthetic analysis). Data from the Beta-For project, Enhancing the structural diversity between patches for improving multidiversity and multifunctionality in managed forests, are used for illustration.

Anne Chao

Institute of Statistics, University National Tsing Hua University, Taiwan

Anne Chao is a Professor in Statistics. She is currently 60% statistician, 30% mathematician, and 10% ecologist. For over 40 years, she has been fascinated by the mathematical and statistical challenges that arise in ecology and environmental sciences. Her expertise lies in ecological statistics, statistical methodologies, and statistical sampling/analysis of survey data. Together with her colleagues and students, she has developed several biodiversity measures/estimators, including Chao1, Chao2, ACE, and ICE, which are used to assess species richness. She has also contributed novel standardization methods and software (including iNEXT, iNEXT.3D and iNEXT.beta3D) for inferring and comparing biodiversity across scales.

Pia Bradler

Leuphana University Lüneburg and the Technical University of Dresden

Pia Bradler is a doctoral researcher. She has a background in global change ecology and has worked on investigating the impacts of global change, particularly warming and land use change, on plant communities and functional diversity. Her current work focuses on how an increase in structural heterogeneity in temperate managed forests affects understory plant diversity and functioning across spatial scales using iNEXT in different analyses.

Examining the changing threats and solutions for Amazonia's forests

Jos Barlow[1]

[1]***Lancaster Environment Centre, Lancaster, UK***

The Rio'92 Earth Summit underpinned the development of organised international action via the UN conventions on Climate Change (UNFCCC) and Biodiversity (CBD). More than thirty years on, South America is in the spotlight again; COP16 of the CBD was held in Colombia and COP30 of the UNFCCC will be held in the Amazon for the first time. This has brought renewed focus on the Amazon and surrounding ecosystems at a crucial time when recent events and research highlight the growing risk of critical thresholds being crossed that could undermine the sustainability and functioning of the whole basin. Here, I outline those emerging risks by: (i) showing how disturbances within the remaining forests are adding to the negative impacts of deforestation, driving changes in traits and winner-loser species replacement; (ii) examining the role of climate extremes, which are increasing at a faster rate than mean annual changes in temperature, and (iii) exploring what these mean for critical thresholds and the potential for abrupt system-level tipping points. Finally, I examine how these changes – and predictions of future change – are altering and diminishing the solution space for the Amazon basin and other tropical forest regions, and show how achieving net-positive ecological trajectories requires going beyond avoiding deforestation or restoration, and must include actions that prevent further degradation.

Jos Barlow

Lancaster Environment Centre (UK) Federal University of Pará (Brazil)

Jos Barlow is a professor in conservation science at Lancaster Environment Centre (UK) and a professor of ecology at the Federal University of Pará (Brazil). His work addresses how human activities impact tropical forest biodiversity and the ecosystem services and functions that biodiversity delivers, with a focus on the Brazilian Amazon where he has been working since 1998. He is a co-founder of the Sustainable Amazon Network (Rede Amazônia Sustentável), which brings together scientists, conservation practitioners and local stakeholders to further our understanding of the environmental and socio-economic trade-offs in the world's largest remaining expanse of tropical forest. He is a Trustee of WWF-UK, Lead author & member of the Scientific Steering Committee of the UN's Science Panel for the Amazon, and Editor-in-Chief of Journal of Applied Ecology.

Living on the Edge: What Determines Species Range Limits?

***Jean-Philippe Lessard*[1]**
*[1]**Concordia University, Montreal, CA***

Predicting whether species ranges will expand, or contract is a crucial part of managing biodiversity in a changing world. It is nevertheless surprising that scientists have such a rudimentary understanding of processes involved in range dynamics and in setting and maintaining range limits. Perhaps the slow progress made toward understanding and predicting range dynamics results from scientists with different expertise working in isolation. Only the integration of concepts and approaches in physiology, ecology, and evolutionary biology can lead to major advances. Here, I review recent theoretical and empirical advances related to processes governing range limits and range edge dynamics, with a particular focus on the role of physiological plasticity, population genetics, demography, and trophic interactions. I then discuss the implications of a deeper understanding of the determinants of range limits on the ability to explain and predict range shifts in a changing world.

Jean-Philippe Lessard

Concordia University in Montreal, Canada

Dr. Jean-Philippe Lessard is a Professor in the Department of Biology at Concordia University in Montreal, Canada and the Editor-in-Chief of Ecological Monographs, a journal of the Ecological Society of America. His current research investigates the ecological, evolutionary and anthropogenic determinants of biological diversity from local to global scale, geographic range dynamics and ecosystem function. Much of his empirical work uses insects and in particular ants, as a study system. He obtained his BSc from McGill University and his PhD in Ecology and Evolutionary Biology from the University of Tennessee. He then pursued postdoctoral work at the Center for Macroecology, Evolution and Climate, based at the University of Copenhagen and at the Quebec Center for Biodiversity Science, based at McGill University.

Documenting tropical forest biodiversity loss and recovery using sounds

***Zuzana Burivalova*[1]**

[1]***University of Wisconsin-Madison, Madison, US***

Forests are at the forefront of nature-based climate solutions, and this has stimulated a global investment into their protection. Yet, focusing on carbon, many nature-based climate solutions do not automatically protect biodiversity. I will discuss the need to include biodiversity conservation as a major goal for tropical forest nature-based climate solutions. I will demonstrate how we use new technologies, particularly bioacoustics (recording and analyzing sounds that animals and humans make), to document the losses and gains in biodiversity. Using new advances in machine learning to detect animal and gunshot sounds, I will show not only the patterns but also the processes that underly biodiversity changes in the world's most diverse tropical forests. In this talk, I will draw on examples from the Sound Forest Lab's work across tropical forests.

Zuzana Buřivalová

University of Wisconsin-Madison, The Nelson Institute for Environmental Studies and the Department of Forest and Wildlife Ecology, The Sound Forest Lab

Zuzana Buřivalová is Assistant Professor and the Principal Investigator of the Sound Forest Lab. She is a tropical forest ecologist and conservation scientist, based at the University of Wisconsin-Madison, where she is affiliated with the department of Forest & Wildlife Ecology, The Nelson Institute for Environmental Studies, and the Center for Sustainability and the Global Environment (SAGE). Before joining UW-Madison, she was a post-doctoral research fellow at Princeton University and The Nature Conservancy, and received her PhD at the ETH Zürich and BA at Oxford.

Zuzana researches ways to protect biodiversity in tropical forests, both forests that are used by people, for example for logging, and forests set aside for conservation, from national parks to small community protected areas. She tries to answer tricky questions in tropical forest ecology using new technologies, such as through recording soundscapes, where traditional field methods aren't enough. She also collaborates with the environmental news platform Mongabay on understanding, which conservation strategies succeed and fail in tropical forests. Zuzana feels privileged to have worked in the tropical forests of Madagascar, Papua New Guinea, Borneo, Gabon, Peru, and Ecuador.

Zuzana is the 2021 winner of the nature award for driving global impact. In 2023, she received the Bassam Z. Shakhashiri Public Science Engagement Award, and the WINGS Women of Discovery Award.

Agroecology in a changing world: challenges and novel frontiers

Lorenzo Marini[1]

[1]***University of Padova, Padova, IT***

In the next decades, the growing human population will pose significant challenges to meet global food demand while protecting biodiversity across agricultural landscapes. To increase the resilience of cropping systems, different disciplines including biotechnology, agronomy, and agro-ecology are trying to provide farmers with a diverse portfolio of solutions. In this context, agro-ecology has proposed local and landscape diversification as a general strategy to both sustain yields and protect biodiversity. However, after decades of ecological research intensive agriculture is still one of the major drivers of biodiversity loss worldwide. We still have incomplete knowledge on single interventions' effectiveness under different environmental contexts and on their potential costs and benefits for farmers and the wider society. This large uncertainty is currently hindering a widespread adoption of agro-ecological strategies. To try to fill these knowledge gaps, I will outline current challenges and novel frontiers in agro-ecological research. From a more theoretical perspective, bridging network theory with landscape ecology can help inform landscape management by improving our understanding of the complex relationships between service-delivering organisms and their environments. From a more applied perspective, expanding the focus from single ecological services to landscape multi-functionality, for instance by incorporating co-benefits such as non-instrumental values, can help overcome current barriers to the adoption of agro-ecological strategies into conventional farming systems. Integrating different disciplines could foster synergies between food production and biodiversity conservation goals.

Lorenzo Marini

University of Padova, DAFNAE

Lorenzo Marini is a professor of general and applied entomology at the University of Padova. His research focuses on understanding how major anthropogenic pressures impact plant and insect diversity, as well as associated ecosystem services, with the ultimate goal of developing management solutions to mitigate negative effects on agricultural and natural ecosystems. In agroecology, he primarily works on plant protection and pollination, contributing to the design of sustainable cropping systems. His research also extends to global change, species range shifts, and biological invasions. He employs diverse methodological approaches, including manipulative experiments, observational studies, macroecological analyses, and syntheses. Following various international research experiences, he established his research group at the University of Padova in 2011, creating multiple Ph.D. and postdoctoral positions funded by European, national, and regional research grants.

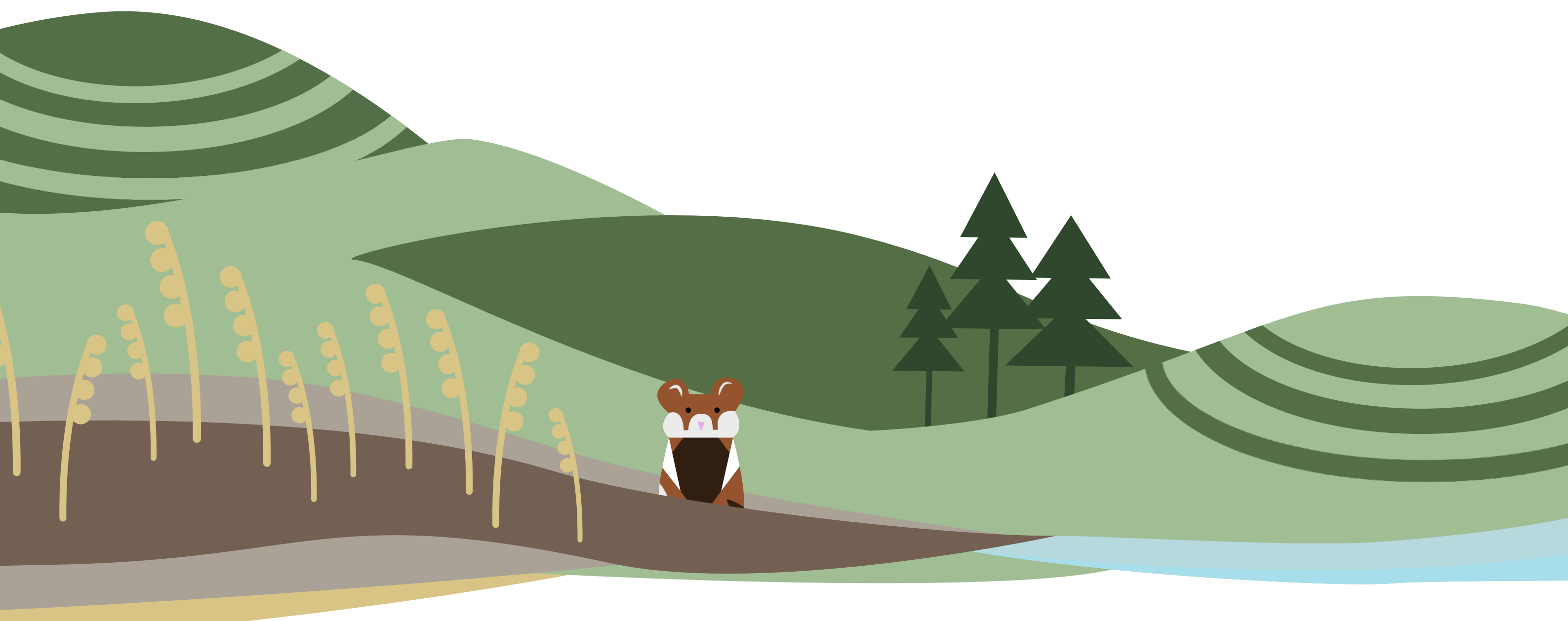
Individual-Based Ecology: when, if not now?

Volker Grimm
Helmholtz Centre for Environmental Research (UFZ), Leipzig

Perhaps the most important task for ecologists in these times is to predict how ecological systems will respond to change. But who or what is responding? For example, an increase in the frequency of droughts will alter the species composition and ecosystem functions of forests, but these changes are due to the response of the trees themselves. Although ecology is a systems science, it will be difficult to make predictions that support conservation and safeguarding without understanding the variability, local interactions and adaptive behaviour of individual organisms. Fortunately, modelling and monitoring the individuals that constitute ecological systems have advanced significantly over the last two decades, making Individual-Based Ecology (IBE) both necessary and feasible. Nevertheless, to better inform and test predictive models, empirical research must refocus and ask the right questions. IBE will complement and unify all existing branches of ecology. Rather than seeing the forest for the trees or vice versa, we should see both and understand how they influence each other's behaviour and responses.

Session 1

Accelerating farming system transition through agroecology



Collaborative agri-environmental governance at the landscape scale to promote social, ecological, and economic benefits

Catrin Westphal[2], Stefan Schüler[2], Marco Ferrante[2], Isabelle Arimond[2], Jule Huber[3], Patricia Joest[2], Menko Koch[4], Alfred Kok[2], Sebastian Lakner[4], Tobias Plieninger[3], Annika Hass[2]

[2]Functional Agrobiodiversity & Agroecology, University of Göttingen,Göttingen, DE
[3]Social-Ecological Interactions in Agricultural Systems, University of Göttingen, Göttingen, DE
[4]Agricultural Economics, University of Rostock, Rostock, DE

Agri-environmental collaboration has become a prominent subject to agricultural research and policy-making in the EU. Collaboration among multiple farmers within landscape-scale agri-environmental schemes (LAES) can overcome the spatial mismatch between the local implementation of agri-environmental schemes and the landscape-scale habitat requirements of farmland species. Therefore, LAES are a promising way to effectively enhance farmland biodiversity. Besides, they can also create social and economic benefits for farmers and other stakeholders.

However, it remains unclear how much area is needed for LAES to be ecologically effective, whether this effectiveness depends on the existing landscape diversity, how stakeholders can be motivated to participate in LAES initiatives, and how positive feedbacks and synergies between social, economic and ecological benefits can be created.

To address these questions, we implemented a collaborative landscape-scale experiment within the project KOOPERATIV by sowing 0-13.5 ha of perennial flower fields (250 ha in total) with a regionalized, native seed mixture in 37 landscapes along an independent gradient of landscape diversity.

First results show that species richness of birds was not affected by the amount of flower fields but by landscape diversity, while wild bee abundance increased in landscapes with flower fields one year after their establishment.

We also found that addressing stakeholder expectations, involving regional facilitators, and establishing cross-sector networks can jointly support the establishment of collaborative LAES. To make LAES an effective tool of the agricultural policy, it is crucial to capitalize on potential synergies among social, ecological, and economic benefits arising from collaborative implementation by regional stakeholders.

The Future of Farming? Rethinking Rural-Urban Partnerships in the Nuremberg Metropolitan Region

***Andrea Früh-Müller*[1]**

[1]***Weihenstephan-Triesdorf University of Applied Science, Weidenbach, DE***

The Nuremberg Metropolitan Region stands at a crossroads where agricultural diversity and urban expansion create ongoing land-use conflicts. Infrastructure development, residential growth, and economic priorities often clash with efforts to preserve cultural landscapes, leading to the loss of agricultural land. With 1,679 hectares disappearing annually, the challenge lies in balancing infrastructural development with conservation while ensuring the long-term sustainability of local food systems.

Despite these tensions, the region sees an opportunity in its Globally Important Agricultural Heritage System (GIAHS) application. By securing this recognition, the region aims to reinforce urban-rural connectivity and promote land-use strategies that integrate agricultural heritage with sustainable development. Strengthening rural-urban links—through localized food chains, stakeholder participation, and digital innovations—can help mitigate conflicts, making agricultural spaces more valuable not only for food production but also for recreation, cultural identity, and ecological resilience.

This study explores how the GIAHS process serves as a tool for transforming land-use disputes into cooperative solutions. By fostering dialogue between farmers, and policymakers, urban planners, the Nuremberg Metropolitan Region exemplifies how heritage conservation and sustainable land management can reinforce resilient agri-food systems.

How to change a running system? Transforming agricultural landscapes using spatially explicit landscape living labs to promote insects.

Stephanie I. J. Holzhauer[1], Bastian Häfner[1], Jens Dauber[1]
[1]Thünen Institute of Biodiversity, Braunschweig, DE

The transdisciplinary project FInAL (since 2018) has set up three landscape living labs (LLL; 3 km x 3 km) in representative agricultural landscapes in Germany in order to initiate, demonstrate and evaluate their insect-promoting transformations.

The long-term transformation is addressed by participatory processes (co-learning, co-design) with local stakeholders like farmers, municipalities, and landscape maintenance associations. The processes consider the economic viability for the practitioners as well as current and future challenges for the practitioners. Thus, economic and social parameters and other factors are recorded and included in these processes expected to strengthen support a long-term change towards agroecological systems. In contrast to AES, in FInAL, practitioners are encouraged to adapt measures regarding insect-promoting, region-specific aims and practical considerations. Applied measures encompass the integrated cultivation of renewable raw materials, other production-integrated measures and measures outside agricultural fields.

The joint effect of innovative, insect-promoting measures and enhanced spatio-temporal landscape structure in the LLL is assessed through landscape-scale monitoring of key organism groups like pollinators and natural enemies, and ecosystem services (ES) including biocontrol within LLL and respective reference landscapes following the BACI-design. Preliminary results on insect diversity, abundance and ES, based on available data from three to four years following the implementation of the measures since 2022 do not yet indicate a significant landscape-wide response. Potentially insect-fostering changes in the choices of measures, however, are increasing in the landscape labs with a trend towards more complex measures and followingly more diverse landscape composition and configuration. Efforts towards higher quality of measures, increased habitat connectivity through measures outside the production areas are in progress.

Tree cover loss and intensified land use simplify bat assemblages in Amazonian cacao agroforestry landscapes

Pablo Aycart Lazo[1,2], Luz Sánchez-Maldonado[3,4], Blanca Iváñez-Ballesteros[2], Carolina Ocampo-Ariza[5,6], Evert Thomas[7], Teja Tscharntke[6], Stefan Dullinger[1], Ingolf Steffan-Dewenter[2], Bea Maas[1,8]

[1]University of Vienna, Vienna, AT
[2]University of Würzburg, Würzburg, DE
[3]Universidad Nacional Agraria La Molina, Lima, PE
[4]Centro de Ornitología y Biodiversidad, Lima, PE
[5]Technical University of Darmstadt, Darmstadt, DE
[6]University of Göttingen, Göttingen, DE
[7]Bioversity International, Lima, PE
[8]BOKU University, Vienna, AT

Agricultural expansion and associated land-use change are major threats to Amazonian biodiversity. Cacao agroforests can support diverse and multifunctional bat assemblages, which are suitable indicators of land-use changes and may therefore provide valuable information for developing land-use policies in Amazonian agricultural landscapes. We sampled aerial insectivorous (AIBs) and phyllostomid bats (mainly frugivores) in 28 cacao agroforests in two neighbouring regions in the Peruvian Amazon that differ in the proportion of remaining forest and cropland intensity. We analyzed how landscape structure affected both groups and projected their taxonomic, functional and phylogenetic responses to two future landscape scenarios predicting either cropland expansion or reforestation. AIB activity (a surrogate of abundance) and feeding buzzes (an indicator of foraging activity) decreased with increasing cropland cover in the non-intensive region only, presumably due to vulnerable species being already scarce in the intensive region. AIB phylogenetic diversity decreased with tree cover in the non-intensive region, but we did not find significant trait-based environmental filtering. Abundance of fruit-eating phyllostomids increased towards landscapes with lower tree cover, while higher edge density was associated with more insect- and large fruit-eating phyllostomids. Furthermore, phyllostomid abundance decreased with increasing cropland cover in the intensive region, probably due to low resource availability. We predicted fewer AIB feeding buzzes and higher frugivorous phyllostomid abundances with ongoing tree cover loss in the non-intensive region. Conversely, tree cover loss is expected to result in lower phyllostomid abundance in the intensive region. Our results suggest that restoring tree cover in agricultural landscapes offers a valuable strategy to mitigate biodiversity loss and phylogenetic homogenization in the rapidly changing Amazon region.

The Role of Hedgerows and Flower Strips for Birds and Bats in Agricultural Landscapes

Brígida M. D. Bowen[1,2], Christina Fischer[1], Péter Batáry[1,2]

[1]Anhalt University of Applied Sciences, Bernburg, DE
[2]HUN-REN Centre for Ecological Research, Vácrátót, HU

Agricultural intensification often leads to landscape simplification, resulting in the decline of animal and plant species. Therefore, promoting sustainable agricultural practices and restoring degraded ecosystems are crucial for promoting biodiversity. However, more landscape-scale studies are necessary to assess the effectiveness of current restoration measures. To address this, we investigate the combined impact of flower strips and hedgerows on biodiversity in the largely simple agricultural landscapes of Saxony-Anhalt, Germany. Using a combination of observational and experimental approaches, we will examine the effects of these measures on birds and bats in farmlands. For the fieldwork in spring and summer 2025, we selected 20 winter cereal fields along a landscape complexity gradient in Saxony-Anhalt. The studied crop fields have one of the adjacent treatment types: (i) grassy margin (control), (ii) flower strip, (iii) hedgerow, or (iii) a combination of flower strip and hedgerow. In each of these fields, we will perform bird transect surveys to assess species presence and abundance. We will study bird nest predation to evaluate predation pressure and predator communities. Further, birds and bats will be recorded using AudioMoth devices. In addition, we will use automated flight-interception traps to estimate potential insect prey availability for bats. We suspect that the combination of flower strips and hedgerows offers a greater value to bird and bat communities than either of the measures alone. The results from the large-scale surveys will provide valuable insights into the effectiveness of these restoration strategies in promoting biodiversity in agricultural landscapes. They will also help to evaluate European strategic plans that promote sustainable agriculture.

Plant-pollinator interactions in spring wheat-aromatic plants strip cropping systems

Birgit Gemeinholzer[1], Alena R. Geffert[1],[1], Lisa Schwarz[2], Christine Becker[1], Annette Reineke[2], Miriam Athmann[1]

[1]University Kassel, Kassel, DE
[2]Hochschule Geisenheim, Geisenheim, DE

Climate extremes are a major challenge for arable farming. They require ecological-functional intensification for sustainable and climate-resistant cultivation systems in order to secure yields and at the same time counteract soil degradation and the loss of biodiversity. As part of the Hessian LOEWE research cluster “Transformative Intercropping Systems for One Health” (TRIO), we are investigating the integration of annual and perennial, deep-rooted aromatic plants in crop rotations with intercropping of cereals as a promising approach for sustainable, biodiversity-promoting arable farming systems under a wide range of site conditions. Using eDNA barcoding of insects and their respective plant traces, we investigate the effects of strip cropping systems with spring wheat (Triticum aestivum L.) and medicinal and aromatic plants, here annual and perennial caraway (Carum carvi L.) and coriander (Coriandrum sativum L.), on insect diversity on two organically and two conventionally farmed sites in Hesse. Our study shows that spatio-climatic factors have a stronger influence on insect diversity and the associated plant diversity than the cultivation techniques or the surrounding vegetation. By conducting a comparative analysis of arthropod diversity and their ecosystem functions in a strip intercropping system, we aim to contribute to a more comprehensive understanding of the significance and role of insects and their ecosystem services in alternative cropping systems and make our data publicly available through NFDI4Biodiversity and FAIRAgro.

Trade-off between landscape diversity and agricultural diversity

Josepha Schiller[1,2], Clemens Jänicke[3,4,5], Moritz Reckling[1,6], Masahiro Ryo[1,2]

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[2]Brandenburgische Technische Universität, Cottbus-Senftenberg, DE
[3]Leibniz Institute of Agricultural Development in Transitions Economies (IAMO), Halle (Saale), DE
[4]Humboldt-Universität, Berlin, DE
[5]Integrative Research Institute On Transformations of Human-Environment Systems (IRI THESys), Berlin, DE
[6]Department of Crop Production Ecology, Swedish University of Agricultural Sciences (SLU), Uppsala, SE

Agricultural diversification across fields, farms, and landscapes is widely promoted as a pathway to more sustainable ecosystems, yet the links between landscape complexity and crop diversity remain poorly quantified. We present how temporal crop diversity is linked with spatial crop diversity and landscape complexity, and how these patterns can be explained by various farm, landscape, and environmental attributes.

We analysed crop information from Integrated Administration and Control System data (2011-2020) (>150 000 fields per year) in Brandenburg, Germany, and employed interpretable machine learning to test the relationship between spatial, temporal, and spatio-temporal crop diversity with habitat and land cover maps, soil and climate information in more than 290 grid cells (10×10 km). Spatial and temporal crop diversity and landscape composition were measured using richness, Shannon's diversity index, and Shannon's evenness index. Landscape configuration was measured using field, farm, and habitat patch sizes and edge density.

We found that (i) spatial and temporal crop diversity are positively correlated with each other, (ii) high farm-level crop diversity is positively associated with both spatial and temporal crop diversity, and (iii) structurally simple landscapes and poor soil quality are linked to higher temporal crop diversity (crop rotations) but not spatial crop diversity.

These results underline that there is a trade-off between crop diversity and landscape complexity, that crop diversity can be limited by poor soil quality, and that decisions at the farm level shape temporal and spatial crop diversity patterns within landscapes, while different factors drive spatial and temporal crop diversity. Although our results are based on the study region of Brandenburg, they highlight the need to identify site-specific characteristics to support informed ecosystem management, such as balancing landscape complexity and crop diversity depending on the local priorities and constraints.

Flowering service crops in intensive orchards provide benefits to multiple stakeholders and local pollinators

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Almond (*Amygdalus communis*) is a large and economically important crop in Mediterranean countries. Insect pollination is a limiting factor to its production. Thus, the conventional practice is to clear the vegetation between the tree rows to reduce competition over pollinators. The result is bare-soil orchards lacking diverse floral resources for wild pollinators and post-winter honeybee colonies. Recently, a regenerative agriculture practice of cover crops has been introduced in Israel, where growers retain or sow plants between the tree rows. In this study, we focused on orchards with flowering cover crops and compared them to conventional orchards with no flowering cover crops. We sampled ten orchards over two years (2023-2024) in the lower Galilee in Israel. We recorded the diversity and abundance of pollinators (netting and pan-traps), visitation rates of pollinators in almond trees, and fruit-set. In three orchards, we also assessed the honeybee colonies' performance by recording the increase in brood size, colony size, and pollen storage during the almond bloom season. We hypothesized that orchards with flowering cover crops would have higher abundance of wild pollinators, higher visitation rates of pollinators in almond trees (pollination services), higher fruit-set of almond (yield), and better honeybee colony performance. In orchards with cover crops, pollinator abundance was 80% higher between trees, almond tree visitation rates increased by 10% (2023) and 73% (2024), and fruit set increased by 8-20% in both years, respectively. Honeybee colonies in orchards with cover crops increased their brood and colony size during almond bloom, whereas colonies in orchards without cover crops did not. Pollen storage increased in both treatments. This suggests that flowering cover crops benefit the almond growers, the beekeepers, and wild pollinators.

Eat the Weed: Exploring rodent seed removal in conventional and strip-till farming systems

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Seed removal is an ecosystem function that can contribute as biological weed control. This is especially important in times of biodiversity decline when it is essential to find environmentally sustainable agricultural methods while maintaining yields. One such method is strip-till farming which reduces tillage activities and has the potential to lower pesticide and fertilizer use.

In our project, we studied the use of a wildflower mixture consisting of seven annual and eight perennial forbs sown in the interrow between the cultivated crops in a strip-till system to enhance biodiversity. For comparison, we used conventional strip-till farming without wildflower sowing and conventional farming. Within the three farming systems, we tested seed removal by rodents, one of the most important species group contributing to this ecosystem function. We selected four harmful weed species (Fumaria officinalis, Galeopsis tetrahit, Avena fatua and Lamium purpureum) and observed seed removal rates in June and July for four nights in winter wheat, maize and legumes before harvest.

Our results show that the seed removal varied by year and was lowest in 2023 (29%) and highest in 2024 (60%). Overall, legumes exhibited highest seed removal rates with on average 54%, followed by winter wheat with 48%, whereas seed removal in maize was only 34%. Furthermore, seed removal was highest in conventional strip-till farming (49%) while it was slightly lower in strip-till farming with wildflower sowing and conventional farming (both 44%).

Thus, our results indicate that seed removal by rodents was influenced by temporal variation, which is likely related to fluctuations in rodent densities. Additionally, seed removal rates were overall high in winter wheat and legumes suggesting that rodents play an important role in biological weed control in these crops. As invertebrates are also important seed predators, they will be included in future analysis of seed removal in these farming systems.

Conserving threatened arable weeds in organic farming: The role of management, land-use history and soil fertility

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Agricultural intensification drastically reduced the number of rare arable weed species, which are now largely restricted to organic farms. Even in organic farming, however, these species are declining, highlighting the need for targeted conservation measures. At the same time, these vmeasures must not promote competitive weeds that reduce agricultural productivity. Hence, we investigated how contemporary management, land use history and site conditions affect arable weed communities in 75 organic winter cereal fields on the Swabian Alb, southern Germany. We analysed how management practices, the duration of organic cultivation and a gradient from low to average yield potential, affect the richness and cover of both threatened and competitive weed species.

We find that long-term organic management supports a higher diversity and cover of threatened arable weeds. Higher yield potential and weed control generally reduce their abundance, but on fertile soils endangered weeds benefit from weed control, probably due to reduced competition. Perennial forage leys were more damaging to threatened species than to competitive weeds. Interestingly, pre-crop forage leys only affected competitive weeds, thus indicating that annual forage leys constitute a good compromise between biodiversity conservation and agricultural productivity.

Our results suggest that conservation strategies for endangered arable weeds should prioritise low-yielding soils and fields under long-term organic management. Importantly, biodiversity conservation and sustainable crop production should be balanced by permitting mechanical weed control, common seed densities and short-term forage leys when dealing with problematic weed infestations. This study provides valuable insights into practical, production-integrated approaches to conserving threatened weeds in organic farming systems.

Unearthing success: Investigating key factors for arthropod overwintering in maize fields

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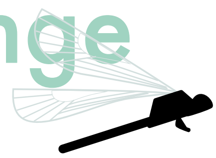
Diversifying maize with undersown crops can mitigate the negative effects of intensive maize cultivation and provide resources for arthropods during the growing season. If there is no tillage after maize harvest, the living biomass or mulch layer of the undersown crop helps to reduce the risk of erosion and nutrient leaching and can provide an overwintering habitat for arthropods. In contrast, catch crops established after maize harvest to cover the soil require soil cultivation, which may reduce overwintering potential for arthropods.

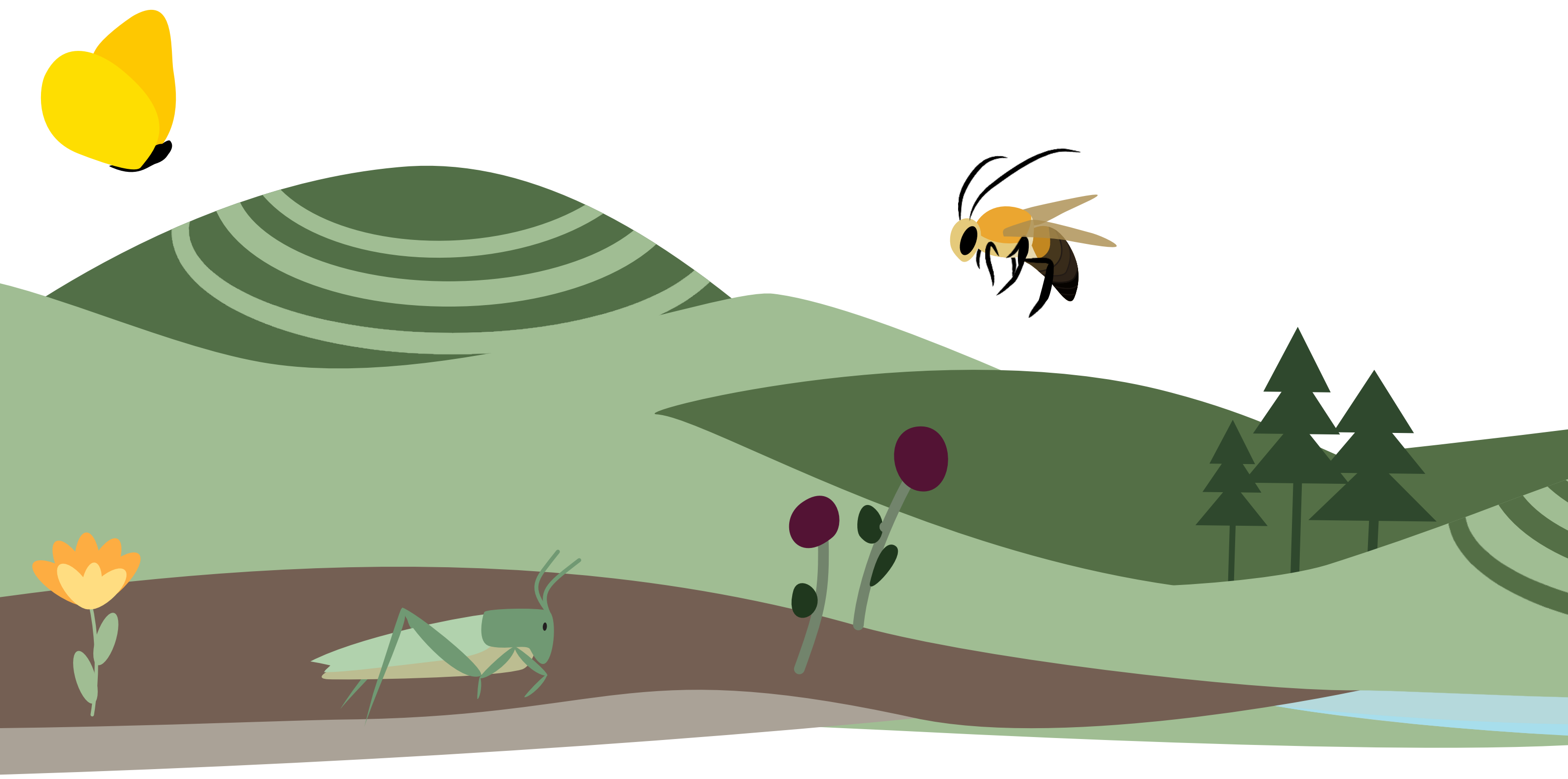
In a field experiment, we assessed arthropod overwintering in two maize undersowing treatments (maize-fescue, maize-clover), two catch crop treatments (landsberger mix, green rye) and maize with and without tillage and an adjacent field margin as negative and positive control, respectively. All undersowing treatments were sown together with maize and not tilled after harvest while all catch crop treatments were tilled before autumn sowing. Overwintering arthropods were assessed in the following spring (March to May) using emergence traps. We aimed to investigate which factor was most decisive for successful arthropod overwintering in maize: soil cover, soil dormancy in autumn (i.e. no tillage), individual treatment identity or the interaction between them.

We found that for total arthropod biomass, ground beetle, dipteran and hymenopteran individuals, autumn soil dormancy was the most important factor, while for all arthropods and rove beetle individuals, the interaction between autumn soil dormancy and high soil cover provided by undersown maize-clover, maize-fescue and field margins was more important. Only for spider individuals did specific treatment characteristics (maize-fescue, field margin) determine the number of emerging individuals. Among other environmental benefits, undersown crops left in the field can provide suitable overwintering habitats for arthropods, but soil dormancy in autumn seems to be even more important.

Session 2

Arthropod communities under global change





Arthropod responses to flower strips and areas in European agroecosystems – A meta-analysis on beetles and spiders

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Since the 1990s, flower strips and areas have regularly been implemented as agri-environmental schemes to counteract insect declines in European agricultural landscapes. Beetles and spiders—two arthropod groups strongly affected by species loss—play key regulatory roles in ecosystem functioning but remain understudied in systematic syntheses in comparison to pollinators. Therefore, we investigated beetle and spider abundance and species richness in sown flower strips and areas compared to different control types, e.g., inner-crop or grassy margins. In the frame of a systematic review, we conducted literature searches in ISI Web of Knowledge and Google Scholar, selecting peer-reviewed studies on beetles and spiders in sown wildflower strips or areas across Europe. Furthermore, we analyzed land-use and climate/weather data for the selected primary studies from the Copernicus project and the CHELSA database as well as age of wildflower strips and number of sown species on both taxa. We identified 38 studies that fit our criteria from 1995 to 2022, covering 14 countries. Results indicated that Shannon habitat diversity positively influenced abundance and richness of both arthropod groups. Beetle abundance and richness benefited from flower sowing in areas with increased annual precipitation, and beetle richness declined with higher annual mean temperatures. Spiders showed only marginal response to climatic variation, but their richness increased with habitat age. Our findings suggest that land-use and climate change have shaped beetle and spider assemblages over the past 30 years. We showed that flower strips can support different arthropod groups. Thus, more and varying habitat structures are needed in agricultural landscapes to sustain biodiversity in a changing climate.

Responses of arthropod and plant species to land-use intensity and environmental gradients

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Anthropogenic pressures such as land-use intensification and habitat fragmentation increasingly threaten biodiversity by altering habitat structure and connectivity, particularly in grasslands and urban greenspaces. Arthropods and plants show highly variable responses to these pressures depending on the species and its requirements.

In two complementary studies, we used quantitative niche models to assess species-specific responses of arthropods and plants to mowing, fertilizing, and grazing, as well as to isolation and urbanization. The first study analyzed 1,352 arthropod species across 150 grassland plots in Germany between 2008 and 2018. The results reveal twice as many species were categorized as losers compared to winners and that mowing and fertilizing had the most detrimental effects. The second study focused on 249 urban greenspaces across three German cities, documenting 342 plant and 667 arthropod species. Again, the losers outnumbered the winners in arthropods and in plants even more clearly. Yet, both studies show that neutral species still predominate, and most species are generalists to human pressure, but results may vary depending on the traits a specific species possesses. A further comparison of the results with the protection and conservation status on the Red List shows that many management practices affect the already most vulnerable species.

Together, the findings underline niche modeling as a robust tool for analyzing species-specific responses to land-use and management practices, which can be used as a basis with the Red List to develop targeted conservation strategies tailored to the ecological requirements of vulnerable species.

Every species counts: Arthropod species loss, but not their identity, underpins biomass declines

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Arthropod diversity, abundance and biomass are unparalleled by any other animal group, making their recent declines central to the global biodiversity crisis. Yet, we lack a mechanistic understanding of the respective contributions of species richness, species identity and abundance to overall biomass change, and how the environment filters these processes. Synthesizing 11 years of data from a biodiversity experiment and from farmed grasslands across a gradient of plant species richness and management intensity, we show that arthropod biomass declines were predominantly (> 90%) linked to *species richness* losses. *Abundance* declines among persisting species accounted for only 5-8% of lost biomass. The role of *species identity* depended on the environment and diminished over time: especially under high plant diversity and low land-use intensity, rare arthropod species with below-average total biomass and above-average individual biomass contributed disproportionately to species turnover—but only in early years. We conclude that arthropod communities are currently homogenizing towards few common species of similar biomass, likely reducing their adaptability to environmental change. At this point, every species counts, making their conservation pivotal for maintaining ecosystem functioning. Increasing the diversity and reducing the management intensity of grasslands may mitigate ongoing community simplification and loss of arthropod diversity and functioning.

Land-use impacts on crop yield: direct and indirect roles of arthropods and associated ecosystem services in European farmland

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Intensification of land use to increase crop production is often detrimental to biodiversity and associated ecosystem services, thus threatening food security in the longer term. It is questionable whether the crop production achieved by conventional high-intensity agriculture could be approached by enhancing supporting and regulating ecosystem services (i.e. ecological intensification). To disentangle how local and landscape-scale land use affects arthropods (abundance, species richness, and functional diversity), ecosystem services (pollination and natural pestcontrol) and yields, we re-analysed 37 datasets, including community data of three groups of service providers: bees, ground beetles, and spiders in a set of meta-analytical structural equation models. Local land-use intensification reduced the abundance of all three arthropod groups. Spider species richness in the fields was the only variable that was negatively affected by a higher percentage of arable land in the surrounding landscape. A high abundance of bees improved crop pollination and increased crop yields. In

the models for the two predator groups, crop yield was strongly determined by land use, independent of pest control services provided by natural enemies. We suggest that the lack of relationships between predator community structure and levels of pest control services is due to the complexity of predator-prey interactions, which often involve multi-level interactions and intraguild predation motifs that may dampen top-down control of pests. Although many recent studies have highlighted the importance of incorporating functional diversity, our trait-based approach did not reveal strong relationships with the variables studied, which may be due to already highly simplified arthropod communities or a lack of individual-level trait information for arthropods. Our results indicate that the potential for ecological intensification varies between taxonomic groups and target ecosystem services. In the context of current efforts to reduce land-use intensity, our study suggests a potential for ecological intensification in crops where pollination benefits yield, but not for pest control. In addition, different measures of ecological intensification may be required to support natural enemies.

Experimental disentangling the effects of mowing technique and unmown refuges on grassland arthropods

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Roadside verges and meadows can provide habitats and stepping stones for grassland arthropods in urban and non-urban environments. However, arthropods are directly and indirectly negatively affected by intensive mowing. Changing mowing techniques or strategies could reduce displacement and mortality induced by mowing and thus support grassland arthropod populations. However, recently developed “arthropod-friendly” mowing techniques, scare devices, and string trimmers have been rarely studied. Besides the mowing technique change, unmown refuges can play a vital role in urban green spaces to mitigate the negative impacts of mowing.

Conducting two different field experiments on roadside verges and meadows, we compared the direct influence of different mowers on arthropod densities. The first study on roadside verges compares a conventional roadside flail mulcher, a roadside “eco mower”, and a string trimmer. The second study on meadows compares a bar mower, an “eco mulcher”, and a traditional flail mulcher, all techniques commonly used in urban areas. Additionally, for both experiments, we sampled an unmown area directly adjacent to each mown area to study the impact of refuges and the effect of a scare device mounted at the front of the “eco mower”.

Our results indicate a generally negative impact of all mowing techniques on arthropods. Mower types on roadside verges showed no significant differences, while on the meadows, the bar and eco mowers were less negative for arthropods than the conventional mulcher. Arthropod densities in refuges remained unchanged from before mowing, indicating that unmown refuges provided essential habitat during the mowing process.

Regardless of mower type, unmown refuges play a crucial role in mitigating the overall negative effects of mowing on arthropods and can serve as habitats in hostile environments such as roadside verges.

The role of green roof attributes for roof-dwelling arthropod communities

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Green Roofs (GRs) are theorized to mitigate the issue of limited green space in cities and while their numbers are rapidly increasing, their effect on biodiversity conservation is not clear. In particular, plant and insect community assembly on GRs has rarely been investigated. To unravel relationships between GR vegetation, arthropod communities and structural and environmental factors, we conducted a comprehensive monitoring during the summer of 2023 across 75 GRs in the city of Ingolstadt, Germany. We sampled above and belowground arthropods in 1 m2 plots at the center of each GR and tested factors related to building, substrate, management and weather as predictor variables. GR age positively influenced Acari and Nematocera, but had negative effects on Heteroptera. Older GRs showed positive effects on Araneae abundance when plant biomass and plant diversity were also high. Young GRs showed higher Coleoptera and Formicidae abundance when plant diversity was high, this was less important when GRs were older. Height positively influenced Auchenorryncha abundance but negatively influenced groups like Araneae, Nematocera and Coleoptera. GR area negatively affected Acari, while it positively affected groups Auchenorryncha, Brachycera and Nematocera. High soil depths had positive effects on groups Auchenorryncha, Collembola, Aphids, and Coleoptera only when SOM was low. In shallow soil depths, high SOM had positive effects on most of these groups. In GRs with deeper soils, a high WHC was beneficial for Auchenorryncha, Collembola, Formicidae, and Araneae, whereas, in low soil depths, it was the opposite. Temperature had negative effects on total arthropod abundance. Management affected groups differently. Our study highlights the role of site-specific, human management and environmental factors in shaping arthropod communities on GRs. According to our results, GRs represent ecosystems in the urban environment, able to support different types of arthropods. Our findings show the importance of considering specific GR characteristics to favor certain arthropod groups when planning and designing GRs.

When is a pesticide 'low risk'? A simulation-based evaluation of EFSA's equivalence test and an alternative method

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Pesticide use harms non-target organisms despite regulatory risk assessments prior to their approval. These assessments typically follow a tiered structure, where more ecologically relevant higher-tier studies override risk indications from lower-tier studies. Higher-tier studies typically rely on point-null tests, where failure to detect significant negative pesticide effects is interpreted as safety. However, this approach risks overlooking harmful effects in underpowered studies. Honeybee field studies - the standard for pollinator risk assessment - often lack sufficient power.

Therefore, the European Food Safety Authority (EFSA) proposed a shift from point-null tests to equivalence tests. Under the new paradigm, a pesticide is classified as 'low risk' when the reduction in honeybee colony size in the pesticide group relative to the control group is significantly (alpha = 0.2) smaller than 10%. However, concerns have been raised that the new guidance would make it too difficult to demonstrate a pesticide's safety. Hotopp *et al.* proposed an alternative equivalence test that calculates treatment effects as the difference between the pesticide group mean and the lower bound of the 90% confidence interval of the control group.

Here, we evaluate EFSA's and Hotopp *et al.*'s equivalence tests through simulations based on real honeybee field data. We compare the tests' ability to avoid false 'low risk' classifications. We further analyze how accounting for initial colony strength, either as a covariate or via optimized colony allocation using anticlustering randomization, can reduce the required number of sites at different true effect sizes. Our results show that EFSA’s equivalence test substantially better controls false 'low risk' classifications than Hotopp *et al.*'s test and remains feasible with a manageable number of sites, particularly when initial colony variation is accounted for.

Adverse Local Weather Effects Limit Arthropod Activity

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Climate change poses a significant threat to biodiversity and undermines the stability of ecosystems worldwide. This occurs primarily through changes in local weather patterns, such as shifts in temperature extremes, precipitation, and the frequency and intensity of extreme events, which particularly affect poikilotherms like arthropods. Most research aiming to predict the effects of local weather on arthropods is conducted at low spatial and taxonomic resolution; however, understanding how local weather limits arthropod activity is essential for accurately forecasting biodiversity responses to climate change. Such analyses require data with high spatial and temporal resolution, which are rare and challenging to collect in ecological field studies. To overcome this challenge, we deployed AI-based camera traps equipped with object detection models on 27 grassland plots across three German landscapes. These traps continuously recorded arthropod activity and were paired with high-resolution weather data from climate stations located within five meters of each camera. Because weather conditions tend to constrain rather than define arthropod activity, we applied quantile regression to detect these limiting effects across multiple weather variables. We tested the influence of temperature, precipitation, wind, photosynthetically active radiation (PAR), soil moisture, humidity, and soil temperature on the hourly activity of total arthropods and six orders: Arachnida, Diptera, Hymenoptera, Coleoptera, Hemiptera, and Orthoptera. Our results revealed both general patterns and taxon-specific responses. For example, total arthropod activity was strongly limited by temperature (optimum curve) and positively influenced by humidity. Among other effects, PAR increased activity in Orthoptera and Diptera, and humidity had a strong positive effect on Diptera and Hemiptera. Our findings show that while changes in weather affect all arthropods, other environmental variables tend to influence only a subset of taxa; moreover, the complex and taxon-specific nature of these responses highlights the need for high-resolution data to accurately predict arthropod responses to changes in local weather and climate change.

Bush encroachment in Namibian rangelands and its impact on arthropod communities and ecosystem functions

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Arthropods are key contributors to ecosystem functioning in Namibian agroecosystems. Smallholder farmers depend on the ecosystem services provided by arthropods because they cannot replace them with anthropogenic activities. Knowledge of arthropod biodiversity or the effects of land use on arthropod communities in Namibia is very limited. This gap is of concern as more than 70% of Namibia's human population is economically dependent on the agricultural sector. Large areas of Namibia's semi-arid regions are used for livestock grazing. Bush encroachment, mainly driven by a few shrub species (*D. cinerea, S. mellifera and T. sericea*), is therefore a major threat to agricultural production and human livelihoods. We determined the effects of these major encroacher species and different bush control techniques on ground, foliage and aerial arthropods and their functional roles in replicated plots on three farms in the Kalahari basin of Namibia during the dry and wet seasons. Both the identity of the dominant encroacher species and the method chosen to control encroachment (thinning: 50% or 100% and treatment: arboricide or cutting) had pronounced effects on the taxonomic and functional composition of arthropod communities. Foliage-dwelling arthropods contributed most to the observed community dissimilarity between plots with different encroacher species, but also soil-dwelling taxa (e.g. woodlice) occurred exclusively in plots dominated by *S. mellifera*. In the short term, the impact of bush cutting on local arthropod communities and ecosystem functions was stronger compared to arboricide treatment. In times of well-documented arthropod declines in several regions of the world, it is crucial to understand how anthropogenic activities alter arthropod communities in historically understudied regions. Considering only the economic dimension and ignoring the environmental consequences due to lack of knowledge will repeat past mistakes and may cause major problems in the future.

Bergmann's Rule and Thermal Melanism Shape the Phenological Assembly of Butterflies

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Phenological diversity arises from life cycle constraints and alignment with seasonal abiotic conditions, yet the mechanisms shaping phenological structure remain poorly understood. We tested whether the physiological and developmental mechanisms that structure butterfly assemblages across space also shape their seasonal assembly. To do so, we analysed community-weighted means of body size and colour lightness from 477 assemblages evenly distributed across Great Britain and the group's flight season. Variation in both traits was greater across the season than across space, stressing the primary contribution of phenology in diversity variation. Assemblages had larger-bodied species in early and late season—coinciding with low temperature and radiation—in line with Bergmann's rule, but opposite to the spatial trends found. This pattern was driven by species overwintering as adults. Ventral wing colouration darkened in early and late season, consistent with seasonal thermal melanism, and covaried with body size, suggesting thermoregulatory interaction between both. Our findings contribute to understanding the mechanisms underlying insect phenology, suggesting that both life cycle constrains and physiological alignment with seasonal environment play key roles.

Species-specific reduction of survival and aphid consumption in temperate ladybirds exposed to prolonged and intensified heat waves

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Global climate change is accelerating the frequency and intensity of heat waves, posing severe risks to ecosystems by disrupting species survival and interactions, and modifying species ranges. Insects are highly sensitive to thermal extremes, showing species-specific physiological breakdowns with cascading effects across community dynamics. Critical insect-mediated ecosystem services, e.g., agricultural pest control, can deteriorate when heat-impaired predators die or fail to capture herbivores. In this study, we tested how insect predators responded to various heat wave regimes (prolonged duration, increased temperature), derived from realistic meteorological data. In five ladybird species (*Coccinella septempunctata, Ceratomegilla undecimnotata, Harmonia axyridis, Hippodamia variegata* and *Propylea quatuordecimpunctata*), survival was monitored over 12 days and aphid consumption was measured every 3 days. Ladybird survival did not differ between realistic heat waves and control treatments represented by average summer temperatures. Extreme heat waves (realistic heat wave +5°C) reduced the survival of all ladybird species except for *Hippodamia variegata*. However, only the prolonged exposure to extreme heat waves (>6 days) significantly reduced survival in *Coccinella septempunctata* and *Ceratomegilla undecimnotata*. Interestingly, the most vulnerable species to extreme heat waves were the globally invasive ladybird *Harmonia axyridis* and the small-sized native *Propylea quatuordecimpunctata*, reaching over 50% mortality in less than 2 days. Individuals of *Harmonia axyridis* and *Coccinella septempunctata* exposed to the realistic heat wave showed reduced aphid consumption throughout the heat wave duration. By integrating realistic meteorological data with an interspecific approach, our study highlights species-specific survival and predation patterns under heat waves, which can be crucial for future pest control strategies in a warming world.

Effects of arthropods on decomposition processes and decomposer communities of plant and animal necromass in changing forests

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Decomposition of necromass (e.g. carrion, leaf litter, deadwood) is a key ecosystem process associated with arthropod and microbe decomposers. Considering that arthropods are declining; a better understanding is needed how they affect decomposition. Moreover, since forest ecosystems are changing rapidly due to climate-change related mortality, it is important to understand how this affects decomposition and related decomposer communities of involved taxa.

To quantify the effect of arthropods on decomposition as well as effects of canopy openness on decomposition rates and decomposer communities, we exposed carrion, leaf litter and deadwood with and without arthropod exclusion in paired closed-canopy and gap plots in three climatically different regions in Germany and sampled arthropods, fungi and bacteria. The effects of canopy openness and arthropods on decomposition rates differed clearly between necromass types: Carrion was decomposed three times slower in the absence of arthropods, while for deadwood, arthropods accelerated decomposition particularly in warmer and drier forests. Communities of arthropods, fungi and bacteria differed between closed forests and gaps and arthropod exclusion modified fungal and bacterial communities for all types of necromass.

These findings suggest that arthropods play an important role for decomposition processes and influence microbial decomposers, and that canopy openness is a major driver of decomposers and decomposition. Increasing tree mortality and declining arthropod populations could, thus, have far-reaching effects on decomposer biodiversity as well as on carbon and nutrient cycling. Conservation measures should aim at maintaining open and closed forest conditions and provision of necromass, particularly deadwood and carrion, to maintain decomposer biodiversity and associated ecosystem functions.

The hidden costs of fish farming on freshwater invertebrates

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In a human-altered cultural landscape, many invertebrates have faced many challenges in the form of pollution, invasive species, or ecological traps. The problem lies mainly in the fact that for the assessment of quality, individuals use mechanisms that simply do not work in human-altered environments. It is no different in freshwater habitats, where humans, through their management, change a number of key elements affecting the survival and overall fitness of freshwater invertebrates, including dragonflies. Fishponds, like many other human-made habitats, often appear very attractive, but this does not reflect their "true" quality. In our manipulative experiment, we compared the body size, fitness, immunity, and mortality rates of dragonfly larvae (*Sympetrum spp*.) reared in ponds (n = 18) with different intensities of fish farming management. The larvae were placed for 40 days in an enclosure covered with nylon netting with a mesh size allowing prey to colonize the enclosures. After this time, the larvae were collected, and their body size, immune parameters, and the amount of fats and proteins were measured. Based on our results, it was evident that even if we eliminated the direct effect of predation, the overall fitness of larvae (especially fat and protein reserves) was lower in larvae placed in intensively managed ponds. This probably reflects mechanisms that are not directly related to predation, but overall quality of the environment, causing long-term deprivation, stress, and other non-lethal effects associated with intensive fish farming management.

Linking biodiversity conservation and ecosystem service management in Mediterranean olive cultivation landscapes

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Global declines of biodiversity and associated ecosystem services are tightly linked to land-use intensification and climate change. Agroforestry systems, such as traditional Mediterranean olive groves, can buffer these effects if managed to support key species and ecological functions.

The ECO-OLIVES project investigated biodiversity-management-production relationships in 12 organically managed olive groves in Tuscany, Italy. The groves were selected to represent high and low levels of surrounding semi-natural habitat cover, and we studied the effects of local and landscape structure, predator presence, and systematic pruning over a three-year period (2022–2024). We conducted bird point counts, bat acoustic monitoring, different arthropod sampling methods, and harvest measurements, combined with predator exclusion experiments and seasonal pruning treatments (Feb vs. Apr).

Our results show that surrounding SNH cover and local vegetation structure significantly shaped biodiversity. Bird abundance and functional richness, as well as bat activity, were higher in low-SNH groves (<30%), while high-SNH groves (>30%) supported more insectivorous specialists and arthropod richness. Local shrub cover increased bird abundance by 10%. Bird species richness, as well as arthropod and bat activity varied seasonally.

Bird and bat exclusions led to increased pest infestation and reduced olive yields. February pruning significantly enhanced both yield and fruit quality, while increasing beneficial arthropods such as ants and spiders, and reducing pest taxa such as olive flies.

Our findings demonstrate that local vegetation structure, semi-natural habitat cover, and targeted pruning jointly shape biodiversity patterns, pest control, and olive yield. These results underline the importance of biodiversity-based management in Mediterranean agroecosystems and contribute critical evidence toward integrating conservation and ecosystem service delivery into sustainable land use development.

Effects of winter conditions on post-overwintering performance of Harmonia axyridis

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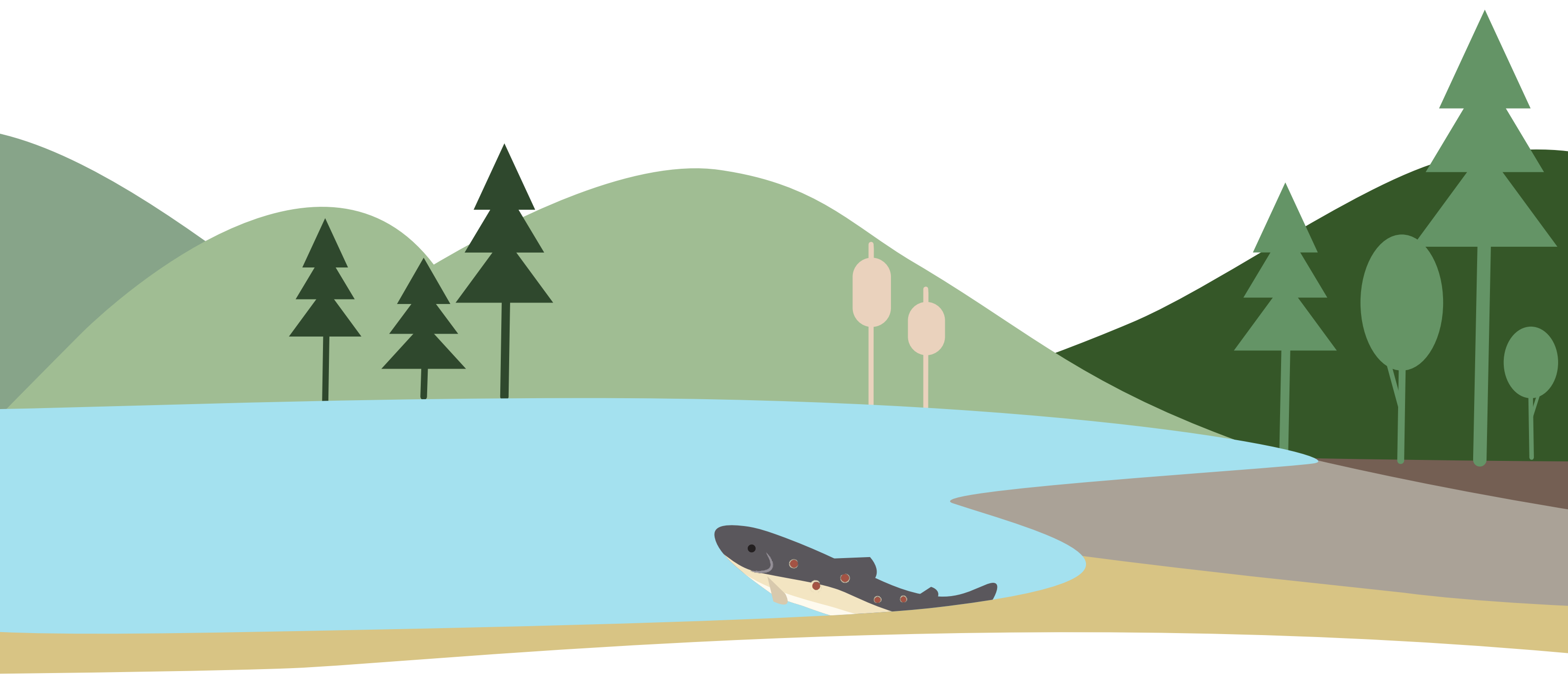
Overwintering is one of the most energetically demanding periods an insect can go through. Environmental conditions during this time, particularly under shifting climatic conditions, can significantly affect not only survival but also post-winter physiological performance in insects. In this study, we examine how variation in abiotic factors influences post-overwintering survival and body mass changes in the harlequin ladybird (*Harmonia axyridis*), an invasive species that undergoes a weak diapause followed by quiescence. Ladybirds were overwintered at multiple field sites differing in altitude and microclimate, with data loggers recording local temperature and relative humidity. Upon spring, we collected the beetles and recorded the number of survivors. Surviving adults were then isolated without food and provided only with water, and their longevity under starvation was monitored as a proxy for remaining energy reserves. Our preliminary results indicate that microclimate, including temperature and relative humidity, significantly influences both ecological and physiological parameters. In particular, relative humidity appears to be a key predictor of post-overwintering survival and changes in body mass, even more so than temperature. However, winter worm spells seem to have a significant effect on ladybird long-term survival. Our findings highlight the complex effects of abiotic stress on post-winter survival and may improve predictions of invasive species persistence and range shifts under climate change.

Session 3

Behavioural and movement ecology



Female dark eye display in sand gobies covaries with male attention and nest building, regardless of sex ratio

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Little is known about what factors promote the evolution of female ornaments under sexual selection. In the sand goby, *Pomatoschistus minutus*, a small marine fish, females are very cryptic, except for a temporary ‘dark eye’ display, a highly conspicuous black pigmentation near the eyes. Nest-building males show nuptial coloration and courtship to attract mates, but no dark eyes. The function of this female trait remains unknown. We aimed to investigate whether the adult sex ratio affects the occurrence, duration, or latency of dark eye displays in female sand gobies. Two adult sex ratio treatments that reflect natural conditions (male bias: 3 females, 4 males; female bias: 3 females, 2 males) were used. We predicted more frequent or longer displays under a female-biased adult sex ratio if its main function relates to intrasexual competition. We found no significant effect of adult sex ratio on the occurrence, duration, or latency of the display. However, relatively rounder females displayed for longer, implying it may signal spawning intent. Consistently, spawning was more likely to happen in replicates in which a dark eye display was observed. Furthermore, better quality nests were associated with a higher frequency of dark eye displays, suggesting that nest quality affects the display or that the display encourages more male investment in nest building. Dark-eyed females also received more attention from males than non-displaying females. Together, our results suggest the function of the display is related more to communication between the sexes than to competition among females. However, further research is needed to explore to what extent it is used by males in mate choice, affecting whether it should be called an ornament.

Foraging distances and habitat use of four honey bee species across Southern Indian landscapes.

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Honey bees are among the most important pollinators in natural and agricultural landscapes but are increasingly under threat due to multiple factors, including habitat loss, fragmentation, agricultural intensification, invasive species, and climate change. While much of our understanding of honey bee biology, including their behavior and ecology, comes from the Western honey bee (*Apis mellifera*), relatively little is known about other Apis species that occur in Asia. The southern Indian state of Kerala is home to three native Asian honey bee species: *A. cerana, A. dorsata,* and *A. florea*, along with the introduced *A. mellifera*. This region offers a unique opportunity to compare these species across landscapes that differ in the proportion of forests, plantations, and urban areas. Although foraging ecology of A. *mellifera* has been widely studied, systematic comparisons of habitat use and foraging distances among native Asian species and *A. mellifera* remain scarce. Given their shared traits, such as high resource demands and efficient foraging via dance communication, substantial overlap in habitat use is expected, particularly in human-modified landscapes with reduced resource availability. In this study, we decode waggle dances across landscapes with varying habitat compositions to investigate species-specific foraging distances and habitat preferences. By comparing species-specific foraging strategies, we aim to understand how land-use change shapes foraging strategies among different honey bee species in tropical environments. Our findings will provide new insights into honey bee foraging ecology and contribute to understanding pollinator responses to landscape modifications in a rapidly changing world.

Urban bumblebees diversify their foraging strategy to maintain nutrient intake

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Anthropogenic ecosystems can alter individual functions and ecological processes such as resource use and species interactions. While variability of morphological traits involved in diet and resource use has been observed between urban and non-urban populations of pollinators, the consequences on the dietary and pollen-transport patterns remain poorly understood. Here, we investigate the variability in the diet breadth of rural and urban individuals of two bumblebee species and the consequences for nutrient intake and pollen transport. We show that urban bumblebees exhibit a larger diet breadth than their rural counterparts, driven by the enhanced floral diversity in cities. However, we found that the nutrient intake remained similar across urban and rural ecosystems, indicating that bumblebees' foraging strategies can be adapted in terms of diet breadth to maintain intake and rations of critical nutrients. Finally, we found distinct pollen-transport patterns between urban and rural individuals, with urban individuals being more dissimilar than rural ones in the transported pollen both in the body and in the leg- baskets. Our findings highlight the importance of considering complementary facets of species'' diet and interactions when assessing the effects of anthropogenic ecosystems.

Habitat requirements and home range use of the threatened garden dormouse (*Eliomys quercinus*) in a coniferous forest

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Understanding habitat use and requirements is essential for the conservation of endangered species, such as the garden dormouse (*Eliomys quercinus*). Therefore, we radio-tracked garden dormice (n = 39) in the Black Forest National Park (Germany) between 2019 and 2021, determined home range size by calculating autocorrelated kernel density estimates, located resting sites during the day, and analyzed their resting behavior. Furthermore, we investigated their crossing behavior across paths varying in width, in the degree of canopy closure, and understory. Median home range size was 3.8 ha (Q25 = 2.3 ha, Q75 = 6.6 ha) in adults and 1.9 ha in juveniles. Adult males increased their home range sizes during reproduction. In September, shortly before hibernation, adults used smaller home ranges, likely to save energy. During the day, garden dormice used nest boxes and natural nests under the ground as resting sites. Ground holes were an important resource as they were most frequently used by reproductive individuals and also at low ambient temperatures (0.1–14.7 °C). In contrast, nest boxes were used only at higher ambient temperatures (> 5.9 °C). Forest trails with tree cover and/or undergrowth were frequently crossed by adults, while 4 m wide forest paths without tree cover or undergrowth were rarely crossed. The results of our study show that the preservation of natural resting sites, the restoration of forest trails, or the installation of crossing structures are important conservation measures for the garden dormouse, facilitating migration and colonization of new habitats and reducing the risk to lose genetic variability.

Conservation insights from a long-term movement study on a bird of prey

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Long-term studies on movement ecology are essential for understanding the life histories and conservation needs of wildlife. Moreover, studies on the landscape use of a focal species can provide reliable baseline data for mitigation measures. In a long-term study on a European species of conservation concern, the Red Kite (*Milvus milvus*), we used telemetry data to provide recommendations for sustainable wind energy utilization. Over a timespan of eight years, we analysed >20 million transmitter-based data points of 37 adult Red Kites in Hesse, Germany. We monitored their movement in relation to breeding sites, their vertical flight patterns, and evaluated observation-based space use analyses, a standard method applied in approval procedures for wind turbine construction. Our results show a a strong bond to the nest site over the course of the entire breeding season of both sexes, with a main activity radius of 1.5 km around the eyrie. Therefore, mitigation assessments to reduce collision risk of the species should not only focus on the mere breeding phase of the Red Kite between March and July, but should also consider the post-breeding phase until September. Moreover, the altitudinal flight patterns during the breeding season showed that more than a quarter of flight movements took place in the rotor area of currently operating wind turbines, while this proportion would be lower at future turbines with higher hub heights. A critical proportion of 90 % of all Red Kite flights could be protected from potential collision by applying cut-in wind speeds of approximately 5.4 m/s. When comparing field observations with telemetry data, we found that certain methods to analyse space use of Red Kites led to a significant over- or underestimation of the actual movement patterns, which entails the risk of misjudging uncritical wind power locations in the landscape. Our findings underscore the value of long-term telemetry for informing adaptive conservation strategies.

Hidden Markov movement models reveal state-switching behaviour of a nomadic species in response to environmental dynamics

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Animal movement is a key strategy for adapting to changing environments, enabling individuals to track foraging resources or avoid environmental risks, with important implications for survival and fitness. As extreme weather events intensify and human activities increasingly alter landscapes, predicting species' movement responses becomes critical for conservation. Hidden Markov Models (HMMs) applied to GPS telemetry data offer a powerful approach to infer unobservable behavioural states from observed movement, helping to identify behaviours and areas of conservation importance. We applied HMMs to hourly GPS data (2020–2023) of nomadic Mongolian gazelles (*Procapra gutturosa*), a species with extensive movements across the steppe. The ability of these gazelles to travel vast distances is central to their survival, yet is increasingly challenged by harsh weather and expanding anthropogenic land use. We fitted separate HMMs for summer and winter, and were able to reliably distinguish three behavioural states: encamped, area-restricted search (foraging), and traveling. Our results revealed that during the snow-free season, NDVI (a measure of vegetation greenness) most strongly influenced movement behaviours, while snow cover was the dominant factor in winter. In summer, gazelles used areas with intermediate NDVI values for foraging and higher values to rest at night (i.e., taller vegetation that provides more cover). In winter, gazelles were more likely to become encamped (i.e., trapped) with increasing snow cover. Although the highly dynamic nature of these environmental drivers and strong individual variability prevented us from identifying specific key areas for each behaviour, our findings highlight the environmental factors most influential to gazelle behaviour and provide valuable knowledge for future conservation efforts.

Prophylactic amputations and therapeutic wound care behaviours in ants

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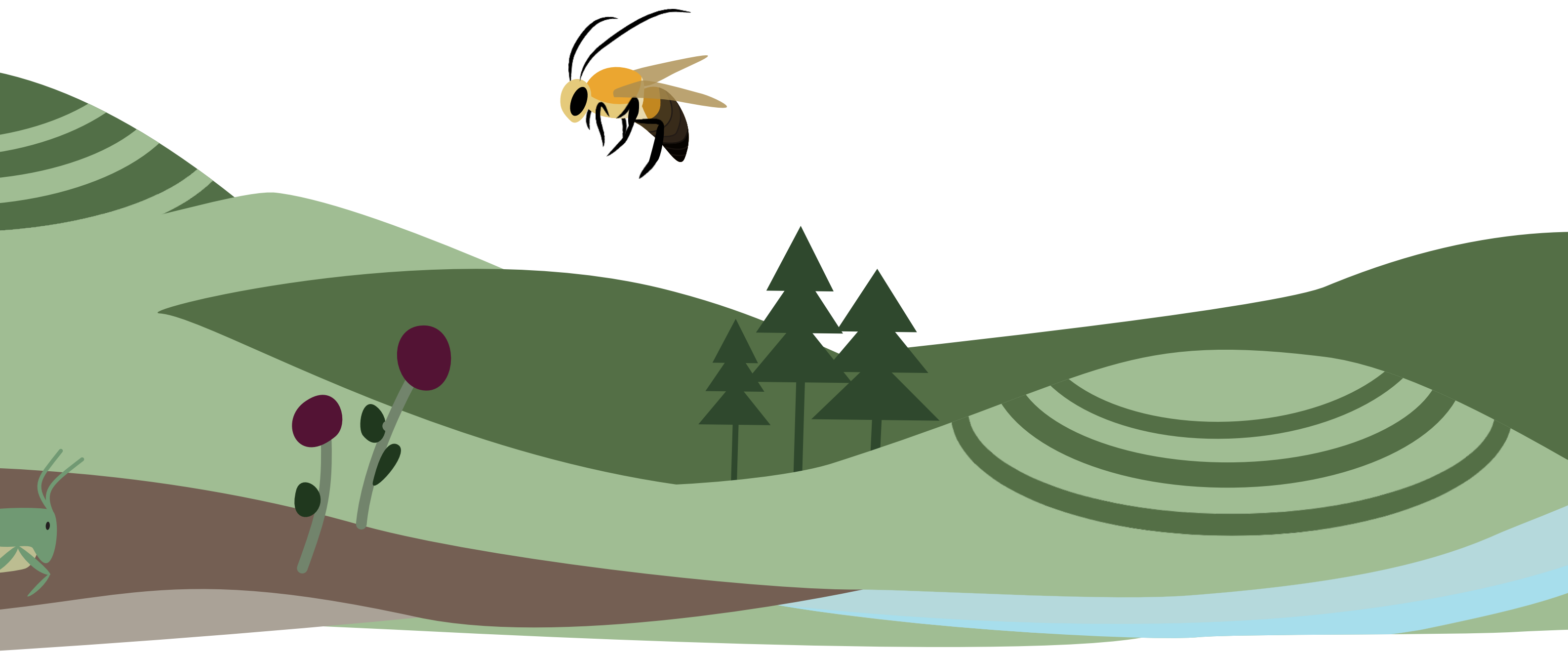
Open wounds pose major infection and mortality risks in animals. To mitigate this threat, different species have evolved distinct behavioural strategies. We compare two contrasting forms of wound care: one dependent on the metapleural gland, and one independent of it. In *Megaponera analis*, infected wounds are treated therapeutically with antimicrobial secretions from the metapleural gland, reducing mortality by up to 90%. Chemical analyses revealed over 121 compounds and 41 proteins in these secretions, around half with antimicrobial properties. In contrast, *Camponotus* ants, lacking a metapleural gland, employ a strikingly different strategy: workers amputate the infected limb by biting it off at the base. This prophylactic behaviour halts infection and ensures survival. The phylogenetic distance and ecological divergence between *Megaponera* (a group-hunting predator) and *Camponotus* (a solitary generalist forager) suggest that wound care has evolved independently and may be more widespread in ants than previously recognised. Our findings reveal a complex, plastic system of social wound care that can distinguish between sterile and infected injuries and adaptively deploy either therapeutic chemical treatments or prophylactic amputations. This highlights the evolutionary flexibility of cooperative behaviours under pathogenic pressure and the convergent emergence of functionally analogous solutions in response to a shared threat.

Session 4

Biodiversity and ecosystem functioning across scales



Unveiling key drivers of global variation in plant diversity effects on productivity

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The positive impact of plant diversity on productivity has been widely reported, primarily explained by two main effects: complementarity effects and selection effects. However, the extent of these effects varies significantly, and the underlying causes remain insufficiently understood. Through a meta-analysis of 452 global experiments, we find that productivity increases on average by 15.2% from monocultures to species mixtures with an average species richness of 2.6. The net biodiversity effects are more pronounced in grassland and forest ecosystems but weaker in container, cropland, and aquatic systems. Among these effects, complementarity contributes 65.6%, while selection accounts for 34.4%. Several factors enhance complementarity effects, including greater phylogenetic diversity, the mixing of nitrogen-fixing and non-nitrogen-fixing species, and increased functional diversity in leaf nitrogen content. These findings highlight the roles of niche partitioning, biotic interactions, and abiotic facilitation in driving complementarity. In contrast, stronger selection effects are associated with higher species biomass inequality in their monocultures. Over time, complementarity effects tend to strengthen, whereas selection effects weaken, though both remain stable across different climatic conditions. These findings offer crucial insights into the global variability of biodiversity impacts on productivity. They emphasize the need to consider both complementarity and selection mechanisms in biodiversity conservation and ecological restoration strategies.

Leaf it to the canopy: Vertical patterns of herbivory in temperate forests

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Herbivory is a key ecological process that influences plant community dynamics and mediates interactions across trophic levels, playing a central role in shaping biodiversity and ecosystem functioning. In forest ecosystems, complex vertical structures and diverse species assemblages highlight the need to understand the drivers of herbivory to better predict ecosystem responses. While biodiversity effects on ecosystem processes are well documented, their variation across vertical forest layers, and via physiological and structural attributes, remains unclear. In this study, we investigate invertebrate herbivory across canopy and understory layers in a temperate beech forest. We assessed physiological and structural diversity, herbivore identity, and microclimatic variation. Preliminary results reveal higher leaf area loss in the canopy, potentially due to higher light and resource availability. Leaf area loss across layers showed mixed relationships to herbivorous arthropod abundances, suggesting different functional roles of herbivore taxa. Aboveground biomass and temperature were negatively associated with herbivory, in contrast to canopy height heterogeneity, possibly due to greater niche availability and lower predation pressure. Layer-specific analyses revealed divergent drivers of herbivory: in the canopy, herbivory increased with plant area index, canopy height heterogeneity, and temperature variability. This suggests that structurally complex canopies may either support herbivore persistence or reduce predation. Conversely, ground-layer herbivory declined with increasing biomass and plant area index but increased with foliage height diversity. These contrasting patterns underscore the importance of stratified assessments and highlights complex interactions between vegetation structure, climate, and trophic dynamics. Ongoing work will integrate physiological stand attributes to further disentangle the mechanisms driving herbivory patterns across forest layers.

Secondary Seed Dispersal and Dung Beetles

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Zoochory is crucial for seed dispersal in tropical forests. Different primate species contribute to varying degrees. Dung beetles attracted to mammal dung act as secondary seed dispersers, relocating seeds from the dung to safer microclimates and potentially enhancing germination rates. Our study focuses on the Ecuadorian Chocó, presenting a tripartite network involving primate dung, dung beetles, and seeds. We also quantify seed removal within 32 sites of differing ages.

We evaluated predictors of seed dispersal, including exposure to dung beetles, presence of ants, seed size, and forest age as fixed effects, with site as a random effect in a Generalized Linear Mixed Model. Exposure to dung beetles ($p < 0.0001$), presence of ants ($p < 0.0001$), and seed length ($p < 0.0001$) were important predictors; forest age was not significant ($p = 0.0517$).

We quantified morphospecies and seed mass from brown-headed spider monkey and mantled howler monkey dung and dung balls from four dung beetle species. Howler monkey dung had less seed mass than spider monkey dung. Four dung beetle species were exclusive to howler dung and three to spider dung, indicating preference and possible resource partitioning, though the network was not significantly specialized ($H2' = 0.049$).

Dung beetle partitioning of mammal dung resources is supported by primate dung partitioning and distinct volatile profiles. The dung beetle–seed network was slightly more specialized due to seed size filtering ($H2' = 0.44$). Using seed mass as a proxy for dispersal efficiency, we found significant differences between monkey species. Examining seed mass to dung mass ratio, dung balls from howler dung were 0.079 g/g, and spider monkey dung balls 0.26 g/g ($t = -3.82$, $df = 42.8$, $p < 0.001$). This suggests howler monkey dung provides a resource advantage to dung beetles and that seeds within howler dung may face fewer negative effects of conspecific proximity.

Food Web Complexity Underlies the Relationship Between Biodiversity and Ecosystem Functioning

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Biodiversity change has elicited widespread concern over the consequences for functions and services provided by ecosystems. Despite extensive evidence for a positive effect of biodiversity on ecosystem functioning within a single trophic level, how this biodiversity effect varies with multitrophic food web structure remains unresolved even though most ecosystems contain two to six trophic levels. We investigate how food web complexity modulates BEF relationships in nature by quantifying energy fluxes as proxies of two major ecosystem functions—primary consumption and predation—in 319 highly-resolved, complex food webs from marine, lake, stream, and soil ecosystems. Ecosystem functioning increased consistently with taxon richness across all trophic levels and ecosystems, which arose from greater vertical diversity (i.e., maximum trophic level) in more taxonomically diverse food webs. Furthermore, consumer trophic dissimilarity (trophic complementarity) positively influenced predation fluxes in all ecosystem types except soil. These findings highlight the threat of trophic downgrading to critical ecosystem functions (e.g., biological control and maintenance of ecosystem stability) provided by predators, which are typically most vulnerable to anthropogenic disturbances. Our study demonstrates that the consequences of biodiversity change are deeply entangled within the web of life, emphasizing the need to conserve the trophic complexity underlying positive biodiversity-ecosystem function relationships.

Investigating the impact of aboveground invertebrate decline on soil ecosystem functioninga

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Ecosystem processes and multifunctionality are impacted by global change through the alteration of above-belowground multitrophic communities in terrestrial ecosystems. Global change manifests in many ways, one of them being the decline of aboveground invertebrate communities. Sharp invertebrate declines have been reported for German grasslands in particular, with heretofore little information about the consequences for trophic interactions and ecosystem functioning. With our study, we aim to investigate how aboveground invertebrate declines are impacting various soil ecosystem processes. We established an Ecotron experiment, titled Insect Armageddon, in which we experimentally reduced aboveground invertebrate biomass in three levels: 0% reduced, 64% reduced, and 100% reduced. A comprehensive set of approaches allowed us to assess belowground decomposition and energy fluxes via the construction of soil food webs for estimating integral ecosystem processes such as belowground herbivory and pest-control. We expect intact aboveground invertebrate communities to support higher ecosystem functioning, and decreased functioning for communities with simulated aboveground invertebrate decline. Our first results show that reduced aboveground invertebrate biomass significantly decreases belowground decomposition. Given the crucial importance of decomposition processes for overall terrestrial ecosystem functioning, the present results highlight that a decline in aboveground invertebrate communities may threaten element cycling and soil health.

Modelling interactions between different types of functionally diverse tundra vegetation at large scale

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The Arctic tundra is a highly diverse ecosystem where different types of vegetation, including mosses, lichens, grasses and shrubs, provide key functions that are relevant from the local to the global scale. The tundra vegetation not only serves as a habitat and food resource for wildlife, but is also involved in nutrient acquisition and cycling, in particular regarding nitrogen. The vegetation cover regulates microclimate via albedo and evaporation, and may exert a cooling effect on the soil, thus protecting permafrost carbon under a changing climate.

While these processes have been studied in detail for individual vegetation types, such as non-vascular vegetation or shrubs, it is largely unclear how interactions between different groups affect overall ecosystem functioning. More specifically, how will shifts in the functional composition of one group alter the composition and functions of another group? Understanding these interactions is crucial for improving projections on tundra biodiversity and ecosystem services under climate change and associated stressors, such as forest invasion.

Here, we present a process-based, eco-evolutionary modelling approach that explicitly simulates different functionally diverse groups of tundra vegetation and their interactions. By switching on and off the effects of one group on the functional composition of the other group, we are able to quantify separately the impacts of biotic interactions between groups and of abiotic environmental conditions on the community composition and associated ecosystem functions at high latitudes.

Leaf litter decomposition dynamics across forest succession in the Ecuadorian Chocó

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Litter decomposition by arthropods, microbes, and fungi is a key ecosystem process in tropical forests, yet its response to disturbance and recovery remains poorly understood. We investigated decomposition dynamics across a forest succession gradient in the Ecuadorian lowland Chocó (Esmeraldas) using a chronosequence of 32 plots, from active cacao plantations and pastures (age 0), through secondary forests (1–38 years), to old-growth forest. Aboveground (AG, 5 mm mesh) and belowground (BG, tea mesh) litterbags were used to isolate arthropod- and microbe-driven decomposition, respectively. Each bag contained standardized leaf litter from five common tree species and was collected at three time points over 135 days. AG decomposition was modeled against forest age and environmental factors including tree aboveground biomass, surface temperature, litter biomass, elevation, and slope. BG decomposition was modeled using soil pH, C:N ratio, soil moisture, soil temperature, and slope. We also tested the effects of disturbance and large animal exclusion using four treatments: control (C), fenced (CF), perturbed (P), and perturbed-fenced (PF). AG decomposition increased with forest age but followed a U-shaped curve in plots recovering from cacao, with mid-successional declines and higher rates in old-growth. Key drivers included surface temperature, elevation, and biomass. BG decomposition was unaffected by forest age, declined with higher C:N, and peaked at intermediate soil moisture. Large animal exclusion had no effect alone, but disturbance (P, PF) altered decomposition. Notably, decomposition in P plots recovered over time, while PF plots remained suppressed, highlighting the role of large fauna in facilitating recovery.

Arbuscular mycorrhizal fungal diversity mediates plant and soil driven biodiversity effects on ecosystem functioning

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Multiple facets of biodiversity interact with environmental change, shaping biodiversity–ecosystem functioning (BEF) relationships and modulating ecosystem responses to stress. Yet most BEF research focuses on guild-based facets of biodiversity, assuming that effects of different guilds on ecosystem functioning are independent. This overlooks the potential of cross-guild interactions – such as plant–microbe interactions – to impact ecosystem functioning.

We addressed this gap in a 15-month mesocosm experiment manipulating plant diversity (one, two, or six grassland species), soil biodiversity (via whole-soil inoculation), and drought. Using 18S rRNA metabarcoding, we quantified arbuscular mycorrhizal (AM) fungal diversity and assessed eight ecosystem functions related to productivity, fertility, and water dynamics. This enabled us to disentangle the roles of plant, AM fungal, and soil biodiversity in driving ecosystem multifunctionality.

Plant diversity emerged as the strongest driver of ecosystem multifunctionality, followed by soil biodiversity. AM fungal diversity independently enhanced multifunctionality, impacting five of the eight measured functions and mediating up to 59% of plant- and soil-driven BEF effects. Drought increased the importance of specific plant and AM fungal taxa in sustaining ecosystem functions. However, all three facets of biodiversity showed trade-offs, with gains in some functions occurring at the expense of others.

Our findings reveal complex, non-additive interactions among plant, AM fungal and soil biodiversity. They challenge the notion of biodiversity as a universal enhancer of ecosystem functioning, instead uncovering nuanced trade-offs across biodiversity facets. By demonstrating the importance of cross-guild interactions within the BEF framework, we highlight the potential of integrative BEF research to inform resilient and adaptive ecosystem management strategies.

Contrasting effects of deadwood and gaps on the trophic structure of forest soil microarthropods

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Understanding the mechanisms driving forest biodiversity is challenging, especially in soil. Deadwood input and gap formation are major disturbances from tree mortality, altering ecological niches of forest organisms, but their individual and interactive effects on soil animals remain unclear.

The trophic niche is a key dimension of animal ecology. Trophic diversity, defined as the area organisms occupy in trophic niches, links resource processing to ecosystem functions. Changes in trophic diversity can arise from shifts in species diversity or in the trophic niches of individual species. While effects of disturbances on species diversity are well-documented, their role in shaping trophic diversity of soil animal communities remains poorly understood.

Across three regions in Germany, we conducted a full-factorial experiment manipulating deadwood addition and gap formation, examining trophic niches in Collembola using stable isotopes (^{13}C, ^{15}N). Deadwood addition generally increased trophic levels (higher $\Delta^{15}N$), while gap formation increased use of plant carbon (lower $\Delta^{13}C$), especially in epedaphic and sexual species. Deadwood also enhanced community trophic diversity, whereas gap formation reduced it in euedaphic Collembola. Notably, these changes stemmed from trophic shifts within species rather than species turnover.

Shifts due to deadwood addition likely resulted from increased habitat heterogeneity and resource use, contributing to trophic differentiation. In contrast, gap formation promoted understory plant growth, increasing plant-derived resource use. Reduced trophic diversity in euedaphic Collembola suggests trophic homogenization, likely from uniform root consumption. These findings highlight contrasting disturbance effects: deadwood enhances habitat heterogeneity and trophic differentiation, while gap formation induces trophic homogenization but biomass gains in euedaphic Collembola, reflecting ecological trade-offs.

Soil microbial associations with ecosystem multifunctionality during 50 years of forest development: comparing monoculture tree planting and natural regeneration

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The recovery of ecosystem functioning is one of the main challenges of forest restoration worldwide in recent years. While monoculture plantations are one of the most common practices and effective in producing timber at the expense of biodiversity, natural regeneration is gaining attention because of its effectiveness in restoring forests' diversity and vital functionality. However, despite its importance, little is known about the association of soil microbes with ecosystem functions during long-term forest development. Here, we aim to understand how soil microbial diversity contributes to ecosystem development over time,

especially under different forest restoration strategies.

This study focused on the long-term response of the ecosystem over a 50-year chronosequence to two restoration methods in northern Japan: monoculture planting and natural regeneration, using old-growth forests as a reference. Using DNA metabarcoding, we analyzed two soil bacterial and fungal communities that are functionally vital but have different environmental preferences and dispersal abilities. We explored ecosystem multifunctionality by considering crucial ecosystem functions like nutrient cycling, decomposition, and below-ground production during two types of forest succession.

In the plantation, the decline of soil fungal α-diversity with forest age was related to specific functional development, such as decomposition rates. By contrast, microbial α-diversity remained stable after natural regeneration, and compositional similarity with the old-growth forest was associated with higher multifunctionality. Notably, while fungi contributed to decomposition, bacteria were important for plant-available nitrogen cycling, suggesting their complementary roles in ecosystem functioning. Overall, these results underscore the importance of soil microbial diversity in promoting multifunctionality and highlight the benefits of natural regeneration in long-term forest restoration.

Bridging ecological modelling and ecosystem services: an adaptive approach to constructing ecosystems using plant and animal functional groups

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Climate change and anthropogenic activities are causing environmental damage, resulting in biodiversity loss and decreasing ecosystem services. To improve living conditions for both humans and other organisms, ecological restoration and Nature-based Solutions (NbS) are particularly effective strategies, especially in areas that have been severely impacted, such as urban or degraded ecosystems. To better forecast the impacts and future dynamics of ecological restoration and NbS, it is essential to model the plants and animals within these ecosystems effectively as either species, or Functional Groups (FGs) or Types (FTs). While FGs have an adequate level of detail and coverage to retrieve meaningful modelling results across a variety of ecosystems, they currently lack traits that are relevant in estimating the ecological, thermal, or hydrogeological impacts on their surroundings, especially in relation to other stakeholders within the ecosystem (i.e., humans, plants, mammals, and birds).

Moreover, FGs are usually not readily linkable to the single species and to their individual properties such as e.g., invasive potential, aesthetic characteristics, or ecological relationships such as diet preference. In this study, we propose an adaptive approach to represent ecosystems through a novel classification framework that retrieves plant functional groups (PFGs) and animal functional groups (AFGs). First, we developed globally applicable PFGs that integrate traits related to shading, pollution removal, CO2 sequestration, enhancement of outdoor thermal comfort for humans, soil-plant interactions, ecological networks, and pollinator requirements. Second, we construct AFGs based on traits related to diet preferences, body mass range, and taxonomic classification.

This innovative framework to represent ecosystems through PFGs and AFGs, facilitates the estimation of a broad range of ecosystem services across various modelling and abiotic factor configurations. The approach holds significant potential for guiding urban planning, managing restoration efforts, and evaluating or optimising Nature-based Solutions (NbS).

Biodiversity makes happy - but which biodiversity?

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Biodiversity can have positive effects on human health and wellbeing. But what is it about biodiversity? Which pathways link biodiversity to wellbeing? How do perceptions of biodiversity matter and are there differences via the visual and audio sense? And does familiarity matter? Here, we present empirical and experimental research on linkages of actual and perceived biodiversity with mental health and well-being in forests and urban ecosystems. Finally, we discuss how spatial planning and landscape management or behavioural interventions could help foster positive experiences.

Biodiversity Oasis - Urban Cemeteries as Biotopes and Stepping Stones: Recognizing, Enhancing and Communicating Biodiversity

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Oases of Diversity – Cemeteries as Structurally Rich Biotopes for Urban Biodiversity

Can and should urban cemeteries be rewilded - and how? As green spaces within densely built environments, cemeteries are often perceived as valuable oases - not only for grieving and remembrance, but also as places of recreation and nature experience: They provide critical habitats for a variety of plants, animals and fungi.

Yet, cemeteries are under increasing pressure. Some are being closed, repurposed, built over, or maintained in ways that may not support biodiversity. What kind of maintenance supports ecological value? How should cemeteries evolve from a biological perspective? Should they be managed as natural oases - or be left to fallow - or be build over? And what other factors shape biodiversity in cemeteries - such as size, isolation, urban context, or human presence?

This doctoral project aims to assess the existing biodiversity of urban cemeteries and identify key parameters for enhancing it. It combines ecological field studies with citizen science approaches to monitor various animal taxa, including mammals (bats and terrestrial species), arthropods (beetles, bugs, spiders), and others. The ultimate goal is to highlight the ecological potential of cemeteries and provide actionable recommendations for their management. Promoting biodiversity in times of global biodiversity loss and climate change is more urgent than ever. Enhancing structural diversity and preserving cemeteries as habitats for animals, plants, and fungi is therefore essential for sustaining urban biodiversity.

Decoding the role of emergent microbial traits and functions in the persistence of microbial-derived soil carbon as shaped by land use intensity and biodiversity

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Microorganisms play a crucial role in soil organic carbon (SOC) cycling. Emerging paradigms highlight that the continuous turnover of microbial life and death significantly contributes to the long-term stabilization of persistent SOC, primarily through the transformation of plant-derived carbon into microbial necromass that is bound to soil minerals. Key microbial traits, such as microbial growth and carbon use efficiency (CUE), and microbial functioning, are central to the formation of persistent SOC from microbial necromass. However, the quantitative and mechanistic understanding of how these emergent microbial traits and functions influence the microbial contributions to SOC storage remains unclear. By studying these concepts within the Biodiversity Exploratories framework, here we provide a comprehensive analysis of how land use and changes in above- and belowground biodiversity affect microbial physiological traits and functional potentials, and their roles in microbial-derived C in SOC storage in the topsoil (0-10 cm) of grassland and forest soils across three distinct regions in Germany. Our preliminary results reveal distinct microbial mechanisms underlying the general concepts of necromass contributions to SOC persistence. In higher intensively managed grasslands, we observed higher microbial biomass, growth rate, and CUE, potentially leading to more efficient necromass recycling, which in turn results in lower microbial-derived carbon in SOC. In contrast, in forests, the higher growth rate and CUE potentially promote necromass production and stabilization in clay-rich soils, thereby enhancing microbial contributions to SOC. Furthermore, we aim to disentangle the roles of environmental setting and different microbial communities as drivers of key microbial traits and functions that influence the persistence of microbial-derived SOC, which is shaped by land use intensity and biodiversity loss.

Roe deer and earthworms in the forest: friends in the sun, foes in the shade

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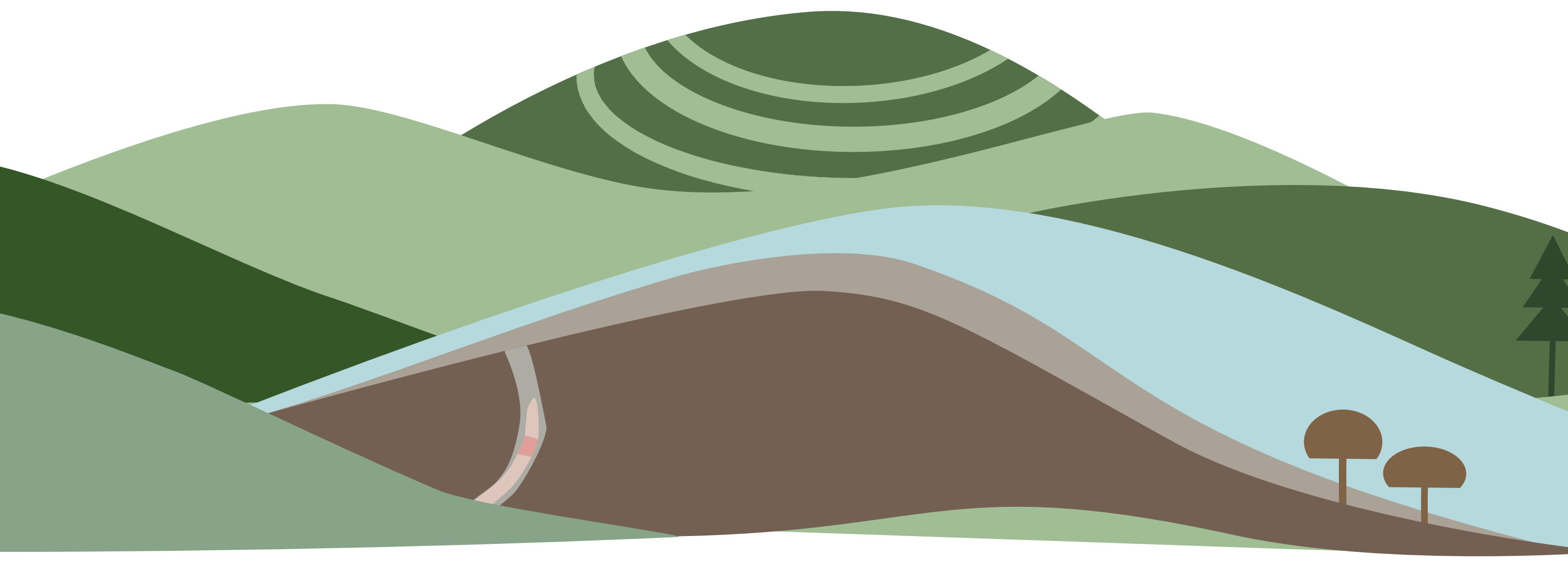
Earthworms are crucial ecosystem engineers that enhance soil structure, decompose organic matter, and support nutrient cycling, contributing to forest resilience under global change. However, forests face increasing pressures from climate change, including canopy dieback and shifts in browser populations. In temperate Europe, rising tree mortality creates canopy gaps and alters understory light, while growing roe deer (*Capreolus capreolus*) populations intensify browsing pressure. These factors influence tree regeneration and above–belowground interactions, potentially impacting soil fauna like earthworms. To date, no study has combined high replication with a full-factorial design to disentangle the interactive effects of canopy gaps and browsing on earthworm communities. To address this, we conducted a field experiment in a temperate forest in Germany. We artificially created canopy gaps and installed 6×6×2 m deer exclosures (n = 21) alongside control plots in shady, dense forest stands (n = 54). Our results show that earthworm abundance and biomass were significantly higher in canopy gaps compared to shaded forest patches. While roe deer alone had a limited effect, browsing in canopy gaps increased earthworm abundance, whereas browsing in shaded areas reduced it.

Session 5

Biodiversity trends



Overarching functional shifts in Germany's plant communities: persistence matters most

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While most habitat types of German vegetation do not have suffered from species loss over the last century, land use change and climate change have resulted in considerable species turnover. We here ask whether taxonomic turnover has also resulted in functional shifts. Using the ReSurveyGermany dataset of 7,738 (semi-)permanent vegetation plots that were surveyed between 2 and 54 times from 1927 to 2020, we calculated the linear trends in community-weighted means for 60 traits for all of the ca. 100 terrestrial EUNIS habitat types in Germany and explored both the overarching and the habitat-specific patterns. Besides including typical traits of the leaf and roots economics spectrum, we particularly included traits on persistence, such as woodiness, clonality and resprouting capability. Our analyses suggest a functional shift from fast growth and short life cycles to persistent and conservative strategies for the majority of habitat types. Over all community types, species gained in cover and became more frequent that were taller, less annual, more woody and more wind-pollinated, had thicker and denser roots, and rooted deeper. These shifts mainly suggest an effect of natural succession following the abandonment of traditional management in most habitat types. However, not all habitat types followed the same trend. In wetlands, also the proportion of helo- and hydromorhic species decreased, indicating decreasing water supply. In wetlands and oceanic to subcontinental inland sand grasslands, proportions of species with scleromorphic leaves increased, indicating drought effects, and thus, possibly reflecting climate change. Their habitat types, such as heathlands, show trait shifts that indicate eutrophication. Grasslands and wetlands suffer from losses of specialist and Red List species. The insights gained from these functional shifts allows conclusions on potential drivers that will help to develop habitat-specific conservation and restoration measures in Germany.

20th-century insect trends follow intensification and climate change

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With the growing interest in insect declines, temporal trends in insect communities have been increasingly studied in recent years. Several anthropogenic drivers, such as land-use or climate change, have been identified as important drivers of observed changes in insect communities in recent decades. However, many of these drivers have been affecting insect communities for many decades or longer, but long continuous time series of insect communities are lacking. Using 1.2 million species records, we reconstructed continuous changes in the distributions of 811 saproxylic beetle and butterfly species in Switzerland between 1930 and 2021, covering a period of major land-use and climate changes. From the 1930s to the 1950s, both groups declined. While saproxylic beetles stabilised and then recovered, butterflies continued to decline until the 1980s and have not recovered since, resulting in an average richness 15% lower today than in 1930. Declines have been greater for specialist and cold-adapted species and during periods of increased agricultural mechanisation. With climate warming, especially warm-adapted species have increased since the 1980s. Our results show clear declines in insect distributions during the 20th century, following widespread processes such as agricultural intensification. Recoveries in recent decades due to climate warming benefit primarily warm-adapted species, but also highlight improvements, for example in forest ecosystems.

Nationwide Bumblebee Monitoring in Agricultural Landscapes in Germany: Insights into Population Trends, Phenological Patterns and Floral Resource Use

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Bumblebee populations are declining globally, despite their critical role in maintaining ecosystem functions such as the pollination of wild plants and crops. Alongside climate change, intensive agricultural land use is a key driver of this decline. To better understand trends in bumblebee populations within agricultural landscapes, comprehensive, long-term, and large-scale data collection is essential. We established a nationwide, citizen science-based monitoring program in agricultural landscapes across Germany (https://wildbienen.thuenen.de/), employing a standardized sampling design based on non-lethal transect surveys and expert-validated species identification.

Here, we present data from the first five years of the program (2021–2025), encompassing more than 100 monitoring sites across the country. Although 41 bumblebee species are documented in Germany, our data reveal a strong dominance of just three species or species groups, which together account for approximately 75% of all observations. We also recorded the presence of species listed as threatened or critically endangered on the national Red List, indicating that agricultural landscapes can still serve as habitat for rare and declining species. Furthermore, we analyzed the phenology and floral resource use of bumblebees. Despite interannual variability, phenological patterns between years were remarkably consistent, and bumblebees utilized a broad spectrum of floral resources, spanning over 80 plant genera. We identify plant genera of particular importance throughout the year and discuss their relevance for pollinator-friendly agricultural practices. Over the long term, this monitoring effort provides a robust baseline to detect shifts in bumblebee populations in response to land-use intensity and climate change. By integrating land-use data, the program also offers a framework for evaluating potential mitigation strategies and their effectiveness.

Bird population trends since the 1950s: a resurvey across Germany

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Birds are among those taxa for which we know most about long-term population change, and about potential drivers of change. This is due to coordinated monitoring schemes that involve a large number of volunteers. In Germany, population trends from standardized, plot-based and replicated schemes that cover over 100 species are available since 1990.

However, standardized breeding bird surveys had been conducted much earlier, since the 1920s, with an upsurge in the 1960s. Most of the data from these surveys is scattered across local publications and the grey literature, or unpublished. So far, little synthesis on population trends has been attempted.

Tracking population trends back as far as possible is important, because i) fundamental drivers of population change such as agricultural intensification and changes in forest management have occurred already long before 1990, ii) there are few data available informing debate about population baselines for restoration and conservation policies, iii) the first generation of quantitatively working ornithologists is now retiring, suggesting potential loss of data.

We have set up an initiative to synthesize standardized historical bird surveys across Germany. We also developed a platform to motivate birdwatchers to conduct resurveys at historical plots in a citizen science approach (www.dda-web.de/monitoring/historische-daten).

In our talk, we present an overview of the available data and first results on population change in birds since the 1950s. Recurring patterns suggest that agricultural intensification has led to a strong decline in farmland bird species since the 1960s, likely even exceeding that observed since the 1990s. In contrast, many forest birds and shrub breeders were likely stable or increased in abundance over the past 70 years, mirroring a strong increase in wood volume across Germany.

Assessing the impact of past climate and land use change on bird occupancy dynamics in North America

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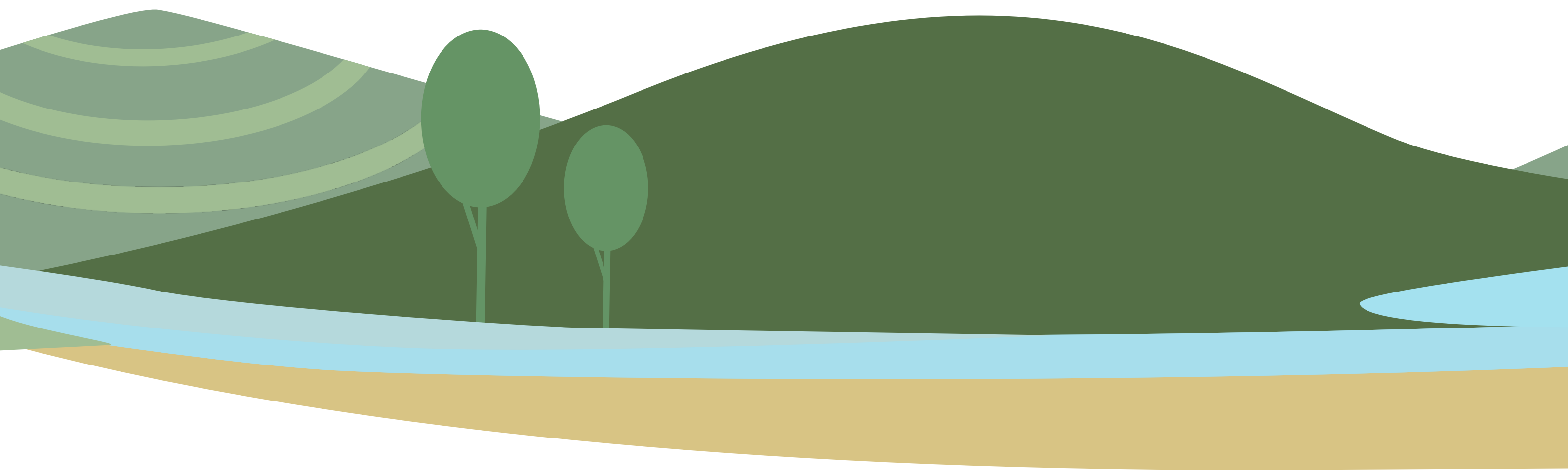
There is growing evidence that the ranges of many species change in response to environmental change. How different global change drivers contribute to colonisation and local extinction across species is, however, poorly understood. Here, we use dynamic occupancy models that simulate simple metapopulation dynamics to assess changes in occupancy of 159 bird species across the conterminous USA over 25 years (1995-2019). We then attribute these changes to climate and land-use changes. We focus on US breeding birds as the North American Breeding Bird Survey provides a comparatively extensive data set on species occurrences across space and time. In the dynamic occupancy models, we relate site-level colonisation and extinction to climate and land use variables using a Bayesian approach. Simulated occupancy dynamics are evaluated using a spatial and temporal block cross-validation. Finally, we quantify the relative contribution of climate and land use change to the simulated occupancy dynamics based on counterfactual scenarios with detrended climate and constant land use at the levels of 1995, the first year of our observation time series. Our statistical framework allows robust attribution of multiple global change drivers on transient bird occupancy dynamics. This can provide valuable information for species management under environmental change and represents an important step towards operationalising detection and attribution in biodiversity science.

Session 6

Climate change effects on biodiversity



Climate Niche Divergence: The Impact of Local Climate on Biodiversity Change

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The ongoing impact of climate change on biodiversity will increase in the near future. Global trends have been widely studied, but there is still limited knowledge on the landscape-scale level effects. The present study investigates representative climate niches in the study region around the city of Bonn at the transition of the atlantic to a continental climate, with local differences in precipitation and temperature also due to topography. The present study aims at modelling climate change impact on biodiversity of four climatically distinct municipalities within the study region to investigate whether changes follow parallel or diverging trends. We identify European climate analogues (based on a sigma dissimilarity metric, reference period 1981–2010) to infer potential future vegetation for the study region based on climate projections for the high emission scenario SSP5-8.5 (2071–2100).

The climate analogues of the municipalities extend over large distances from the Upper Rhine Valley in Germany to Nouvelle-Aquitaine in southwestern France.

The majority of plant species currently found in the study region are also reported from the climate analogues. Shared species predominantly show moderate or no clear temperature preference. Species complement and land use show broad overlap between both study region and climate analogues, yet natural vegetation differs sharply. The study region (across the four sites) is currently characterised by beech and mixed beech forests. Conversely, the climate analogues of municipalities at higher elevations are dominated by oak-hornbeam forest, while those at lower elevations are dominated by submediterranean downy oak forests.

This study highlights the magnitude of potential biodiversity change at a landscape level and the divergent development of climate niches in closely adjacent regions, indicating the need for fine-grained models for developing strategies for conservation and climate adaptation.

Climate change in context: elevation and species traits mediate plant community shifts

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Climate change is reshaping biodiversity, triggering species to shift their ranges in search of suitable thermal conditions. These shifts are driving thermophilization—a directional replacement of cold-adapted species by warmth-demanding ones. However, community responses often lag behind climate warming, a pattern hypothetically associated with slow-growing and long-lived life-history strategies, dispersal limitation, and microclimatic buffering. Mountain systems, with their sharp climatic gradients and diverse plant communities, offer ideal settings to examine context-dependent changes. We reassessed vegetation plots in Mount Rainier National Park (US), originally surveyed in the 1970s, to evaluate how overstory communities have changed over four decades of global warming. Using hierarchical joint species distribution models (HMSC), we quantified overstory species' responses to warming, snowpack reduction, and moisture change, and tested how these were shaped by elevation and species traits (thermal niche, seed mass). Species' responses were highly variable and contingent on elevation and thermal niche. Overall effects were weak, but warm-adapted species declined in occurrence at lower elevations while benefiting at higher elevations. These patterns suggest that the thermal niche influences how sensitivity to warming changes along the elevational gradient. Our findings highlight the importance of integrating environmental context and species traits to better predict community reassembly under climate change.

Long-Term, High-Resolution Landcover Reconstructions from Fossil Pollen and Deep Learning

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In the context of modern climate change, understanding spatiotemporal patterns of land cover change is increasingly important. Although modern satellite-based land cover datasets provide detailed spatial information about contemporary landscapes, they only cover the last few decades and are therefore inadequate for investigating vegetation dynamics over millennial timescales. In contrast, fossil pollen records offer a unique insight into the history of vegetation over extended timescales. However, the compositional nature of pollen data, coupled with their coarse and uneven spatial distribution, limits their direct integration with modern land cover products.

To address these issues, we have reconstructed the distribution of major land cover classes across the Northern Hemisphere over the past 20,000 years using the fossil pollen dataset LegacyPollen 2.0 and modern relationships of pollen and land cover. We then spatially downscaled these reconstructions to a resolution of ~ 300×300 m using the spatial distribution of modern climatic variables, the relationships between landcover classes and climate, and an assignment algorithm. To address spatial gaps where no pollen records exist, we use a deep learning model, trained on observed patterns, to extend coverage across unsampled regions.

The resulting dataset provides a continuous, high-resolution view of terrestrial land cover change throughout the Holocene and the late glacial period. We present the dataset alongside initial validation results to demonstrate their utility for ecological analyses. This dataset offers a novel resource for exploring the interactions between vegetation, climate, and human activity over long timescales, supporting fundamental research and conservation planning.

Global insect-fungus interactions and its response to climate

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Species interactions shape biodiversity patterns and regulate critical ecosystem processes, yet their responses to changing climatic conditions remain poorly understood. While studies across different climatic zones have suggested stronger predation and herbivory in tropical regions compared to higher latitudes, a comprehensive understanding of how species interactions influence broader biodiversity patterns and community dynamics across global climate gradients remains limited.

Here, we conducted a global field experiment across 53 forest sites spanning broad temperature and precipitation gradients to investigate how climate influences interactions between wood-decomposing fungi and insects. By manipulating insect access to deadwood and comparing fungal diversity between treatments with and without insects, we show that insects significantly altered fungal community composition and diversity. Fungal alpha diversity decreased with increasing temperature regardless of insect presence, but increased with precipitation, with a stronger positive effect observed when insects were present. For beta diversity, temperature alone had no significant effect; however, precipitation increased community differences between treatments, and this effect was temperature dependent: beta diversity between treatments decreased with precipitation at low temperatures, but increased with precipitation at high temperatures.

These results demonstrate that insects play a key role in shaping fungal diversity and community composition at a global scale, with climatic conditions modulating these interactions. Our study highlights the importance of incorporating biotic interactions and their climate dependencies into models predicting deadwood decomposition and carbon cycling under future climate scenarios.

Alpine butterflies under pressure: How community and species traits respond to warming temperatures

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Global warming forces species to move their distributional ranges poleward or uphill to track their climatic niches, potentially favoring species with certain life history traits. Thereby disadvantaged species are experiencing higher pressure to adapt to warming temperatures by other means, possibly triggering changes in physical properties like body size or color lightness. Yet, few studies have observed inter- and intraspecific trait changes over time in a common study setting. Here, in 2019, we repeated a butterfly monitoring from 2009 on 33 grassland sites along five elevational transects in the National Park Berchtesgaden (Germany). We collected several life history traits (body size, color lightness, dispersal ability, voltinism) of each observed butterfly species from literature and used them to monitor changes in community traits along the elevational gradient and over time. For the genus Erebia, which turned out to be especially under pressure by rising temperatures in the Alps, we further measured the wingspan and color lightness of each individual in each year to also consider intraspecific trait changes along elevation and over time.

TERENO Long Term Monitoring: Impacts and mitigation of extreme events on birds and bees

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Within the TERENO (Terrestrial Environmental Observatories, https://www.tereno.net) network, we are conducting a monitoring program focusing on wild bees and birds since 2009 at the Harz/Central Germany Lowland Observatory run by UFZ. While "normal" years are informing us about the baseline of population variation from year to year, years with extreme weather events can be taken as a proxy for expected impacts of climate change. The years 2018-2020 and 2022 were taken as examples for extreme weather events, as they were characterized by severe droughts and high temperatures. This opened the opportunity to investigate the hypothesized impacts on bee and bird populations by comparing the situation of 2009-2017 (baseline before extreme events) with the years 2018-23 (response after extreme events). We expected that population stability, species traits and environment play a role in the reaction of populations to extreme events, with birds being more affected than bees due to the higher trophic level.

Our results supported theoretical expectations, e.g. a higher negative impact of dry and hot years on less stable populations, larger and cold adapted species, and long-distance migratory birds. We also found evidence that woody elements and rich flower resources could buffer the impacts of heat waves at least in wild bees, likely by providing more suitable microclimatic conditions and increasing population resistance. Our results thus show options for land use-based mitigation which should aim at increasing (i) overall population stability; and (ii) the amount of woody features such as hedgerows and mass flowering crops locally to buffer negative effects of heat and drought waves.

Cold waves in the Amazon rainforest and their ecological impact

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Cold waves crossing the Amazon rainforest are an extraordinary phenomenon likely to become more frequent under climate change. While the negative impact of cold waves on agriculture and human health has been shown, the impact on natural rainforest ecosystems remains poorly understood. We recorded an extensive cold wave in June 2023 in Amazonian–Andean forests and investigated its impact on lowland animal communities (insects and wild mammals). For this, we analyzed the biomass and abundance before, during and after the cold wave, and compare environmental temperatures to experimentally measured thermal tolerances of insects. We found strong reductions in activity abundance, biomass and/or diversity of all animal groups under the cold wave. However, mammal activity and the biomass of most insects recovered over the next season, but dung beetle biomass remained low. In accordance with this finding, tropical lowland animals showed thermal tolerance limits below the lowest environmental temperatures measured during the cold wave. However, a quarter of all insects showed very small thermal safety margins (0.62 °C) with respect to the recorded minimum temperature of 10.5 °C, suggesting that an increased intensity of cold waves in the future could imperil cold-sensitive taxa of Amazonian animal communities.

Red List criteria underestimate climate-related extinction risk of range-shifting species

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Climate change is a major threat to biodiversity, elevating extinction risks and causing global redistribution of species. Early identification of the most vulnerable species is urgently needed to apply conservation measures with sufficient warning time. The IUCN Red List provides guidelines for assessing species at risk from climate change, relying on species distribution models (SDMs) and spatially explicit population models (SEPMs). Yet, it has never been systematically tested how well these guidelines work for species not only undergoing range declines but also range shifts. In this study, we used a simulation approach to investigate the ability of the Red List criteria to detect climate change risks for species with different life history traits and climate vulnerability. For this, we used SEPMs to simulate virtual species (varying in four traits: niche position, niche breadth, growth rate and dispersal distance) under climate change and fitted different SDM algorithms to the data. Among all traits tested, the niche position proved most important for the accuracy of the Red List assessment. Specifically, SDM-based Red List assessments underestimated extinction risk of warm-adapted, range-shifting species because dispersal limitations prevented colonisation of newly available habitats. In contrast, for cold-adapted, range-contracting species, SDM predictions accurately approximated expected range loss and related extinction risk. Red Listing based on SEPM-based extinction probability, rather than SEPM-based abundance predictions, provided delayed warning for all species. Based on our findings, we provide tentative recommendations for updating the IUCN Red List guidelines for assessing extinction risk imposed by climate change.

Identifying knowledge gaps on above-belowground fauna responses to global change.

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Ecosystems are under constant pressure by global change. Abiotic and biotic components being altered by drivers like land use or climate change can lead to the loss of ecosystem functions and services crucial for either the ecosystem or humans. Fauna fulfills many of these functions like herbivory, predation, pollination or decomposition. Hereby, aboveground and belowground fauna often complement or interact with each other. For example, pollination is limited to aboveground fauna while decomposition is mainly achieved by belowground fauna like arthropods, microbes, or earthworms. However, it has been shown that they can be differently affected by global-change drivers and thereby show various responses. This underlines the importance of simultaneously studying both aboveground and belowground fauna to evaluate the impacts of global change on ecosystems and humans. Most published studies focus either on aboveground or only belowground fauna. To evaluate the availability of studies and potential knowledge gaps investigating the impact of global change on aboveground and belowground fauna in terrestrial ecosystems, we conducted a systematic map literature assessment. We searched the Web of Science for studies fitting our criteria which were that the impact of at least one global change stressor on above- and belowground fauna (animals, microbes and fungi) was empirically investigated. Of the 4000 studies screened only about 100 studies fit our inclusion criteria. These articles were then screened for information on study period, geographical location, investigated taxa, ecosystem types, global change stressors and conducted methods. Our analysis provides an overdue summary of what we know and where we urgently need to close existing knowledge gaps to comprehensively understand global-change impacts on terrestrial ecosystems.

Terrestrial biodiversity in a changing world: exploring contrasting responses of multi-level biodiversity to climate and land use

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The way in which we use our land has significant impacts on biodiversity and consequently human wellbeing. The transformation of natural habitats into agricultural areas or settlement changes the species inventory and therefore the provision of ecosystem services such as pest control, pollination and decomposition. At the same time, land use impacts on biodiversity and ecosystem services may be reduced or enhanced by climate change (and vice versa). However, biodiversity responses to single or interactive global change drivers may vary, showing contrasting patterns or different sensitivities depending on the climate variable or taxonomic group considered. The climate research project LandKlif investigates the biodiversity of plants, animals and microbes along independent climate and land use gradients in Bavaria, Germany. Our research covers 179 study sites across contrasting local and regional terrestrial land-use types that differ fundamentally in the level of anthropogenic impact, which allows us to investigate how the effect of climate on biodiversity is modulated by land use. Here, we will present the synthesis of the variety of biodiversity data assessed within the project and identify trade-offs and synergies across taxa. This knowledge is fundamental for developing strategies to climate change mitigation and adaptation as well as biodiversity conservation.

Bees at risk - Interactive effects of climate and land use across trophic levels and spatial scales

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Climate and land-use change are among the leading causes of insect decline, but we still know relatively little about how their combined effects influence insect communities across trophic levels and spatial scales. In this study, we explored how temperature and land use interact to shape insect communities—from flowering plants and cavity-nesting bees to predatory wasps, their natural enemies, and associated parasitism rates. We used trap nests in a large-scale, space-for-time design across 60 regions in Bavaria differing in mean annual temperature and dominated by semi-natural, agricultural, or urban landscapes. Within regions, a total of 179 plots were established in forest, grassland, cropland, and settlement habitats, and local temperatures were recorded with thermologgers. This design allowed us to compare insect community patterns across gradients of climate and land-use intensity at both local and landscape scales.

Bee richness and abundance increased with warmer daytime temperatures and overall warmer climates, but only in low-intensity habitats. High night-time temperatures, in contrast, had negative effects on bee communities. Species at higher trophic levels were less sensitive to local temperature extremes, both during the day and at night, and showed consistent benefits from warmer climates. Parasitism rates were lowest in local arable habitats but remained stable across habitat types within semi-natural regions, suggesting that enough semi-natural habitats at landscape scales help mitigate local disturbances. Our findings reveal that night-time temperatures, though largely overlooked, can significantly affect diurnal insects, and suggest that rising temperatures can intensify the impacts of land use on pollinators.

Natural and Human Disturbances Have Non-Linear Effects on Whole-Ecosystem Carbon Storage in an African Savanna

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Uncertainties in carbon storage estimates for disturbance-prone dryland ecosystems hinder accurate assessments of their contribution to the global carbon budget. This study examines the effects of land-use change on carbon storage in an African savanna landscape, focusing on two major land-use change pathways: agricultural intensification and wildlife conservation, both of which alter disturbance regimes. By adapting tree inventory and soil sampling methods for dryland conditions, we quantified aboveground and belowground carbon in woody vegetation (AGC and BGC) and soil organic carbon (SOC) across these pathways in two vegetation types (scrub savanna and woodland savanna). We used Generalized Additive Mixed Models to assess the effects of multiple environmental drivers on AGC and whole-ecosystem carbon storage (C_{total}). Our findings revealed a pronounced variation in the vulnerability of carbon reservoirs to disturbance, depending on land-use change pathway and vegetation type. In scrub savanna vegetation, shrub AGC emerged as the most vulnerable carbon reservoir, declining on average by 56% along the conservation pathway and 90% along the intensification pathway compared to low-disturbance sites. In woodland savanna, tree AGC was most affected, decreasing on average by 95% along the intensification pathway. Unexpectedly, SOC stocks were often higher at greater disturbance levels, particularly under agricultural intensification, likely due to the preferential conversion of naturally carbon-richer soils for agriculture and the redistribution of AGC to SOC through megaherbivore browsing. Strong unimodal relationships between disturbance agents, such as megaherbivore browsing and woodcutting, and both AGC and C_{total} suggest that intermediate disturbance levels can enhance ecosystem-level carbon storage in disturbance-prone dryland ecosystems. These findings underline the importance of locally tailored management strategies–such as in carbon certification schemes–that reconcile disturbance regimes in drylands with carbon sequestration goals. Moreover, potential trade-offs between land-use objectives and carbon storage goals must be considered.

Marine Ecosystem Conservation: A Novel Real-time Tool for Monitoring Coral Reef Bleaching

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Coral reefs are important and valuable marine ecosystems that protect underwater life and coastal areas and contribute to tourist attraction and food security. However, coral reefs are currently under threat and are declining worldwide due to different environmental and anthropogenic stresses such as increased water temperature due to climate change, destructive fishing practices, and coastal development. Current coral reef surveillance and inspection strategies are laborious and time-consuming which delays coral conservation and restoration strategies.

This study used remote sensing to support the identification of coral reefs and bleaching events to develop a Web-based GIS tool that would allow for real-time monitoring of coral reef bleaching events in the Dar es Salaam coast islands. The data used in this research were Sentinel-2 images, sea surface temperature, and ground truthing used to train a Random Forest machine learning algorithm. The algorithm was coupled with Remote Sensing and Geographic Information System (GIS) techniques to develop a Web-Based GIS tool and optimized by incorporation of Remote Sensing data to include the benthic habitats classification and bleaching detection.

Random Forest (RF) algorithm was employed to classify the benthic features, the overall accuracy of this classifier is 97.24%, 89%, 85.71%, and 87.5% for the years 2019, 2020, 2021, and 2022 respectively. Analysis of the extent of benthic cover from 2019 to 2022 revealed variations in the areas occupied by corals, sand, seagrass, and water. Coral bleaching levels were assessed for each year, with sea surface temperature data used to identify bleaching hotspots, represented by different color classes.

The results obtained were visualized on a web application named “ReefWatch: Coral Bleach Monitor” implemented with Python and the most recent web frameworks and Google Cloud. This application enables the near real-time visualization and communication of coral bleaching events, facilitating proactive and targeted interventions, informed decision-making, and the resilience of coral reef ecosystems.

A climate companion for ecologists: the quest for the right climate products.

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Climate influences the distribution of species, productivity of ecosystems, large-scale biodiversity patterns and is, thus, central to ecology. Ecologists have been using climate data for more than 200 years, starting with the pioneering work of Wladimir Petrovich Köppen and Alexander von Humboldt. Since the 1950s, climate data has greatly expanded in size, quality, and availability, a trend that is continuously accelerating. For ecologists, however, this also meant an increasing complexity of the landscape of climate data available to them. Discouraged by jargon, the plethora of climate products that look similar to outsiders, and the lack of effective communication has created a gap between the highly sophisticated climate products and their uptake from the ecological community. Many ecologists are unaware of the kind of climate products available today, how they are derived, and which one is best suited for their goals.

In this talk, I will outline how to shorten these gaps and facilitate the communication between the two communities of climate scientists and ecologists by developing a guide to climate products for ecologists. This guide has three main goals: 1) Overview the climate products available today and explain concisely how they are derived, making ecologists familiar with the necessary jargon. 2) Group ecological questions into categories that require specific climate products. And 3) Provide recommendations for ecologists for choosing the products that best fit their goal. Moreover, I will illustrate how choosing different products can influence ecological inference and provide guidelines for validating climate data. Finally, I will conclude with recommendations to shorten the gap in communication between climatologists and ecologists, laying down an agenda to facilitate this.

Space-for-time substitution approach in flowering phenology under climate change

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Understanding phenology changes is important because it influences specific dynamics, like species interaction, but also drives essential ecosystem functions, like carbon uptake. Space-for-time substitution method (SFTS) could help to analyze phenological changes easily. SFTS predicts phenology under future temperature conditions based on spatial temperature gradient, assuming space-time equivalence.

We assessed this assumption and climate change's impact by comparing the phenological responses to an increase in temperature on a temporal and spatial gradient. We use mean annual temperature data from the Era5-Land product and flowering phenology data from 23 herbaceous species from the PEP725 database. To assess climate change's influence, we divided our data into the periods 1950-1985 (early decades) and 1986-2022 (recent decades) and selected the species with observations in all years. We ran linear mixed effect models and compared the slopes as an indicator of the phenology response to increasing temperature, using t-test and Jensen-Shannon distance.

We found that flowering responses to temperature are significantly different on the spatial and temporal gradients; however, the response shares 65% similarity, showing mostly negative relationships. Responses were species-specific; some species show high similarity between both gradients, while others show divergent patterns or with different magnitudes. Recent decades showed more consistent (72% similarity) and steeper negative phenological responses than early decades (65%). We conclude that, in a climate change context, flowering phenology is responding strongly to temperature, masking the influence of other factors in determining the flowering time. The implementation of SFTS in phenology leads to a correct response direction to the increase in temperature, but it would most probably be underestimated. We recommend being cautious when drawing general conclusions when using SFTS.

Assessing slow system dynamics using 'ontogeny-for-time' substitution

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Capturing the dynamics and trends of slow ecosystems such as forests is challenging because the processes of interest often occur over much longer time scales than those recorded in typical monitoring programs. Therefore, true dynamics are sometimes approximated by comparing young and old (or small and large) individuals, an approach that we introduce here as 'ontogeny-for-time' substitution. This is in analogy to the common 'space-for-time' substitution, where spatial variability is used to quantify temporal effects such as climate warming. The comparison of individuals of different ages is another approximation of long-term dynamics in ecology. For example, the ratio of small to large individuals in static data is used as a proxy for population growth rates, or the geographic distribution of young and old individuals of a species is used to infer range shifts in response to climate change. However, such approximations ignore that young trees are not simply small adults, and that demographic strategies and environmental filtering vary with ontogeny. Furthermore, replacing true time series or repeated measures with age-structured data poses statistical challenges. The presentation will explore the challenges and opportunities of using 'ontogeny-for-time' substitution and how its risks can be assessed and minimized.

Ecological connectivity of Central European calcareous grasslands and limestone beech forests with future climate analogues

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Genetic adaptation and range shifts are the two primary options for species survival under climate change but habitat fragmentation hinders dispersal and gene flow. This also applies for many protected habitat types which often harbour high numbers of threatened species.

In this study, we modelled habitat connectivity for two protected habitat types under consideration of projected climate change. We used a two-step modelling approach focussing on calcareous grasslands and limestone beech forests in south-western Germany. First, we identified climate analogues for current locations of both habitat types representing future suitable habitat. Second, we assessed the connectivity between current and future suitable habitats using models based on electrical circuit theory incorporating land use, soil type and climate data. Analyses were conducted under two climate scenarios (RCP4.5 and RCP8.5) and for two time periods (2041–2061 and 2061–2080).

For both habitat types, we identified analogue climates being located in the Western Carpathians, the Swiss Jura, in parts of the Alps and in within southwest Germany itself. The similarity between current and modelled analogue climates decreased substantially under the more pessimistic climate change scenario. Connectivity between current and future suitable habitats was low for both habitat types, illustrating the high level of habitat fragmentation in Europe.

The presented approach showed promising results for identifying priority pathways for species dispersal and gene-flow, providing a valuable tool for conservation planning under climate change.

Integrating Individual-Based Modeling and Genetic Data to Forecast Treeline Dynamics in a Warming Arctic

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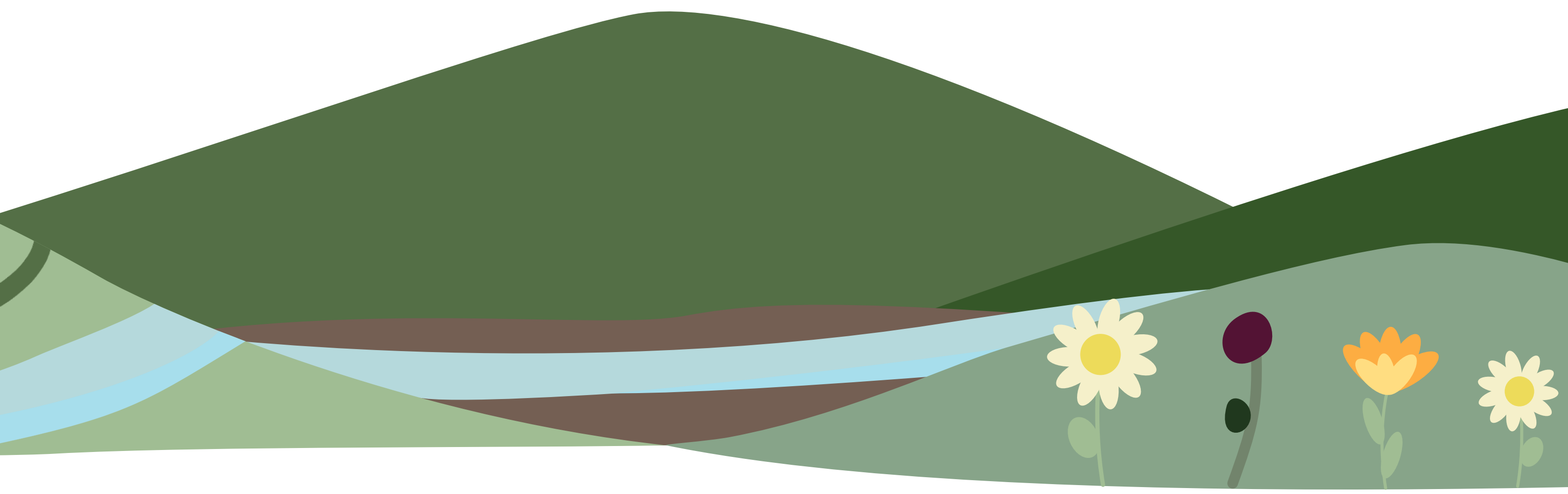
Climate warming is driving significant ecological transitions in high-latitude ecosystems, with northern treeline dynamics representing a critical frontier for understanding climate-vegetation feedbacks. As boreal forests potentially advance into tundra regions, concerns arise regarding biodiversity loss, permafrost degradation, and positive climate feedback loops through altered surface albedo. However, considerable uncertainty remains regarding the speed, extent, and controlling mechanisms of these treeline shifts. Our research employs LAVESI (Larix Vegetation Simulator), an individual-based spatially explicit model, to investigate complex drivers of northern treeline dynamics across typical latitudinal gradients. We parameterized the model using extensive field data from northern boreal forest ecosystems and from genetic information derived from microsatellite and GBS analysis.

Simulation results reveal that treelines exhibit significant time lags in response to climate warming, with slow migration rates. Long-term simulations through 3000 CE demonstrate that even with temperature cooling, forest expansion exhibits an "overshooting" effect, with strong tundra area extent reductions depending on emission scenarios. Our findings highlight the critical roles of seed dispersal limitations, genetic adaptation to extreme winter conditions, and the presence of refugia populations in determining migration potential. Density-dependent interactions between trees shift from facilitative to competitive with increasing stand density, creating non-linear responses to warming.

The integration of genetic information with individual-based modeling reveals that local adaptation and genetic legacy may constrain migration rates below those predicted by climate envelopes alone. This combined approach can help reduce uncertainty in projections of high-latitude vegetation dynamics and provides critical insights for conservation planning in threatened tundra ecosystems. Our results emphasize the need for ambitious climate mitigation strategies to preserve arctic biodiversity while accounting for the complex interplay between migration lags and genetic constraints in forest ecosystem responses.

Session 7

Conservation, management and restoration



Effectiveness of agri-environment measures in enhancing farmland bird diversity

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Global biodiversity loss is one of the main challenges of the 21st century. Farmland birds are among the most rapidly declining species, with their loss leading to reduced ecosystem services and negative consequences for humans. Agricultural intensification has been a key contributor to this decline, largely propelled by the Common Agricultural Policy (CAP), the primary mechanism through which Europe influences farming practices. Today's CAP recognizes the importance and value of biodiversity and attempts to shift towards more ecosystem and biodiversity friendly practices. However, the effectiveness of CAP measures is not consistently evidenced and little is known about potential trade-offs between CAP measures across species.

In this study, we focused on farmland birds as biodiversity indicator species and investigated the effectiveness of different CAP measures related to good agricultural and environmental conditions and Eco-schemes.

To quantify the potential effect of land cover and land use practices on bird occurrence, we applied a nested SDM approach to account for different environmental drivers acting at different spatial scales and to avoid niche truncation. At the coarse European scale, we trained SDMs on climate data, and at the finer German scale, we trained SDMs on land use, soil moisture, mowing intensity, and topographic data. The resulting models allow assessing preference and avoidance of different land uses. Additionally, we implemented a set of CAP scenarios to evaluate the effect of different CAP measures on the habitat suitability of various farmland birds and potential trade-offs between species and measures. The results can support decision making of farmers and policy and guide more targeted implementation of region-specific or species-specific agri-environment measures.

Ground-nesting birds and grazing cattle – Can virtual fences solve the dilemma?

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Extensive livestock grazing is an established approach to preserve open landscapes, such as semi-natural grasslands, and associated biodiversity. However, grazing by large herbivores comes along with a conservation conflict, as nests of ground-nesting birds are threatened by trampling, which can lead to high percentages of nest failure. Consequently, temporary fences are required to foster the breeding success of bird species nesting within pastures. Installing such fences is labour-intensive and therefore a challenge in the agricultural practice. The rising technology of virtual fencing (which is not yet approved in the EU) could facilitate such bird protection efforts. Virtual fences are drawn on a digital map via a mobile device and communicated to a GPS-collar on the grazing animal. When the animal approaches the fence line, the collar emits audio cues, and an electric cue if the animal does not draw back. We tested whether virtual fencing is effective in reducing trampling damage by grazing cattle in a national park at the Baltic coast in 2024. Over a period of 33 days, 19 heifers were grazed on a 19-ha pasture. The pasture was classified into four vegetation types. Per vegetation type, we placed one small (100 m^2) and one large (300 m^2) virtually fenced exclosure. We deployed artificial nests in the exclosures and in equally sized reference plots. Nests were checked for damage five times during the grazing period, resulting in a total of 912 nest inspections. Virtual fencing reduced the trampling damage by 77%, with 14 and 62 destroyed nests in exclosures and reference plots, respectively. The percentage of destroyed nests was independent of exclosure size and vegetation type. We conclude that virtual fencing can effectively reduce bird nest losses caused by cattle trampling under extensive grazing. Consequently, virtual fencing could facilitate both the conservation of open habitats and bird protection should the technology become available for use in the farming and conservation practice.

Optimizing Flower Strip Plant Composition for Aphid Management in Sugar Beet Fields

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Flower strips (FS) are known to enhance pollination services and support natural pest control, yet their impact in sugar beet fields remains underexplored. We conducted a large-scale field experiment to assess the effects of three FS mixtures—perennial FS, autumn-sown annual FS, and spring-sown annual FS—on aphid populations in sugar beet fields. Our study focused on *Myzus persicae*, the primary vector of virus yellows disease, and *Aphis fabae*, the most abundant aphid in sugar beets.

Our findings revealed species-specific responses to FS composition. The abundance of *M. persicae* was slightly higher near autumn-sown annual FS compared to perennial FS, while *A. fabae* tended to be less abundant near autumn-sown annual FS. We hypothesized that while the pattern in *A. fabae* could be explained by predation, the pattern in *M. persicae* might result from a spillover effect of certain plant species within the FS. To investigate this, we conducted a greenhouse choice experiment, testing *M. persicae* preferences among 12 plant species found in the FS mixtures. Aphids were released in the center of four plant species, including a sugar beet control, to assess their host preference.

The results demonstrated that *M. persicae* exhibited clear plant-specific preferences, which aligned with the field observations. All plants from the autumn-sown annual FS were similarly attractive to *M. persicae* as the control plant sugar beet. In the perennial FS, *Vicia sativa* and *Trifolium pratense* were significantly less attractive than *Achillea millefolium* and sugar beet. These findings suggest that FS composition is crucial for targeted pest control. In sugar beet cultivation, FS should incorporate plant species that deter *M. persicae*, while also effectively reducing *A. fabae* populations. A combined approach integrating both perennial and annual FS species may offer an optimal strategy for enhancing conservation biocontrol of aphids in sugar beet fields.

Nature conservation – It's a choice!

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Protected areas are considered the most efficient way of conserving biodiversity and therefore form the basis for most conservation strategies. However, resources for the management of protected areas are often limited, which can lead to shortcomings in management efficiency. For example, more and more case studies demonstrate how data gaps in protected areas can lead to suboptimal on-site management. In the wilderness area Königsbrücker Heide long-term monitoring was started in the year 2000 including various taxa, habitats and environmental parameters. We use this data to highlight general difficulties of long-term monitoring in protected areas and discuss potential improvements for future approaches.

How much land can be dedicated to climate-smart rewilding in Europe without compromising food production and while maximizing the benefits for biodiversity and carbon storage?

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Climate-smart rewilding integrates dynamic, process-based ecological restoration with carbon sequestration to mitigate climate change. However, little is known about suitable locations for climate-smart rewilding in Europe due to a lack of continental-scale spatial assessments. Moreover, the indirect effects of large-scale rewilding on food provision, carbon sequestration, and biodiversity mediated through redistributions in the land system remain widely underexplored. Based on a multicriteria mapping approach that integrates indicators from ecological, carbon and societal dimensions, we identify suitable locations for climate-smart rewilding in Europe. We then aim to identify a portion of land with high rewilding potential that can be used for rewilding without compromising food production, carbon storage, and biodiversity across Europe. We utilize the agent-based model CRAFTY-EU, a spatially-explicit representation of the European land system which also provides estimates of various ecosystem services (e.g., food, carbon, habitat provision). We iteratively remove an increasing portion of land from production in CRAFTY-EU and analyze trade-offs in ecosystem service provision. Our results show that high rewilding potential is heterogeneously distributed across Europe, with hotspots primarily located in mountainous regions such as the Alps, parts of Scandinavia, the Iberian Peninsula, and Eastern Europe. Preliminary results from CRAFTY-EU simulations show that rewilding land areas with a high potential lead to a gain of biodiversity and carbon sequestration services in these areas. However, these are partially compensated by unintended losses due to redistributions of the remaining land resources to ensure food production in Europe. Our findings highlight that by carefully considering trade-offs to avoid unintended impacts on food production and other ecosystem services, climate-smart rewilding can boost biodiversity and carbon storage in Europe.

Beyond the water: How small stream restoration affects plant and bird diversity

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River restoration aims to improve water retention in the landscape and the ecological value of water bodies around the globe. In Europe, most restoration projects focus on small streams, yet their ecological benefits are poorly documented. Effects on aquatic biota are often limited, as unrestored sections hinder colonization, and short restoration stretches have little impact on water quality. We therefore investigated how small stream restoration affects terrestrial biota - in particular plants, insects, and birds - as these groups provide important ecosystem services and have a high conservation value. We surveyed 55 restored and adjacent non-restored small stream sections in Hesse, Germany, using vegetation and bird surveys alongside malaise traps with DNA metabarcoding for insect identification. Restoration increased plant species richness, the abundance of moisture-associated plant species and the heterogeneity on a landscape level. Plant species richness strongly varied with restoration age: it was highest in young restorations, declined until year 16, and then increased again. The plant moisture index was significantly related to the channel depth. Bird diversity and abundance also increased with restoration, mainly driven by the coverage of woody plants. Next, we will analyze insect community responses to restoration and synthesize all three tropic levels to gain a broader understanding of how small stream restoration supports biodiversity.

Response of endemic reptile populations to rodent and cat eradication on Floreana Island in the Galapagos Archipelago

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Approximately 61% of global extinctions since the 1500s have occurred on islands. Invasive cats and rats in particular have caused numerous extinctions resulting in overall biodiversity loss. Loss of species or sudden population abundance changes can alter ecosystem function and at times trigger unexpected and unwanted ecological repercussions. This is more pronounced on islands. Island eradications with aerially applied toxic bait remains the most effective long-term strategy for conservation of native and endemic island species.

Globally, eradication studies have mainly focused on native bird recovery, while reptiles, often endemic and ecologically important, are underrepresented in such research. On the Galápagos Islands, reptiles like lava lizards play vital ecosystem roles. Lava lizards are primary seed dispersers, while lizards and geckos are key prey species for both endemic and introduced predators across the Archipelago. Their population changes can thus significantly influence food web dynamics. In 2023, Floreana Island in the Galapagos underwent an attempted large-scale toxic rodent and feral cat eradication to restore the island's ecosystems and facilitate the reintroduction of 12 locally extinct species. Before the toxic eradication, invasive mammals likely suppressed populations of small reptiles, affecting their distribution, abundance, and behavior. Thus, the eradication of these introduced predators is expected to greatly influence the lizard population on Floreana Island. In this study we investigate the abundance response of Floreana lava lizards (*Microlophus grayii)* and geckos (*Phyllodactylus baurii, P. reissii*) to the reduction of their invasive predators. We use a Before-After, Control-Impact (BACI) design and hypothesized that the use of toxin (eradication) would lead to increases in the population of both lizard species as well as in increase in juvenile abundance.

We used generalized linear mixed models (GLMM) to test whether lizard and juvenile abundances were higher in areas treated with toxic bait (post-eradication - reduced introduced predators). With these models we also included certain environmental predictors to identify other factors influencing lizard abundance. In this talk, I will present the preliminary results from this study.

Swiftly squeaky clean: lessons learned from eradicating an overpopulation of rats on an island of constraints

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Invasive rats threaten island biodiversity, disrupting ecosystems and endangering native species. While rat eradication has succeeded on many islands, tropical islands present unique management challenges. Strict regulations and financial constraints on some tropical islands further limit proven eradication methods, complicating rodent management. This study addresses these challenges by demonstrating a real-time active adaptive management (RAM) approach, providing a cautious, cost-efficient, scientifically grounded, and adaptive pathway to eradication while adhering to strict environmental regulations. We implemented RAM on a Brazilian island at USD 3,300 per hectare, integrating rodenticide (brodifacoum) application, population monitoring, and iterative management adjustments. This approach eradicated a rat overpopulation within five months and presented rapid population recovery signs for the endemic Noronha elaenia (*Elaenia ridleyana*), Noronha skink (*Trachylepis atlantica*), and the threatened masked booby (*Sula dactylatra*). Despite logistical constraints, RAM proved effective and cost-efficient, marking its first application in a biological system. Our findings highlight the value of innovation, interdisciplinary collaboration, and adaptive decision-making when the application of best-practice methods is constrained.

Session 8

Designing agricultural systems for sustainable insect pest management

The good, the bad, and the vulnerable: How habitat manipulations shape predator interactions and tree health in pear orchards

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Vertebrate and arthropod predators both contribute to pest control in agroecosystems, often complementing each other by targeting different pest types and sizes. However, vertebrates may also reduce arthropod predator effectiveness through intraguild predation, weakening overall pest suppression. Despite their importance, the combined effects of these predators on tree vitality in fruit orchards remain poorly understood. We conducted manipulative experiments in organic pear orchards to assess the impact of birds, bats, and arthropod predators on pest abundance and tree vitality (leaf biomass, damage, chlorophyll content, photosynthetic activity, and fruit yield). Vertebrate predators were excluded using mesh cages, while arthropod predators were supported through habitat enrichment with cardboard bands on trunks and branches. Control trees received no treatment. Control trees hosted the highest abundance of sap-sucking herbivores, the lowest number of spiders, and showed the weakest vitality parameters. In contrast, trees with vertebrate exclusion and spider enhancement had the fewest herbivores, most spiders, and strongest tree vitality. Structural equation model identified spiders as the primary agents reducing herbivory, likely through non-consumptive effects. Ants, conversely, were associated with increased herbivore presence. Our findings show that insectivorous vertebrates disrupted pest control by suppressing spider mesopredators, whereas increased habitat heterogeneity reduced such intraguild predation. These results highlight the importance of spiders in maintaining tree vitality and improving productivity in pear orchards. Enhancing habitat complexity by placing cardboard bands on tree trunks and branches offers a practical, low-cost method to support spider activity, minimize intraguild predation, and strengthen overall ecosystem functioning.
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Spatial arrangement of intercropping impacts natural enemy abundance and aphid predation in an intensive farming system

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Crop diversification is an increasingly recognized management strategy to support biodiversity and ecosystem services, like pest and disease control, in agricultural systems. However, a significant obstacle to its adoption is the potential trade-off between ecosystem services and optimizing yields. We used a two year, on-farm study in Eastern Germany to test how different spatial arrangements of soy (*Glycine max L.*) and winter wheat (*Triticum aestivum L.*) can affect pest abundance, aphid predation, and natural enemy biodiversity as well as yields. We compared conventional sole cropping to three types of spatially diversified cropping systems: relay intercropping, wide strip cropping, and patch cropping. Strip cropping generally supported some of the highest levels of carabid abundance both years and spider abundance in 2022 without any yield penalties. While the relay system failed due to insufficient precipitation, strip cropping produced similar or higher yields than sole cropping (124 % and 96 % of the sole wheat yield and 96 % and 109 % of sole soy yield in 2022 and 2023, respectively). Strip cropping supported significantly more carabid beetles compared to sole cropped soy both years and sole cropped wheat in 2022. We found significantly different carabid community composition between wheat strips and patches and the corresponding soy strips and patches. There were no differences in aphid abundance between systems. Nevertheless, we found 51 % and 36 % higher aphid predation rates in wheat strips compared to wheat patches in 2022 and 2023. Our results provide initial insights into the potential of strip cropping to support both natural enemies and yields while also being an approachable diversification strategy for farmers.

Do natural enemies control insect pests of different sizes and toughness equally well?

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Natural enemies, such as ground-dwelling predators, are considered important for natural pest control in crops because many of them consume insect pests and are almost ubiquitous in crop fields. However, insect pests vary widely in size and toughness, so questions arise as to whether all insect pests are equally well controlled by a given natural enemy community, which taxa contribute to the removal of which prey type, and which role prey and natural enemy traits play in this.

We used prey cards of six different prey types (*Sitobion avenae* aphid, *Lucilia* maggot, *Calliphora* pupa, small and large $_{\text{mealworm}}$ larvae, and wax moth larva) covering a wide range of prey length and toughness. In 12 cereal fields, one prey card per type was placed around a pitfall trap in four positions per field. A total of four prey cards of each type were equipped with cameras. Removal rates were calculated from all prey cards and camera data were manually screened for attack and removal events.

Initial results show that removal by invertebrates varied by prey type, with soft prey (aphids) being almost completely removed within 24 h, hard prey (pupae) being barely removed, and medium-hard prey being removed at intermediate levels, with a tendency for removal to decrease with increasing prey length. Aphids attracted the most diverse set of removers, while all prey types except pupae were attacked by carabids, largely independent of their own size and bite force. This suggests that a given ground-dwelling predator community - as currently observed in conventional cereal fields - is likely to have variable success in controlling pests with different traits, with small soft pests being relatively well predated and particularly hard pests being poorly predated.

The role of functional diversity and species identity of assemblies of predatory arthropods for cereal aphid suppression

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It has long been recognized that conserving diverse communities of natural enemies in agricultural systems can enhance pest suppression. However, empirical evidence linking natural enemy diversity to biocontrol efficiency remains inconsistent. Natural enemies' diversity may strengthen prey suppression directly through complementary interactions between predatory species, in concordance with functional diversity (FD). Another contributing factor may be the presence and activity of particularly efficient predators in the community (i.e., identity effect). To differentiate between the roles of these two mechanisms driving pest suppression efficiency, we conducted a controlled mesocosm experiment with artificially made assemblages of predatory arthropod species. A total of 80 cages containing wheat plants infested with cereal aphids (*Rhopalosiphum padi*) were each assigned to one of the following treatments: assemblages of 3 predatory species with either high or low FD, single predatory species, or no predators (control). The effect of the overall interactions between predatory species was quantitatively evaluated for high and low FD assemblages. Results showed no significant impact of FD on aphid suppression, and the directional effect of predator interactions in high FD assemblages suggested interference among predators rather than complementarity. Furthermore, the presence of the seven-spotted lady beetle (*Coccinella septempunctata*), the most efficient predator, dominated the efficiency of the whole assembly. These results suggest the importance of predator identity within a natural enemy assembly over functional diversity in determining pest control efficiency. This may explain the discrepancies between previous studies and emphasize the need to consider both overall diversity and species identity in conservation biological control.

Landschaftsstruktur und ihr Einfluss auf das Frühauftreten von Schadinsekten im Winterraps

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Winterraps (Brassica napus) ist eine wichtige Kulturpflanze in Deutschland, die jedoch häufig von Schadinsekten wie dem Rapserdfloh (Psylliodes chrysocephala) und dem Schwarzen Kohltriebrüssler (Ceutorhynchus picitarsis Gyll) befallen wird. Diese Schadinsekten können erhebliche Ertragsverluste verursachen, da sie in verschiedenen Wachstumsphasen des Rapses aktiv werden und verschiedene Pflanzenteile schädigen. Prognosemodelle und Entscheidungshilfesysteme (EHS) spielen eine wichtige Rolle bei der Optimierung von Pflanzenschutzmaßnahmen und der Vorhersage des richtigen Zeitpunkts für deren Anwendung. Im EntoProg-Projekt wird ein EHS zur Überwachung und Bekämpfung von Schädlingen im Winterraps entwickelt.

Die Landschaftsstruktur hat einen erheblichen Einfluss auf das Erstauftreten und die Verbreitung von Schädlingen. Verschiedene Studien zeigen, dass angrenzende Landschaftselemente wie Hecken, Wälder und Brachen den Schadinsekten Unterschlupf bieten und deren Überwinterung sowie das frühe Auftreten im nächsten Jahr beeinflussen können. Diese Landschaftselemente fördern das frühe Einwandern der Schädlinge in die Rapsbestände und können auch die Verbreitung der Schädlinge in Übergangszonen zwischen verschiedenen Habitaten begünstigen.

Im Rahmen des EntoProg-Projekts wird untersucht, wie Landschaftsmerkmale das Erstauftreten von Schädlingen im Winterraps beeinflussen. Durch mehrjährige Fallenfänge in Rapsfeldern aus sieben Bundesländern werden GIS-gestützte Landschaftsdaten verwendet, um das Risiko eines frühen Schädlingsauftretens standortspezifisch zu bewerten. Diese Daten werden in das EHS integriert, um eine gezielte und effizientere Bekämpfung der Schadinsekten zu ermöglichen, was zu einer Optimierung der Pflanzenschutzmaßnahmen führt

Climate Adaptation and Biodiversity: Carabidae Responses to Soil Practices in Agroecosystems

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The ongoing decline of vertebrate and invertebrate species across Europe is strongly linked to habitat loss, landscape fragmentation, disruption of ecological corridors, urban expansion, and the intensification of land use. Conventional agriculture—especially large-scale monocultures—has contributed significantly to these pressures. In contrast, conservation-oriented agronomic practices have demonstrated the potential to sustain biodiversity even within intensively cultivated areas lacking extensive semi-natural habitats. Our research centers on ground beetles (Carabidae: Coleoptera), a widespread and ecologically significant arthropod family, well-established as bioindicators of agroecosystem health. We investigated carabid communities in wheat fields under contrasting soil management regimes — conservation versus conventional—to evaluate the biodiversity benefits of reduced-disturbance practices. In addition to species richness, we analyzed key morphological traits linked to environmental filtering and functional diversity across trophic levels. To explore carabids' potential responses to climate change, live specimens were also evaluated under controlled environmental conditions, focusing on their adaptive capacity and resilience to elevated temperatures. These findings provide valuable insights into how agronomic practices can shape both ecological function and climate resilience in agroecosystems. Our results contribute to the broader effort to reconcile biodiversity conservation with effective pest management. By illustrating how conservation soil practices can support carabid populations—natural enemies of many crop pests—we underscore the potential of designing pest-suppressive agricultural landscapes that reduce dependency on chemical inputs.

Predator activity and predation under different climatic conditions in Europe

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Climate change will increasingly affect biodiversity and the resilience of the ecosystem services they provide. As ectothermic organisms, the activity of insects is strongly influenced by climate and weather, affecting their ability to provide ecosystem services. One example of this is the effect of changing temperatures and humidity patterns on the activity of ground-dwelling predators and the predation of insect pests in agricultural systems. To study this, we collected temperature and humidity data alongside data on the activity of ground dwelling predators and predation of sentinel prey in cereal fields in four European countries with different climates: Italy, Austria, Germany and Sweden. Using this data, we hope to learn more about the climatic drivers of predator activity and predation, as well as local adaptation of ubiquitous species and predator communities under different climates. We aim to understand how to best manage agricultural systems to support resilient biological pest control under future climate change scenarios.

Optimizing flower area design to enhance ground-active predators in European agricultural landscapes

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The establishment of flower strips or fields (here "flower areas") is a widely adopted agri-environment-climate measure in Europe, aimed at providing essential habitats and food resources for many ecosystem service providers, including important pest control agents - ground-active predators, such as Carabidae, Araneae, Coccinellidae and Staphylinidae. Despite increasing calls to tailor flower areas for these predators, comprehensive evidence on how to optimize their design remains limited.

To quantify the impact of flower areas and their characteristics on the abundance and species richness of ground-active predators, we conducted a meta-analysis across Europe. After screening 2712 articles, 36 studies met the inclusion criteria and were incorporated into our analysis. Moreover, we examined how the overall effects varied in terms of different reference habitats (i.e. semi-natural habitats and crop fields), regions (i.e. Central and Northern Europe and the Mediterranean), and flower area characteristics (i.e. shape, age, and sown plant species richness).

Flower areas significantly increased the species richness (Hedges' $g = 0.65$, $p < 0.01$) of ground-active predators but not their abundance (Hedges' $g = 0.21$, $p = 0.12$). The impact on abundance varied by region, with the greatest positive effects in the Mediterranean. The benefit on species richness was stronger when compared to crop fields than to semi-natural habitats. Shape was the key characteristic driving the effectiveness of flower areas, with flower strips demonstrating effect sizes 0.69 units higher than flower fields in promoting the abundance of ground-active predators, and 0.86 units higher in enhancing their species richness.

These results provide evidence in support of the use of flower areas for the conservation of ground-active predators and offer practical insights into flower area design and agri-environmental policy.

Positive effects of wildflower strips on pest control are linked to temporal complementarity among predator guilds

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Wildflower strips are widely used measures to support biodiversity and ecosystem services, including pest control, in ecological intensification schemes. However, their effectiveness in reducing pest abundance and supporting natural enemies is highly variable. Here, we studied the effect of wildflower strips on egg abundance and predation rates of cereal leaf beetles (CLB) across four sampling periods spanning the phenology of cereal crops. Using sentinel cards, we quantified predation by piercing-sucking, chewing and unknown predators, while CLB eggs were also sampled directly from cereal plants. We analyzed the influence of wildflower strip presence, distance to the field margin (12 or 36 m), and sampling period on CLB egg predation, accounting for different predator guilds, and CLB egg abundance. CLB predation was mainly attributed to unknown predators (i.e., missing eggs), followed by piercing-sucking predators, which were more active in late May, while chewing predators were more important in early May. Predation rates were higher in wildflower strips compared to control sites, especially in late June, and tended to be lower far from field margins. CLB egg abundance peaked in early and mid- May and, contrary to our expectations, was positively related to predation rates. The positive association between egg abundance and predation suggests that resource concentration effects are important drivers of CLB control, especially in sites without wildflower strips. Our results underscore the importance of incorporating spatial and temporal dynamics of both pests and predators into conservation biological control strategies which can help enhance the benefits of wildflower strips for pest suppression.

Landscape diversity increases aphid predation but not predator abundance

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Enhancing natural pest control through landscape management is a key goal for sustainable agriculture. In this study, we investigated how landscape diversity and the share of perennial flower fields in agricultural landscapes influence aphid predation, aphid abundance, and predator populations in conventional winter wheat in central Germany. We sampled 27 landscapes (1km2) along two independent gradients of landscape diversity and flower field shares (ranging from 0% to 13.5%) one year before flower field establishment (2022) and in the first vegetation period after flower field establishment (2023). We quantified aphid predation in two wheat fields per landscape using over 2,000 artificial aphid cards placed at both the vegetation and ground levels. Vegetation-dwelling predators and aphids were assessed through visual surveys of wheat plants, while ground-dwelling predators were sampled using pitfall traps.

We collected 8274 carabids, 6596 spiders and recorded 4370 aphids and 610 vegetation-dwelling predators. Landscape diversity significantly enhanced aphid predation rates, particularly at the vegetation level, while predator abundance showed no consistent response. However, carabid abundance was negatively correlated with aphid abundance. The presence of flower fields had little effect on predator populations or predation rates, likely due to their recent establishment.

Our results suggest that promoting landscape diversity can enhance ecosystem services such as natural pest control but also highlight the context-dependence of predator-prey interactions in natural pest control. Newly established flower fields do not seem to be effective in enhancing natural pest control, even when available in large proportions of the landscape. Moreover, our results illustrate that arthropod abundance, or diversity, does not always translate into enhanced pest control services, especially under conventional management.

Effects of agroforestry strips with and without adjacent flower strips on arthropod communities and associated ecosystem services in cereal systems

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Agricultural intensification has led to landscape homogenization, reducing arthropod populations and ecosystem services. Reintroducing structural elements like agroforestry systems could support local arthropod communities by providing shelter, alternative habitats such as hibernation sites, and resources, while generating additional income for farmers. Flower strips support arthropod communities, but research on the combined effects with agroforestry strips remains limited. We investigated how the presence of agroforestry strips alone or in combination with flower strips affects both the emerging and the vegetation-dwelling arthropod communities (Aphididae, Coleoptera, Dermaptera, Heteroptera, Formicidae) in cereal farming systems on two organic and two conventional farms in Brandenburg, Germany. As a proxy for ecosystem services, the presence of attacks on dummy caterpillars and seed removal of *Viola arvensis* (service) and *Secale cereale* (disservice) were recorded. Effects of the agroforestry strips on arthropod communities in cereal systems were partly dependent on sampling date, farming system and the presence of flower strips. While overall arthropod emergence was highest in cereal fields with only adjacent agroforestry strips, it was significantly lower in cereal fields with adjacent agroforestry and flower strips. Seed removal of *V. arvensis* was highest in agroforestry strips before harvest, but higher in flower strips after harvest. Before harvest, the attack rate was highest in the reference cereal fields, but after harvest, it shifted to the cereal field in the agroforestry systems without adjacent flower strips. In both cases, beetles were the main contributors to the attacks. Our results suggest that the presence of agroforestry strips has pronounced effects on arthropod communities and ecosystem services in cereal systems, but that the effects depend on the presence of flower strips, the sampling date and the local farming system.

TheCacaoWeb: Disentangling the role of mesopredatory arthropods in biological pest control in cacao agroforestry

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Insectivorous animals, such as birds and bats, play a vital role in biological pest control and enhancing productivity in cacao production. However, these insectivores may also consume predatory arthropods, a phenomenon known as intra-guild predation, which has rarely been evaluated in tropical agricultural areas. Predatory arthropod species are also likely pest control agents, yet their contribution to this ecosystem service remains unquantified. Our previous research in cacao agroforests in Peru showed that predatory taxa make up approximately 33% of arthropod morphospecies identified on cacao trees, making them key elements in food webs within these agroecosystems. We also found that birds suppress the activity of predatory arthropods, which was ca. 15% lower in the presence of birds (30.12 ± 4.11%) than within bird exclosures (45.29 ± 5.97%). We discuss how these diversity patterns vary in different geographical regions and potential consequences for ecosystem service provision.

Our upcoming project, TheCacaoWeb, will explore the diet of key predatory arthropods in cacao agroforests of Côte d'Ivoire —the world's largest cacao producer— by combining metabarcoding analyses, observational surveys and experiments. We aim to assess how different shade tree species and landscape characteristics impact the diversity and dietary composition of predatory arthropods, and to quantify their role in biological pest control and crop yield. By integrating these findings with research on the dietary composition of birds in our study region, we will construct a first comprehensive overview of food webs in cacao agroforests, and analyze potential impacts of intra-guild predation. Our results will provide robust evidence of the importance of predatory arthropods for biological pest control in tropical agroforestry, and identify management strategies to enhance them in the field.

Enhancing macadamia yield and quality through ecological intensification: The role of pollinators, predators and habitat conservation

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Conventional agricultural intensification threatens biodiversity and ecosystem health. Ecological intensification offers a sustainable alternative by enhancing natural processes in agricultural landscapes, particularly pollination and biocontrol. This study investigates the potential of ecological intensification in macadamia (*Macadamia integrifolia*) orchards in Levubu, South Africa, focusing on the roles of animal pollinators, predatory birds, and bats in improving crop yield and quality. Using exclusion experiments and visual pollinator and bird surveys, and acoustic bat recordings in ten intensively managed orchards, we assessed the effects of these ecosystem services on nut set and insect damage, alongside orchard spatial design, agronomic practices, and natural habitat cover. Insect pollination increased initial and final nut set by up to 525%. Natural habitat cover and orchard tree rows oriented perpendicular to adjacent habitats enhanced pollination success, while agronomic practices (irrigation, managed honeybees) showed little effect. Predator exclusion revealed that bats and birds together reduced insect damage by up to 43%, improving nut quality. Bat abundance consistently reduced insect damage while the effect of bird abundance varied with species assemblages. Pollinators and predators complementary support both yield and quality. Our findings highlight the importance of conserving natural habitats and implementing smart orchard designs for sustainable, high-quality macadamia production.

Session 9

Diversity below species level

Large-scale genetic patterns of the semi-natural grassland plant species Primula veris L. (Primulaceae) in Europe

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Habitat fragmentation is one of the major threats to European ecosystems. It often leads to decreased patch area and increased isolation of populations. Both processes are expected to result in genetic impoverishment and reduced resilience to environmental changes in populations inhabiting fragmented landscapes. In particular, semi-natural grasslands, which represent one of the most species-rich habitats in Europe, are suffering from human-induced habitat fragmentation caused by intensification or abandonment of management. Grassland plant species that depend on external vectors for pollen and seed dispersal and rely on a specific mating system for successful reproduction are most sensitive. In our study, we investigate the population genetics of the heterostylous, self-incompatible and insect-pollinated grassland plant Primula veris using GBS to identify single nucleotide polymorphisms (SNPs). Samples were collected in five European countries spanning most of the species' distribution range. In each country, samples were taken from contrasting landscapes of fragmented vs. connected semi-natural grasslands creating a gradient of grassland fragmentation sites on a European scale. We expect to find reduced genetic diversity in populations inhabiting fragmented landscapes compared to those in connected ones. Genetic differentiation will be more pronounced among fragmented populations with the effect becoming stronger towards the margin of the species' distribution range. Furthermore, we expect a decline in potential mating partners in fragmented populations, possibly leading to an overall decrease in population size and further reduction in genetic diversity. Our study will provide valuable knowledge to the consequences of ongoing habitat fragmentation. It will contribute to develop and reassess management strategies to restore fragmented habitats, to maintain connected ones, and to preserve resilient populations.

Seed traits seem to be linked to genetic structure in a rare Alpine endemic Physoplexis comosa

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Physoplexis comosa (Campanulaceae) is endemic to the Southeastern Limestone Alps and the Bergamasque Alps where it occurs from 300 to 2,800 m altitude. The chasmophytic species inhabits calcareous rocks, rock faces and crevices in early stages of succession. One of the major potential threats is global warming and the associated changes and shifts in habitats, as well as the degradation of ecosystems. Until now, patterns in distribution of genetic diversity, genetic structure and how these are related to life history traits, in particular seed traits, have not been investigated in detail. We detected that private allelic richness was elevated in populations along the southern margin of the species' distribution range, reflecting recurrent isolation into multiple long-term stable refugia. We found extensive ongoing gene flow between neighbouring populations, reflecting a classic stepping stone model, by applying Mantel tests based on geographic and genetic distance. The STRUCTURE analysis revealed two genetic clusters separating populations in the Eastern and a Western part of the species' range. In addition, we found considerable differences in seed mass between populations. Using GLMs, this differences could be best explained by membership in a specific genetic cluster and by distance from refugia, rather than by differences in genetic diversity (Pi) and relative private allele richness between populations, as originally expected. Further parameters reflecting fitness of populations are currently being tested in germination experiments investigating possible adaptations to specific conditions (e.g. altitude).

Strategies to delimit bumble bee populations as a prerequisite for monitoring genetic diversity

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Loss of genetic diversity poses significant threats to bumble bee populations, compromising their resilience and adaptability. Monitoring genetic diversity is essential to understand and mitigate these risks. A key indicator of genetic diversity is the effective population size, which, if necessary, can be assessed in the absence of comprehensive genetic data due to recent advancements. However, a basic requirement and major challenge remains the delimitation of populations of species with a wide dispersion range such as bumble bees.

We investigated factors contributing to genetic structuring among bumble bee populations, to identify gene flow barriers that disconnect populations. Our findings indicate that rare species and clearly isolated populations often exhibit pronounced genetic structuring, a phenomenon that can be captured with isolation-by-distance and/or -resistance approaches. More widespread species maintain connectivity through larger stepping-stone populations, however isolation-by-environment approaches provide insights into less obvious factors inhibiting gene flow. Overall, findings suggest that when the extension of unsuitable habitats for colony establishment exceeds the dispersal capabilities of bumble bees, populations become isolated, leading to the development of genetic structuring over time.

We have followed up this literature review by employing an agent-based model that depicts dispersal capabilities of bumble bees by modelling behavioural patterns such as trajectories, during mating season. This effort aims to create a tool capable of delimiting populations by modelling the potential gene flow (or lack thereof) between colonies. Ultimately, our research seeks to find pragmatic strategies to enhance the understanding of overall gene flow dynamics and genetic diversity in bumble bee populations even in the absence of area-wide, costly and labour-intensive genetic data.

Intraspecific trait variation and phenotypic plasticity in Hordeum murinum across Europe

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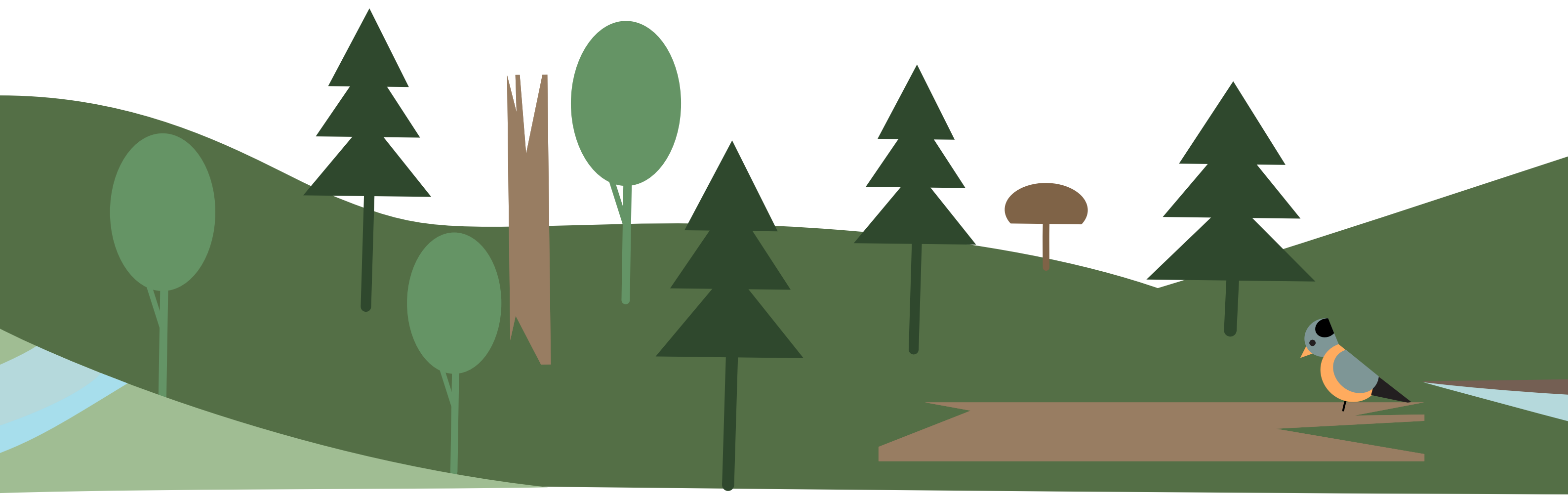
Hordeum murinum is a grass species native to Europe, the Mediterranean, and Western Asia. It grows in disturbed habitats and spreads in response to climate change. In 2023, in collaboration with 50 local researchers, we scored traits of *H. murinum* in the wild across Europe and northern Africa, in total 238 populations. We also collected seeds. In 2024, to test for heritable differentiation among populations, we sown the wild-collected seeds and grew the plants in two types of soil in two common gardens differing in climate.

We further found significant differentiation among populations in nearly all measured traits. All traits were also affected by treatment, and in most traits we found significant treatment x population interaction, which indicates population differentiation in phenotypic plasticity. However, the magnitude of the heritable versus plastic reaction differed between traits. For example, flowering time was predominantly heritable, with population identity explaining 82% of the variation, while treatment and interaction effects accounted for 0.5% and 4%, respectively. In contrast, biomass was highly plastic, with treatment explaining 71% of the variation, while population identity explained only 11%. The population differentiation in plasticity in biomass was similar to flowering time, with interaction explaining 4% of the variability. Trait clines along environmental gradients were similar in situ and in common garden: For example, plants were larger and flowered later in more humid and colder areas in situ. Accordingly, plants from colder and more humid areas grew larger and flowered later in common gardens.

Session 10

Ecological communities in forests: deadwood and decomposition



Structure and Drivers of Saproxylic Insect Communities along a Tree Species Richness Gradient in a Young Subtropical Forest

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Dead wood is a key component of forest ecosystems for nutrient cycling, carbon storage, and biodiversity. Here, we aimed to assess the role of tree diversity, which can influence saproxylic insect communities both directly and indirectly, via deadwood provision to effects on structural heterogeneity, microclimate, and biotic interactions. We investigated this at the BEF-China platform in Jiangxi Province, south-eastern China, which consists of two sites hosting an experimentally manipulated species richness gradient ranging from 1 to 24 tree species.

In each of 300 plots, insects were sampled from five deadwood pieces and from the surrounding environment (tree trunks, soil cores, and ground subplots). Structural equation models showed that ant communities were overall positively influenced by the surrounding insect pool, which in turn correlated with tree species richness, but also indirectly through deadwood itself, and environmental factors such as canopy cover. In contrast, termites showed no clear predictors. This suggests that, at a general level, species presence may not respond directly to deadwood availability or tree richness. However, deadwood positively correlated with saproxylic diversity, indicating that greater resource availability can promote community evenness and support less dominant or more specialized species. Network analyses supported this filtering role of deadwood, as saproxylic communities within deadwood were sparser and less nested than those in the surrounding environment. Ants emerged as the dominant group and exhibited more connected and structured networks, whereas termites occurred more randomly and beetles were rare.

Dead wood specialization and co-occurrence patterns of saproxylic insects along a tropical forest regeneration gradient

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Dead wood decomposition plays an important role in nutrient cycling of forest ecosystems. Once dead wood has fallen on the forest floor, different taxa slow down or contribute to decomposition processes. Understanding the assembly mechanisms and potential interactions between dead wood dwelling organisms and their contribution to dead wood decomposition becomes of increasing importance as dead wood represents an important carbon stock, especially in tropical forests. In this study, we investigated the interactions of dead wood inhabiting ants, termites and beetles along a regeneration gradient ranging from agricultural land, to recovering pastures and cacao plantations aging between 1 and 38 years, to old-growth forest in the Ecuadorian Chocó rain forest. For this, we placed dead wood baits from five different tree species (Sapanillo, Cacao, Fernán Sánchez, Guaba and Mascarei) on 62 plots along the forest recovery gradient and transferred them into emergence chambers after six months. We collected and identified all emerging insects to species level using DNA barcoding. A network analysis from the resulting dead wood communities showed a generally low specialization towards a wood type but interaction networks of saproxylic insects with wood types were more specialized in agricultural land than in regenerating and old growth forests. Co-occurrence analysis of the genera inhabiting single wood pieces has shown that most species communities (95.4 %) co-occur randomly in dead wood pieces, while 3.8 % were positively and less than 1 % negatively associated. In this context we compare our results with the assembly mechanisms of communities in other strata such as leaf litter, forest floor and tree trunks that have previously shown strong effects of the regeneration gradient on species richness and community composition of ants but not of termites.

Effects of invertebrates and local environment on decomposition rates of dead plant and animal biomass along elevation

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Decomposition of necromass, the dead biomass of plants and animals, is a key ecosystem process influenced by climate, necromass type, decomposers, and local environmental factors. However, it remains unclear how decomposition patterns vary among different necromass types. We examined how elevation (as a macroclimatic factor) and local conditions (microclimate, vegetation, soil) affect decomposition rates and the role of invertebrates across five necromass types: carrion, dung, leaves, beech wood, and spruce wood. Along a 600–2000 m gradient in the German Alps, we used treatments that either included or excluded invertebrates. Invertebrate effects varied: they enhanced decomposition of carrion and spruce wood, slowed it for dung and leaves, and had no effect on beech wood. Decomposition generally declined with elevation, significantly so for carrion and beech wood. Local conditions, especially tree cover and microclimatic buffering, reduced decomposition of carrion, leaves, and beech, but increased it for dung and spruce. Soil pH was particularly important for carrion and beech. Invertebrate influence on carrion declined with elevation. These results show that decomposition drivers differ among necromass types, with local conditions often playing a stronger role than elevation. Both necromass traits and site-specific factors are essential for understanding decomposition processes.

Effects of different forest management strategies on deadwood fungal diversity and decomposition – lessons from a large stand-scale experiment

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It is more important than ever that our forests be managed with multifunctionality in mind, so that we not only focus on timber production but also on forest biodiversity, supporting carbon and nutrient cycles, and other key forest qualities and processes. The process of decomposition in forests is relevant to the carbon and nutrient cycles and the chief decomposers in temperate forests are fungi. In terms of forest structure, fungi are influenced greatly by resource availability and microclimate. In a broad-leaved German forest, and as part of the larger BETA-FOR project, we assessed the effects of enhanced deadwood availability and canopy cover (open vs. closed) on microbial fungal diversity (alpha and beta) of two host tree species (*Fagus sylvatica* and *Pinus sylvestris*) as well as decomposition rates. In terms of alpha and beta diversity, we found significant effects of deadwood availability and canopy cover on the microbial fungal communities. We further found that deadwood availability affected deadwood decomposition of the microbial communities' host wood. The largest effect on alpha diversity was due to the host tree species of the microbial fungal communities. Our results indicate that forest management initiatives focused on enhancing deadwood availability and altering canopy cover would indeed have important influences of the microbial fungal communities and related forest functions and processes, such as decomposition.

Successional patterns of fungal and bacterial communities during deadwood decomposition

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Deadwood decomposition is a protracted process that can take decades, depending on wood properties, environmental factors and the decomposing communities. Data, analyzing the entire succession of decomposition in experimental setups, are scarce and often based on chronosequence approaches. However, time-series analyses by repeated sampling of the same deadwood logs provide a valuable opportunity to explore temporal successional dynamics of microbial diversity patterns and decomposition processes, allowing for more controlled conditions and greater accuracy. In this study, we investigated fungal and bacterial communities using amplicon sequencing at five distinct time points over 11 years of decomposition of 13 broadleaved and conifer tree species. We aimed to test three hypotheses: (a) species richness increases, (b) beta diversity decreases, and (c) host specialization decreases due to the reduction of plant secondary metabolites and increasing niches availability over time. Using this comprehensive dataset comprising fungal and bacterial community data for ~ 1800 deadwood samples, we followed the successional patterns of diversity throughout decomposition. Our results revealed contrasting temporal trends between fungal and bacterial communities, providing new insights into the complex dynamics of decomposer communities and their functional roles in the degradation of deadwood. These findings contribute to a better understanding of the ecological processes shaping biodiversity during long-term decomposition.

Interactive effects of microclimate and resource heterogeneity on wood-inhabiting fungi communities along elevation

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Decreasing numbers of species and community turnover are common patterns along elevational gradients, usually attributed to harsher macroclimatic conditions and increased environmental filtering. Forests can buffer these climatic extremes with their microclimate, potentially facilitating the persistence of species at otherwise limiting elevations. Moreover, both the quantity and heterogeneity of resources change with elevation, jointly influencing community assembly and diversity patterns. We investigated whether and how these three variables interact in shaping the diversity and community composition of wood-inhabiting fungi, utilizing eDNA metabarcoding data of fungal OTUs. Sampling took place in 2021 from natural deadwood objects in 150 forest plots in Berchtesgaden National Park in southern Germany along an elevation gradient from 600 to 1700 m asl. The plots are evenly distributed among five forest successional stages from gap to terminal phase, representing varying microclimatic buffering. Fungal alpha diversity was positively affected by deadwood diversity and microclimatic buffering. Elevation had no effect on fungal alpha diversity and also did not interact with microclimate and deadwood diversity. In contrast, community composition was mainly shaped by elevation and differences in deadwood composition, with both composition and buffering interacting significantly with elevation. The response of wood-inhabiting fungal alpha diversity underscores its close association with structural features typical of old-growth forests, while variation in community composition reflects a complex interplay between environmental conditions and resource characteristics. As mountain forests face increasing disturbance pressures under climate change, fungal community restructuring may occur, with potential consequences for ecosystem functions such as carbon sequestration.

Succession of Invertebrate Communities in Deadwood

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Deadwood is a key habitat for forest invertebrates, but our knowledge about how many invertebrates use deadwood and which factors – from the deadwood object to the forest stand – affect their diversity and community patterns is strongly biased towards beetles. With a metabarcoding approach, we analysed invertebrates sampled with closed emergence traps from logs of 13 different deadwood tree species in nine forest stands with varying conifer share. Sampling was conducted over eight years of decay – from the second year onwards in two-year intervals. Across all years, we found more than 4000 unique invertebrate Barcode Index Numbers (BINs), which can be used as proxy for species, excluding those of beetles and true bugs. Diversity and species composition of 14 out of 15 taxa (Diptera, Hymnoptera, Lepidoptera, Psocodea, Thysanoptera, Collembola, Araneae, Acari, Opiliones, Chilopoda, Diplopoda, Isopoda, Nematoda, Annelida, Mollusca) were most strongly driven by time after tree death. Tree species identity had an effect for alpha diversity patterns of few groups, but none for community composition of any taxa. Furthermore, conifer share at the forest stand scale affected ground-dwelling taxa and spatial distance between stands affected weak dispersers with very specific habitat requirements. Our results highlight the importance of diverse deadwood habitats for saproxylic biodiversity even beyond beetles. Deadwood at various decay stages providing high diversity of habitats and food resources has the strongest impact on invertebrate communities.

Session 11

Ecological theory, modelling and statistical analyses

Seven common issues in statistical analysis

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Ecologists typically deal with complex datasets. Finding patterns in these datasets requires appropriate statistical analysis. This is not an easy task when we can choose from many different packages or functions readily available in software such as R. Without a deeper understanding of what these packages do—and how this matches the hypotheses to be tested using the data at hand—it is easy to make inappropriate choices. I assembled a list of seven issues in statistical analysis that I believe are most relevant to ecologists. The first relates to features of dependent variables and potential needs for transformations or generalized linear models. The second issue concerns explanatory terms, when they should be coded as continuous variables or multi-level factors, and how to form contrasts. Third, difficulties often occur when data are hierarchically structured and appropriate random effects must be fitted. Fourth, inappropriate hypothesis tests may result when complex analyses are summarized in tables of estimates rather than analysis of variance tables. The fifth issue relates to selecting explanatory terms from multiple covariates and comparing their contributions to variation in a dependent variable. The sixth issue arises from analyzing subsets of complex datasets separately or analyzing derived data such as differences or slopes. The seventh issue concerns the inappropriate use of random forest, general additive, or structural equation models to test hypotheses. Many issues can be resolved by deeper understanding of base functions such as lm() in R, before moving on to special-purpose packages and functions.

Detecting dispersion problems in generalized linear mixed-effects models

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Modeling ecological data is becoming a complex endeavor. While researchers now have great flexibility in model structure to address diverse data challenges, relatively few tools exist for diagnosing model fit and verifying distributional assumptions. For example, dispersion problems in fitted count data are more common in ecology than a review of the current literature might suggest, since many authors fail to check or report the dispersion of their data. When fitting Generalized Linear Mixed-Effects Models (GLMMs) with counts or proportion data, dispersion problems may arise from (1) greater or lesser variability than expected by the distribution (over- or underdispersion), (2) variability that increase/decreases with a specific predictor (heteroscedasticity), or (3) excess of zeros relative to model expectations (zero inflation). Our main goal is to support ecologists in detecting and solving dispersion problems in GLMMs, by: (i) reviewing the main causes and consequences of dispersion problems in ecological data analysis, (ii) comparing the available diagnostic tools and their typical patterns, and (iii) evaluating alternative modeling approaches to address these problems. We illustrate our discussion with examples using common R packages for GLMMs, such as *lme*4 and *glmmTMB*, and demonstrate diagnostic methods with the DHARMa package. We focus on using simulation-based residual approaches for GLMMs' diagnostics as they operate independently of residual degrees of freedom and can assess assumptions across all levels of the model hierarchy. With this presentation, we aim to promote better model evaluation practices by making dispersion diagnostics more accessible and interpretable, encouraging more robust and transparent modeling practices in ecology.

genvers: A tool for identifying Key Biodiversity Areas based on distinct genetic diversity

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Key Biodiversity Areas (KBAs) are sites that contribute significantly to the global persistence of biodiversity. Distinct genetic diversity has been introduced as one of the metrics to estimate whether a site holds a threshold proportion of a species' global genetic diversity during the KBA identification process. However, genetic data has so far not been used due to the lack of thoroughly tested methods and guidance, although its relevance is becoming increasingly clear. We tested the applicability of Analyses of Molecular Variance (*AMOVA*), allelic overlap, the diversity index Simpson's I, average taxonomic distinctness (AvTD, D+), and effective population size (Ne), calculated with the two different programs Speed-Ne and NeEstimator, for identification of KBAs. We conclude that D+, a measure that has originally been developed to measure taxonomic distinctness of biotic communities, performs best in the context of KBA identification as it encompasses both genetic distinctiveness and diversity. As the calculation of D+ is new in the context of genetic analyses, we provide a simple tool to facilitate calculation of this metric.

How do errors in environmental and species occurrence data cumulate in modeling species-environment relationships?

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Species–environment relationships are often studied using species occurrences and environmental predictors of varying quality. While data quality clearly affects the credibility of modeled relationships, the interaction between errors in species occurrence data and environmental predictors has not been adequately addressed. Here, I investigate whether these errors act cumulatively or whether one has a dominant effect on environmental niche models (ENMs). To test this, I use species occurrence data affected by positional error and six canopy height models (CHMs) representing environmental predictors with different levels of error. In addition, I evaluate whether using a predicted but current global CHM performs better than using an outdated model derived from airborne laser scanning (ALS) data. I used the virtual species approach, complemented by real data on black grouse.

I show that both erroneous predictors and positional errors in species occurrence data decrease model performance, but whether they act cumulatively depends on the magnitude of each. If both errors are relatively small, they act cumulatively. However, when one of the errors becomes large, it masks the effect of the other. Consequently, the use of predicted CHMs in ENMs allows for the inclusion of records with reasonable positional errors (here up to three times the resolution used), and vice versa, when positional errors are large, the choice of CHM becomes less important. Note, however, that ENMs based on decade-old ALS data outperformed all predicted CHMs, except for the Canopy Height Map for Europe, which performed equally well in ENMs of black grouse. This highlights that ALS data should be preferred, even if outdated.

Finally, I stress that these results should not be used to justify the use of inaccurate data; minimizing error must remain the primary objective. However, knowing the nature of errors helps to balance their impact and ultimately allows for larger sample sizes.

Level of invasion of invasive alien plant species under current and future climates

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Invasive alien species (IAS) threaten biodiversity, ecosystems, and human well-being globally. These threats may increase due to new species introductions and synergies with global change drivers like climate and land-use changes. Thus, effective IAS management requires accurate projections of future invasion risks. Previous attempts to model the level of plant invasion (i.e., the number of IAS) across Europe relied on stacking projections from single-species distribution models (SDMs). Our study projects the level of plant invasion in eight broad habitat types across Europe under current and future climates using joint species distribution models (jSDMs) fitted on data for 481 species from GBIF, EASIN, and eLTER. jSDMs enable the simultaneous modelling of multiple species, taking into account co-occurrence patterns among species that are not solely attributable to environmental factors. This approach helps to estimate how environmental drivers influence species distributions and improves predictions of the overall species assemblage. Models were fitted using the Hmsc R package and its Python extension Hmsc-HPC, with computations performed on the LUMI HPC system via TensorFlow. For each of these models, we generated projections of habitat suitability for individual species and the aggregate level of invasion under both present-day and multiple future climate scenarios. We anticipate that the outcomes from our models will assist scientists and decision-makers in optimising resource allocation and prioritising IAS management strategies, in line with the EU IAS Regulation (1143/2014). The modelling workflow is adaptable and freely accessible online, allowing for regular updates with new data to provide up-to-date insights into plant invasion risks throughout Europe.

The Time of Acquisition of Multispectral Predictors Matters: The Role of Seasonality in Bird Species Distribution Models

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Species distribution models (SDMs) analyse the relationships between species occurrences and environmental predictors. Their efficacy largely depends on the selection of ecologically relevant predictors, with remote sensing (RS) data being one of the most commonly used sources. The usability of multispectral predictors is influenced by temporal changes in vegetation and environmental conditions. However, the impact of seasonality is often overlooked, despite its potential to affect model accuracy. This study aims to assess the influence of seasonality in RS predictors on SDM performance for bird species.

The study was conducted for the area of the Czech Republic, using presence-absence data from the Breeding Bird Survey (2018–2021) covering 147 survey squares and 104 bird species. We used Sentinel-2 satellite imagery to derive monthly and full-season composites of vegetation indices and reflectance bands from March to September (hereafter "periods"). Bioclimatic variables, topography, and vegetation structure were also included. SDMs were constructed using Lasso-regularized logistic regression and model performance was assessed through AUC (Area Under the ROC Curve) and R^2. Linear mixed-effects models were employed to evaluate model performance, temporal prediction stability, and predictor importance stability across all species.

Our results show that model performance depends on the period from which the predictors were derived. This dependence varies significantly among species and is partially associated with habitat preferences and prevalence, with forest species exhibiting greater stability. Differences in model performance across periods aligned with shifts in predictor importance causing different RS predictors to become significant with seasonal changes.

In conclusion, seasonal changes in vegetation, as reflected in the temporal variability of RS predictors, significantly affect SDM performance and predictor selection. Although species' ecological characteristics played a role, the effects remained species-dependent, making it difficult to develop universal recommendations. Still, accounting for seasonal variations in RS predictors could enhance model accuracy for many species.

How the choice of spatial resolution affects freshwater fish species distribution models

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Species distribution models (SDMs) are widely used to understand and predict how species respond to changes in their environment. Hence, it is critical to understand how SDMs are influenced by methodological aspects and choices. The choice of spatial resolution is an understudied subject, especially for freshwater fish SDMs. Here, we aimed to analyse how the choice of spatial resolution affects the predictive accuracy, predictor variable importance and spatial predictions of large-scale SDMs of 49 freshwater fish species occurring in Europe. To that end, we fitted SDMs based on point occurrence records of the species combined with environmental predictor variables aggregated at five spatial resolutions as represented by nested hydrological basins (level 8 to 12 in the HydroSHEDS database). Following an ensemble modelling approach, we employed nine modelling techniques to establish the SDMs at each of the resolutions, using temperature, topography, water flow, land use, human population, and dam density as predictor variables. We analysed the differences in predictive performance by testing the models on a geographically independent subset of the data. Predictive performance and variable importance were highly similar across the resolutions, with a median TSS between 0.37 and 0.39, and temperature and topography variables being the most important. In contrast, predicted range size decreased towards higher resolutions, while the difference between predicted and observed range size increased. Overall, our results indicate that the choice of spatial resolution has a small effect on the performance and predictor importance of continental freshwater fish SDMs, while significantly influencing predicted range size.

Hybrid Modelling of Forest Dynamics with Forest-Informed Neural Network (FINN)

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Predicting forest dynamics under climate change is challenging and requires models capable of extrapolating into novel environmental conditions. Complex process-based forest models are often used for this purpose, but they typically incorporate many assumptions, making them difficult to constrain with data. In response to these limitations, data-driven approaches such as Artificial Intelligence (AI), particularly deep learning, have gained attention for their superior predictive performance. Yet deep learning models, while excellent at capturing complex patterns, tend to extrapolate poorly, making them unsuitable for modeling forest dynamics under changing environmental conditions. However, hybrid modeling, which integrates flexible data-driven deep learning models within process-based models, promises the best of both worlds: mechanistic understanding and the flexibility of DL. Here we present Forest Informed Neural Networks (FINN), a novel hybrid approach implemented in torch for R that seamlessly integrates deep neural networks within dynamic vegetation models. Uncertain process submodels (e.g. growth, mortality, regeneration) can be replaced in FINN by transformer models (known from large language models), which can be trained together with the full model via automatic differentiation. We show that FINN achieves high accuracy without any prior parameterization, trained purely on data. Furthermore, we show that tools from explainable AI can be used to understand what the DL submodules have learned, and that these patterns can serve as the basis for new hypotheses about the true processes. By combining mechanistic understanding with the flexibility of AI, FINN provides a robust, scalable framework for inferring and predicting forest dynamics.

A tool for visual analysis and photo-realistic rendering of forest landscape model simulations

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Simulation outputs from Forest Landscape Models are complex, and tools for their visual analysis and effective communication are often limited. In this paper, we present EcoViz, a novel, open-source visualization platform designed to complement existing forest models by providing advanced 3D visualization capabilities. EcoViz facilitates the exploration of simulation results through two primary modes: symbolic rendering, designed for analytical tasks, such as pattern recognition and model evaluation, and photorealistic rendering, leveraging physically-based rendering (Mitsuba 3) and a custom library of European 3D tree models for communication purposes.

The platform imports data in a typical model output format (e.g., spatially explicit individual tree or cohort data) and employs a temporally coherent sampling technique to visualize individual trees derived from cell-based density maps. Key features include: interactive side-by-side comparison of different simulation scenarios or time points, with synchronized navigation (viewpoint, timeline, transects), a mini-map overview, timeline controls with linked ecological metric graphs, and transect analysis tools. Developed using C++/Qt/OpenGL, EcoViz is cross-platform.

The practical application of EcoViz is demonstrated by visualizing simulations of Berchtesgaden National Park under baseline and climate change scenarios exported from the iLand forest landscape model. This case study showcases the utility of EcoViz for comparative scenario analysis across spatial scales and how it aids model evaluation through visual inspection. While symbolic views support detailed analysis, the photorealistic output offers a compelling tool for science communication with diverse audiences, including scientific peers, forest managers, and the public.

Uncertainty analysis of the InVEST® Habitat Quality model for assessing biodiversity trends under land-use change

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Models are valuable tools to better understand biodiversity trajectories amid land-use change. However, to ensure their reliability, it is essential to know how much uncertainty (e.g. arising from variable data sources and parameterization methods) they contain.

Here, we present an uncertainty analysis of the well-established Habitat Quality model from the InVEST® suite. We applied this model to a case study of land-use transformation from tropical rainforest to oil palm and rubber plantations in Indonesia. The model uses habitat quality as a proxy for biodiversity and accounts for negative influences of different land-use types, resulting in varying habitat degradation over space. In this spatially explicit model, landscape configuration is one of the key determinants of habitat quality and, ultimately, biodiversity. We evaluated how different parameterization methods affect biodiversity through space and time and under various landscape compositions and configurations.

We demonstrate three parameterization methods for the Habitat Quality model, based on basic-research knowledge, expert knowledge, and remote sensing, and discuss their variability in model outputs. We show that parameterizations based on basic-research knowledge and expert knowledge have a similar effect on modelled biodiversity, whereas remote-sensing-based parameterization differ. More specifically, we show that modelled biodiversity based on remote-sensing reacts more sensitive to changes in landscape structure. Our results quantify how different parameterization methods influence biodiversity outcomes in a popular biodiversity model, improving our understanding of uncertainties in

Connectivity beyond patches: How a cell-based landscape graph can improve connectivity modelling in cities

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Urban biodiversity contributes to the physical and mental health of city dwellers. Thus, urban planners aim to conserve animals in cities. However, the resources available for urban animals have a patchy distribution and are separated by impassable barriers like buildings, which can prevent them from establishing themselves. Connectivity models are increasingly applied to city landscapes to identify potential corridors and determine locations for stepping stones that improve access to resources. However, the often-used patch-based landscape graphs assume that animals have complete knowledge of the landscape and follow a single optimal path because they model relatively few nodes and paths. Here, we propose the use of cell-based landscape graphs where each patch is divided into comparable pixels that form nodes of the landscape graph. Cell-based landscape graphs assume some knowledge of the surrounding landscape and allow for the choice between redundant paths. We test whether a patch-based or a cell-based landscape graph can better predict the occurrence of movement simulated with an individual-based model that has been successfully used before to compare the predictions of connectivity models. We further compare the capability of both modelling approaches to explain the observed movement of common blackbirds (*Turdus merula*) in the city of Munich. In the simulation and the empirical test, the cell-based landscape graph predicted the occurrence of movement better than the conventional patch-based landscape graph. The cell-based approach for node definition could improve the accuracy and applicability of connectivity models in urban planning by considering multiple possible pathways and integrating animals' knowledge of their environment.

Persefone.jl: evaluating biodiversity impacts of agricultural policy with a multidisciplinary mechanistic model

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The environmental impacts of modern agriculture are of grave concern. Although policies such as the European Common Agricultural Policy (CAP) attempt to mitigate these impacts, the decline of farmland plant and animal species continues at an alarming rate.

A major challenge in designing effective agricultural policies is that these must take multiple economic, social, and ecological aims into consideration. To evaluate potential outcomes of alternative policy scenarios, simulation models can be useful. However, while economic models are frequently used for such evaluations, this is less true of biodiversity models. One problem is that few existing agro-ecological models explicitly simulate agricultural management practices and the spatio-temporal landscape dynamics these generate.

We present Persefone.jl, a new process-based model that simulates agricultural landscapes as social-ecological systems, with interacting submodels of farm management, crop growth, and animal populations. First, we discuss on a conceptual level how modelling management and crop growth allows us to study temporal and spatial landscape processes, and their impact on the abundance and distribution of farmland animal species. Second, we present the results of our crop model calibration, demonstrating how public data and process-based models can be combined to estimate regionally-specific crop yields and phenologies. Third, we show how our model can be used to evaluate the biodiversity impacts of policy, taking as example the recent derogation of fallow-land regulations in the CAP.

We close with an outlook on future work with Persefone.jl. By making the software as accessible and adaptable as possible, we hope to establish it as a useful tool for basic and applied research on agricultural systems and species.

Balancing Yields and Water Quality: Ecological-Economic Modeling of Nitrogen Policy Impacts in German Agriculture

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The use of nitrogen (N) in agriculture supports high yields but contributes to environmental damage and health issues. Yet, there exists limited knowledge on the impact of policy interventions targeting changes in farmers' N management on environmental nitrogen pollution across temporal and spatial scale. We developed the ecological-economic model „SNAg – Sustainable Nitrogen Management in Agriculture" where we calculate economically optimal N fertilizer rates under different policy scenarios and for varying site-specific conditions in Germany. Yield response to N input is based on an emulator of the dynamic global vegetation, hydrology and crop model LPJmL. Policy-induced N surplus reductions are processed further with the water quality model mQM. With this model setup, we explore the trade-offs of nitrogen related policies between food security, environmental damage, and the economic well-being of farmers.

First results show that both land productivity and subsidy design shape farmers' responses under voluntary subsidy schemes for reducing N surplus. Uniform, strict N input limits lead to higher yield losses and economic disparities. In contrast, moderate limits achieve similar N reductions with broader participation and less economic impact. Spatially targeted subsidies can further improve cost-effectiveness and fairness by aligning incentives with local conditions.

These different policy designs also affect nitrate concentrations in groundwaters through the spatial distribution of N surplus across Germany. Together with legacy effects of past N inputs this can influence the evaluation of policy impacts, which we investigate by processing N surplus with mQM in Rhine and Elbe catchments until 2030.

Overall, using computational models can allow for a comprehensive evaluation of policy impacts and provide valuable insights into the effectiveness and fairness of different nitrogen policies in the context of German agriculture.

Individualised niches in a variable environment: consequences for environmental change responses

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Intraspecific trait variation (ITV) can be important for population performance in a variable and changing environment because individuals with different traits have different fitness responses. Furthermore, there are three mechanisms via which individuals can interact with their environment to potentially improve fitness: niche conformance, niche construction, and niche choice (NC^3). These processes become increasingly important in the presence of environmental change, but there is still no mathematical modelling framework that would unite the effects of ITV and the NC^3 mechanisms.

In this talk, we show a general model incorporating ITV and two of the NC^3 mechanisms (niche conformance and construction, NC^2) to investigate how they affect populations in a changing and variable environment via non-linear averaging. We quantify the effects of NC^2 and ITV on average individual fitness using an analytical Taylor approximation and a sampling approach.

Our method allows us to answer the question of what would have happened if individuals in the study system did not have ITV or did not perform NC^2 mechanisms. The answer to this question depends on the curvature of the fitness function and can be estimated via the Taylor approximation.

We illustrate the method with a modelling example and a case study based on empirical data.

The instabilities that are good for biodiversity

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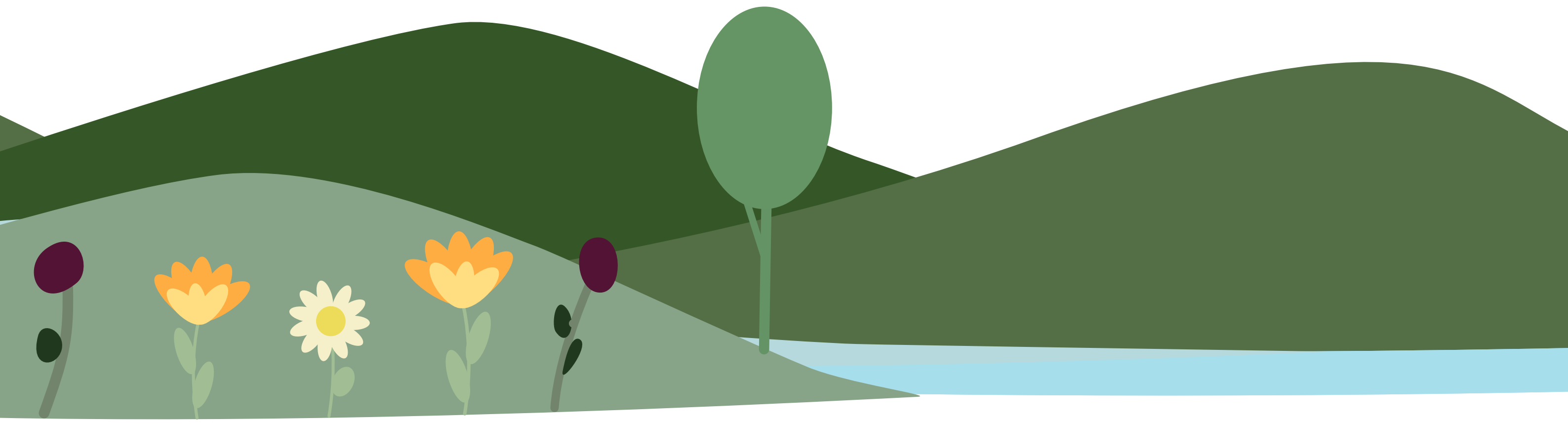
Population instabilities —such as those driven by strong predator-prey interactions— are often viewed as threats to species persistence, as they can cause oscillations in the species' abundances that repeatedly push them to low densities, increasing their risk of extinction due to random fluctuations. However, unlike these more familiar *temporal* instabilities, *spatial* instabilities can actually promote species persistence and enhance biodiversity. As the term suggests, spatial instabilities arise in spatially extended ecosystems and generate heterogeneity in the distribution of resources and species, even under uniform environmental conditions. This emergent heterogeneity, also referred to as self-organised pattern formation, supports species coexistence through several mechanisms, including intensified source-sink dynamics, reduced stabilising selection, eco-evolutionary feedbacks, and relative non-linearity.

Using models of trophic metacommunities, we show that spatial instabilities can be studied with the same mathematical methods as temporal instabilities. These spatial dynamics give rise to either static differences or asynchronous, large-amplitude oscillations in species' abundances across habitat patches. As a result, they help maintain high levels of functional diversity at the local scale, far beyond what would be expected in isolated communities, where stabilising selection typically reduces diversity. Notably, even competitively inferior species can persist when spatial heterogeneity is generated dynamically, either by exploiting favourable conditions in specific patches or by adopting dispersal strategies tuned to fluctuating spatial patterns. These examples demonstrate how spatial instabilities interact with ecological and evolutionary processes to foster species persistence and biodiversity — insights that are especially relevant in the context of habitat fragmentation and declining landscape connectivity driven by human activities.

Session 12

Experimental plant ecology



Populus pruinosa decline in a riparian tugai forest at the Zarafshon River, eastern Uzbekistan: edaphic conditions as a predisposing and drought as the triggering factor

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Anthropogenic changes reduced the area of Central-Asian riparian forests (*tugai*), also involving dieback of *Populus pruinosa*, one of tugai's constituting tree species. In a tugai forest at the Zarafshon River, eastern Uzbekistan, we investigated the role of environmental factors in *P. pruinosa* dieback by comparing one healthy and one proximate declining stand. We measured the widths of tree-rings of the past 25 years (1999—2023), analyzed their carbon isotope ratios (ð13C; 2004—2023), determined physical and chemical soil variables, and retrieved data on groundwater depths and SPEI (Standardised Precipitation Evapotranspiration Index).

Across the entire 25-year period of the investigation, the radial growth did not differ between the trees of the healthy and the declining stand, but the growth of the declining stand's trees exhibited a decreasing trend, and in the last six years (2018—2023), during and after two exceptionally dry years (2018 and 2019), the radial increment of the declining stand's trees was significantly smaller. Correlations between radial growth, ð13C and SPEI that were indicative of drought stress were only found in the declining stand's trees but not in those of the healthy stand. The soil of the declining stand exhibited a higher clay content in the subsoil (> 30—60 cm), higher salt concentrations in the uppermost soil layer (0—10 cm) and in the subsoil, and a lower field capacity across the entire soil profile (0—60 cm). There was no groundwater decline during the study period. We conclude that unfavorable soil conditions have predisposed the trees of the declining stand to dieback, which has been triggered by exceptionally dry years. Our study may contribute to develop further research schemes for analyzing interrelationships between hydrological, edaphic, ecophysiological and meteorological factors in dieback processes of Central-Asian riparian forests, especially in

Habitat preference drives the hydraulic safety-efficiency trade-off across temperate angiosperms but not conifers

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The impacts of climate change on forest ecosystems, particularly drought stress, present significant challenges to the survival and productivity of tree species across Europe. Thereby, the balance between hydraulic safety and efficiency is central for determining how tree species maintain water transport capacity during drought stress.

Here, we present major hydraulic traits, including hydraulic safety and efficiency, leaf-to-sapwood area ratio and wood density, for 25 coniferous and 38 diffuse-porous tree species. All trees were similar-aged and grown at the same experimental site in Central Europe, the ARBOfun research platform, which was established between 2012 and 2014.

We observed marked differences in xylem safety and efficiency according to species' habitat preference. While we could not confirm a general hydraulic safety-efficiency trade-off, our data provide evidence for a strong cross-species trade-off in diffuse-porous trees after excluding riparian species. The results will be discussed with respect to species' habitat preference.

Within the scope of a broader phenotyping study, we aim to gather data on additional functional traits to construct one of the most extensive datasets of plant hydraulic traits for temperate tree species measured with consistent protocols in order to identify common axes of variation in species-level drought response traits.

Plant responses to light competition: does evolutionary history matter?

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Plants can respond to light-competition cues with sets of plastic responses that provide either shade avoidance or tolerance and were suggested to match these strategies to the competition scenarios they experience. However, little is known about the effect of plants' evolutionary history on their ability to shift between these strategies. We performed a common-garden experiment that examined shade avoidance and tolerance responses of the annual plant *Hymenocarpos circinnatus* to a variety of simulated light-competition scenarios, including different heights and densities of surrounding vegetation. These responses were compared across plants originating from six populations along a climatic gradient; from a semi-arid region, where light competition is relatively weak and homogenous, to a mesic-Mediterranean region, where light competition is stronger and more heterogenous. We found little evidence for divergence along the climatic gradient in the responses of *H. circinnatus* to light competition, which might reflect low costs of plasticity in these traits. Interestingly however, regardless of their evolutionary history, *H. circinnatus* were more responsive to cues of neighbor density rather than height in both shade tolerance and avoidance traits. These results suggest that procumbent plants such as *H. circinnatus* might respond more to lateral competition cues than vertical ones, thus highlighting the need to incorporate the two types of cues when studying plastic responses of plants to competition.

Shedding light on drought-induced mortality of tree seedlings under variable light conditions

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To investigate how microclimatic factors affect drought-induced mortality, we studied four tree species (*Abies alba, Fagus sylvatica, Pseudotsuga menziesii* and *Quercus robur*) under controlled greenhouse conditions. Seedlings were exposed to lethal drought under full radiation or shaded conditions. Gas exchange and predawn water potential ($\Psi_{predawn}$) were monitored, with mortality defined at the Ψpredawn corresponding to 88% loss of hydraulic conductivity. Additionally, morphological traits such as stem height, total leaf area and root: shoot ratio were assessed. We used a Cox proportional hazards model with time-varying covariates (soil moisture, VPD (vapor pressure deficit), light condition) and the measured plant traits to assess species-specific seedling mortality risk under drought and light intensity.

Seedlings generally survived longer in the shade due to more favorable soil moisture and microclimate. Higher transpiration rates - driven by greater evaporative demand, plant size, and leaf area -likely explain the increased vulnerability under light. Mortality followed a species-specific pattern in the light (*Q. robur - F. sylvatica - P. menziesii*), whereas shaded seedlings exhibited more uniform mortality. A. alba showed the highest drought resistance, likely due to smaller leaf area and greater water storage capacity. When predawn water potential ($\Psi_{predawn}$) was related to VPD-hours, treatment differences became less pronounced. Overall, species-specific traits, such as total leaf area, emerged as key factors in drought resistance. These findings highlight the need to adapt forest management -through thinning and species selection- to enhance resilience under changing climate conditions.

Environmental factors influencing phenological processes at an experimental forest stand with Fagus sylvatica and Picea abies.

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At an experimental site (Kranzberg Forest, Bavaria) visual observations of bud break in spring and autumnal senescence have been made over a period of 25 years in a mixed stand consisting of *Fagus sylvatica* and *Picea abies*. Onset and the course of bud break has been monitored individually at always the same group of around 50 adult trees of both species as well as senescence of beech. During the period of observation two long-term experiments have been conducted at the site, a free-air ozone fumigation experiment between 2000 and 2008 (SFB 607) and an ongoing drought stress experiment starting in 2014 (KROOF), however using different sub-plots for the different treatments. This way the reaction of the two species to the experimental treatments could be studied as well as the recovery from it. Air pollution (elevated ozone concentrations) as well as drought changed the timing of the phenological stages but within range of early and late performers each individual kept its position stressing the genetic component of phenology in addition to the environmental factors.

Vertical distribution of chlorophyll content in the tree stem and buds of Carpinus betulus during spring development under salt stress

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Salt stress in urban environments is primarily caused by the application of deicing salts during winter, which accumulate in the pits of roadside trees. Certain urban tree species, such as *Carpinus betulus*, exhibit high sensitivity to elevated soil NaCl concentrations. Salt uptake through the roots disrupts key physiological processes, including photosynthesis and transpiration, leading to delayed bud break and premature leaf senescence, often as early as late summer. This results in a shortened growing season, is compromising key ecological functions of urban trees, such as their capacity to lower local temperature and ability to improve air quality.

This study investigates the response of *Carpinus betulus*, a widely planted urban tree species in Vienna, Austria, to a salt stress treatment of 50mM NaCl. We hypothesize that chlorophyll and carotenoid concentrations in the cortex and xylem, both at the base of the stem and the apical end, fluctuate during the seasonal transition from winter to summer. These pigments and Fv/Fm are expected to increase until full leaf development and subsequently decline due to shading. Moreover, below-ground salt stress may reduce corticular and leaf chlorophyll content and lower C sequestration, thereby interfering with metabolic functions. Preliminary results indicate a pronounced sensitivity to salt exposure, as evidenced by a significant delay in bud break. Understanding these physiological responses is crucial for assessing the long-term impact of salt stress on urban tree health and ecosystem services.

Xylem vulnerability segmentation in eight temperate tree species

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Hydraulic failure and carbon starvation are two key interrelated mechanisms explaining drought-induced tree mortality. Hydraulic failure occurs when xylem hydraulic conductance is lost. Plants' ability to resist hydraulic failure is commonly assessed by determining the xylem water potential at which 12%, 50%, and 88% of hydraulic conductance is lost (P_{12}, P_{50}, and P_{88}, respectively). These thresholds can vary within the plant which is referred to as vulnerability segmentation (VS). This posits that more temporary, distal parts of the plant (leaf and fine roots) are more vulnerable to embolism than permanent parts of the plant (stem and coarse root). However, embolism resistance is often assessed by measuring at one location which can result in under- or overestimation of a species drought resistance.

In this study, we used the optical vulnerability method to explore xylem VS in four parts (leaves, stems, fine and coarse roots) in saplings of eight temperate tree species by determining P12, P50, and P88, as well as the time to reach these thresholds (T_{12}, T_{50}, and T_{88}, respectively). Additionally, we measured minimum conductance (g_{min}) in all four parts. We hypothesized that isohydric species show greater VS than anisohydric species, and that the time to reach critical xylem water potential thresholds does not depend on isohydry, but rather on g_{min}.

We found significant VS in six of the eight studied species, however, we did not find anyconsistent pattern of VS along the expected gradient (i.e., thin root < leaf < stem < thick root). Further, the degree of VS was highly species-specific and not related to species isohydryness. Moreover, the time to reach critical xylem water potential thresholds was not related to species isohydry either, but likely to species desiccation tolerance.

Our findings contribute to the understanding of xylem embolism resistance in different parts of the plant which is crucial for understanding species-specific drought resistance strategy.

High resolution dynamics in leaf-level carbon fluxes assessed with a novel distributed sensing network in a mature Fagus sylvatica and Pseudotsuga menziesii forest

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Leaf gas exchange within tree crowns is highly heterogeneous in space and time. Due to the large effort in labour and instrumentation to measure parameters related to leaf gas exchange, important information on spatio-temporal dynamics of photosynthetic efficiency, photosynthesis, and its isotopic carbon discrimination in mature forest trees is largely missing. Especially the combination of leaf level gas exchange with chlorophyll fluorescence (ChlF) measurements is a promising tool to unravel the mechanistic functioning underlying processes and dynamics of photosynthesis under changing environmental conditions. It provides missing information on photosynthetic regulation and energy partitioning, e.g., by investigating the rate of electron transport between the photosystems to net CO2 assimilation (ETR/Anet). In this study, we continuously measured gas exchange, δ13C in sun and shade leaves (n = 5 per species), ChlF (sun leaves, n = 3 per species) and ecosystem carbon exchange in the mature *Fagus sylvatica* and *Pseudotsuga menziesii* ECOSENSE forest with an automated measurement system, including a novel leaf cuvette for broadleaved trees. In several campaigns, emissions of biogenic volatile organic compound (BVOC) were measured in both species. Measured parameters showed distinct seasonal patterns with large, sub-daily spatio-temporal dynamics, illustrating the need for high-resolution measurements. On warm and sunny days, sun leaves of both species had higher net assimilation and BVOC emission rates, however this difference vanished under colder, but sunny conditions, and was accompanied by a decrease of maximum and effective quantum use efficiency. Especially for *F. sylvatica*, cold stress effects were detected at daily air temperatures <15°C, which led to a cold-induced increase in non-photochemical quenching. These results illustrate the importance of a combined measuring approach to better understand spatio-temporal dynamics of carbon exchange in mature forests.

Why starch concentrations in branches are probably not a good indicator for the carbon balance of trees

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Starch is the ubiquitous carbon reserve in trees that is stored decentralized in sapwood parenchyma of branches, stems and roots. As a transitory carbon pool between photosynthesis and carbon sinks (growth, respiration,...), tissue concentrations of starch are assumed to mirror carbon source-sink-relations, with concentrations positively correlating with the net balance between gross primary productivity and the sum of all carbon sink activities of a tree. In my presentation, I will review if starch concentrations in branch sapwood of mature trees are suitable indicators for the annual carbon balance and climatically induced changes of the trees' carbon source-sink activities.

I focus on evidence form mature trees of common European broadleaved species that have been extensively investigated at the Swiss Canopy Crane II facility since 2018. Despite very different climatic conditions in terms of temperature and water availability across the observation years, we found surprisingly small variations of starch concentrations in terminal branches at the end of the growing season across years. This is in stark contrast to leaf gas-exchange and growth that both declined significantly in years with extended drought periods. Further, among all investigated species, deviations from the species-specific average starch concentrations in some years were not consistently correlated with climatic anomalies (e.g., exceptionally dry seasons were not uniformly associated with decreased branch starch concentrations). Very low starch concentrations found at extreme drought stress are likely associated with loss of hydraulic conductance in the xylem and the associated dieback of wood parenchyma cells. Overall, these findings suggest that starch formation in branch sapwood possesses a high priority, and the fast refilling of starch reserves in wood parenchyma of younger branches after spring bud break occurs largely independent of the concurrent total tree carbon relations.

How European trees adjust their root exudates based on external and internal factors

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Root exudation is an important part in the nutrient acquisition of plants. Plants thereby release carbon into the soil, stressing its importance for carbon cycling. Nonetheless, data on root exudation in temperate forests and especially its composition and temporal dynamics are scarce. We investigated four temperate forests differing in forest floor (FF) thickness and temperature in different seasons (late spring and late summer) to examine if exudation differed between the FF and the Ah horizon.

In this study, root exudates of *Fagus sylvatica* (FS), *Picea abies* (PA) and *Acer pseudoplatanus* (AP) were sampled using an in-situ cuvette-based approach. Cleaned roots were incubated in a cuvette filled with glass beads and a nutrient solution for 24h. Exuded compounds were analysed by gas chromatography-mass spectrometry. Further, root, branch wood, branch bark and leaf samples were taken from the same trees and analysed using isotope ratio mass spectrometry to determine the carbon and nitrogen concentration and their isotopic signature.

All species showed a higher rate of exudation in late spring compared to late summer. While PA exuded more in the Ah across all sites, AP exuded more in the Ah only on sites with a thin FF. In FS, exudation was independent on soil depths. The composition of exchangeable cations in the soil influenced the exudation of various compound groups in FS and PA in different ways depending on species and element. We also found a tissue-dependent positive and negative relation between [N] and root exudates in AP and PA, respectively. Further, the $\delta 13C$ ratio, the enrichment of which is an indicator for water use efficiency and drought stress, was related to root exudation in AP and PA, with enriched values in roots of PA and depleted values in bark and wood of AP going along with higher exudation.

We observed species-specific patterns and reactions to site conditions, which advocates for more detailed research on exudation in forest trees.

Tree funcitonal traits driving nutrient cycling in pure and mixed stands of Douglas fir and European beech

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Climate change poses challenges to forest ecosystems, particularly in temperate Europe, where dieback affects both native broadleafs and range-expanding conifers. Adaptive silvicultural strategies include introducing non-native conifers like the fast-growing, drought-tolerant Douglas fir and mixtures with European beech. While mixtures may enhance forest functioning through increased functional diversity, their impacts on nitrogen (N) cycling are largely unknown.

Here, we show elevated nitrate concentrations in soil solution under Douglas fir, indicating a high risk of nitrate leaching, particularly on loamy soils. However, admixture with beech reduced nitrate levels, mitigating nutrient loss and groundwater degradation. The effect is strongly modulated by site (soil texture), emphasizing the environmental dependency of such functional traits. With isotopically labeled tracers, we then show that mature Douglas fir trees *in-situ* predominantly absorbed nitrate from topsoil, indicating that a reduced nitrate uptake from deeper soil contributed to nitrate leaching. Species mixing effects on uptake were limited but suggested a niche complementarity and an increased root functional diversity in the mixed stand. Further, by using sap flow measurements and a doubly-labelled tracer (^{2}H and ^{15}N) in a novel method, we demonstrate that the uptake of water and nitrogen in mature trees is an asynchronous process and present how it is modified by species and site.

The functional traits driving nitrogen cycling in mixed stands of Douglas fir and beech are determined by tree species identity and modulated by species mixing and site conditions. Pure Douglas fir may have adverse effects on the N cycle, which underscores the potential of mixed-species stands with beech to enhance nutrient retention and sustainability of the stand. Insights into tree functional traits driving nitrogen cycling can support the development of climate-resilient strategies for forestry in the temperate zone.

What ecologist might wish to know about (micro)climatology

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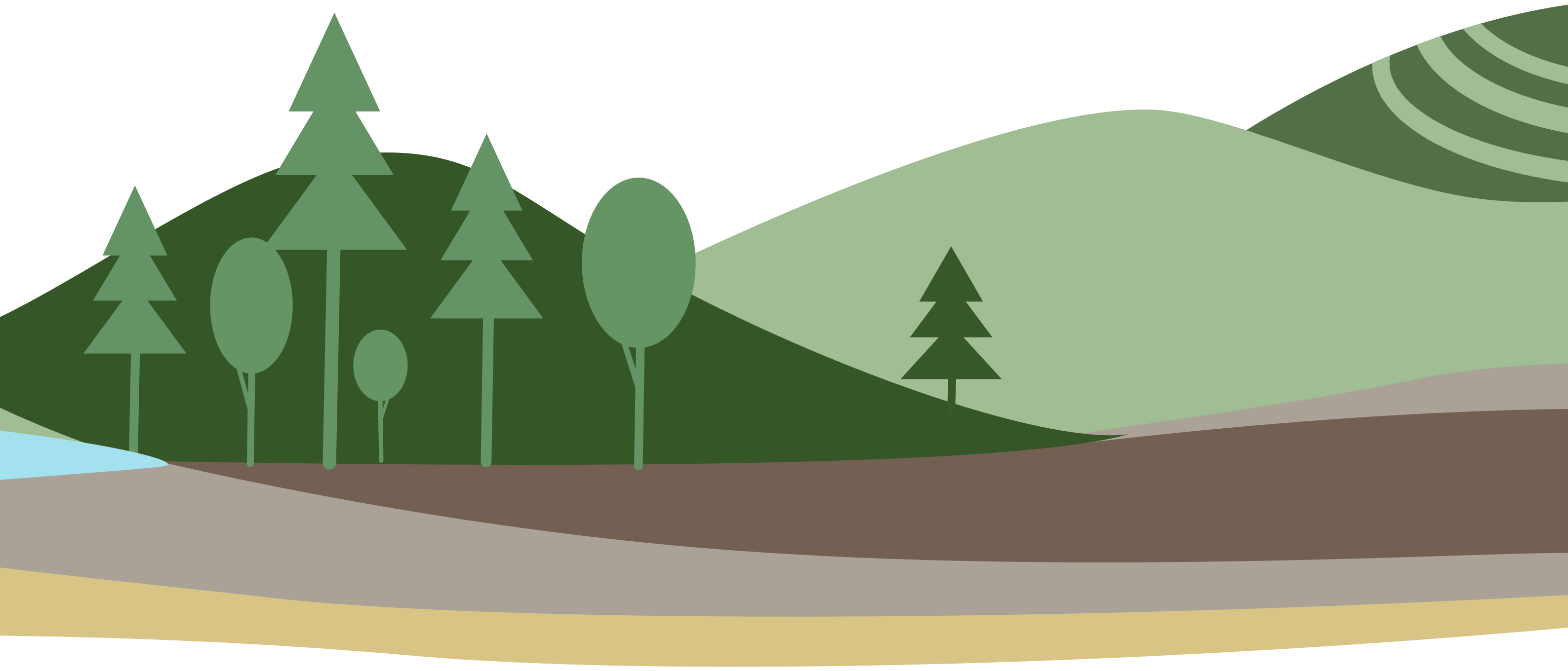
Ecology is the science of interactions: organisms among each other, their interactions with soils and climate. What is the climate that matters? Which errors are to be avoided? I will start by recalling important macroclimatic metrics of temperature, those that are useful and those that are best avoided. Among the latter, annual means (MAT) and means of minima are ecological no-goes, and I will explain why. Similarly, relative humidity is an unsuitable metric. Examples will illustrate, why macroclimatic metrics often lack ecological meaning, calling for microclimatic approaches. Important criteria for selecting adequate microclimatic metrics are their functions, the biological targets, the temporal resolution and available tools. Since almost all biological responses to temperature are non-linear, arithmetic means are best avoided and replaced by frequency distributions. When extremes come into play (frost, heat, drought), thresholds matter, and such decisive singularities require absolute minima or maxima (not reported by popular data bases), with means of such events entirely meaningless. Sensor placement is a most delicate issue, with a few cm distance, periodic insolation or variation in plant cover, potentially creating differences in temperature readings that would otherwise correspond to 1000 m in elevation or 2000 km in latitude, if these readings were from standard weather stations. Ecology curricula should offer such basic training.

Session 13

Forest biodiversity: effects of structure and management



Can we improve our management of beech forests? Altering homogeneous forest stands creates spatially more diverse species communities

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Forest management practices in Central Europe created highly homogeneous forests with closed canopies and similar aged trees. Consequently, species communities in managed forests probably became similar, suggesting biotic homogenisation, and the loss of distinct species communities spread across beech forests. This means that species composition is mostly the same in managed forests, independent of their relative geographical position to each other.

I compared the differences in species composition over a geographical distance gradient (distance decay relationship) within managed forest stands and forest stands which received various management interventions to increase their structural heterogeneity. Distance decay relationships are optimal metrics to measure how species communities become different along a physical distance gradient if areas closely located to each other will have more similar species composition than areas further away from each other. However, it is expected that in homogeneous habitats, this relationship weakens, and all areas will have similar species compositions. Our study confirmed this idea - when looking at arthropods, communities became more diverse between locations of structurally altered forest stands than between locations of managed stands. However, responses were not uniform for all arthropod taxa. Spider communities became more heterogeneous between locations of altered stands than between control stands, whereas beetle communities along a geographical distance gradient did not respond to the forest structure alterations.

Our results indicate that the relationship between arthropod community similarity and spatial distance in managed beech forests is driven by management interventions and consequently structural complexity of the forest stand, but patterns depend on studied taxa. Forest management that increases structurally heterogeneity, will likely result in diverse arthropod communities along a geographical distance gradient.

Climate and forest structure shape decomposer communities of animal derived necromass in temperate forest

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Forest management in central European production forests has shaped forests towards homogenous closed canopy forests leading to a loss of biodiversity and ecosystem multifunctionality. Conservation targeted programs aim at reintroducing structural heterogeneity; however, it is not well understood if species diversity and ecological functions generally profit from more heterogeneity in forest structure.

By breaking down organic matter, decomposition processes and their associated invertebrate communities are an integral part of nutrient and carbon cycling. Through their tunnelling behaviour dung beetle and burying beetle species play an important role in forest ecosystems, not only through the removal of animal derived necromass, but also by improving soil aeration and fertilisation.

As part of the BETA-FOR research unit we assessed community compositions of coprophagous and necrophagous beetles as well as decomposition rates of carcasses and dung in spring and summer on 234 study patches in 11 paired forests landscapes across a climatic gradient in Germany. In each landscape, forest districts were either managed to conserve a homogenous closed canopy or to create a heterogeneous forest structure with forest patches varying in canopy coverage and dead wood availability.

We did not find a higher species diversity of dung beetles or necrophagous beetles in forests managed for higher structural complexity. Instead, local diversity of both groups was lower on study patches with open forest canopies. Additionally, dung beetle biomass and dung removal decreased with increasing temperature along the climate gradient. This demonstrates that some important forest communities might not benefit from increased structural heterogeneity in forest stands. Higher temperatures, especially in combination with open forest canopies negatively impacted dung beetle communities, showing that under future climate warming the central European dung beetle fauna might face increased

Differential effect of introduced and native conifers on moth diversity in temperate forests

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Douglas-fir (Pseudotsuga menziesii) is increasingly planted across Europe due to its economic value and climate-change resilience, yet its ecological effects on native forest biodiversity remain debated. Current knowledge about its influence on moth communities, important indicators of forest ecosystem health, is particularly limited. We assessed how Douglas-fir influences moth communities compared to native broadleaf (European beech) and conifer (silver fir) forests in the Spessart region (Bayern), Germany. Using light traps, we sampled moths (biomass, abundance, richness, and community composition) across 63 forest plots (pure beech, beech–silver fir, beech–Douglas-fir). Structural (LiDAR-derived canopy gaps, canopy height model variability), compositional (beech proportion), and landscape variables (oak presence, forest amount, road density) were also included in our analysis. Douglas-fir-beech plots supported significantly higher macro-moth abundance than silver fir-beech mixtures, with pure beech showing intermediate values. Higher beech proportion at plot level and greater forest amount at landscape level positively influenced moth abundance. While 78 species (37.3%) occurred across all forest types, Douglas-fir mixtures contained the highest number of exclusive species (53.2%). Community composition analysis (NMDS) showed no clear separation between forest types, with broadleaf forest proportion at landscape level being the strongest predictor of community structure. However, indicator species analysis revealed specific associations between certain moth species and forest types. Our results suggest that Douglas-fir, when mixed with native species, can support diverse moth communities. Forest management practices might consider implementing mixed stands rather than monocultures, maintaining structural complexity, and preserving sufficient proportions of native tree species to balance timber production and biodiversity conservation in European forests.

Contrasting effects of native and non-native conifers on soil microbial communities in mixed European beech-conifer forests

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Soil microorganisms are key drivers of carbon stocks and nutrient cycling in forest ecosystems. Tree species composition significantly alters soil microbial community structure and thereby the functioning of microbial communities. In Central Europe, Douglas-fir (Pseudotsuga menziesii) and Silver-fir (Abies alba) are considered promising conifer species to mitigate damage of forests of drought sensitive Norway spruce (Picea abies) by establishing mixed forests of these conifers and European beech (Fagus sylvatica). However, consequences of planting beech - conifer mixed forests with native Silver-fir and non-native Douglas-fir on biodiversity and ecosystem functioning is limited and this also applies to soil microorganisms. Here, we analyzed soil microbial biomass and community composition to varying proportions of Douglas-fir and Silver-fir in beech – conifer mixed forests using substrate-induced respiration (SIR) and phospholipid fatty acid (PLFA) profiling. Soil [SS1] microbial biomass and community composition strongly depended on conifer species and proportions. In Douglas-fir - beech mixed forests, increasing conifer proportion was associated by decreased soil microbial basal respiration, microbial biomass and microbial specific respiration, likely due to increased limitation of nitrogen as reflected by higher litter C/N ratio. By contrast, in Silver-fir - beech forests, increasing conifer proportion increased microbial activity and biomass. The ratio of cyclopropyl PLFAs to their monoenoic precursors (cy/pre ratio) as microbial stress indicator also pointed to intensified nutrient stress with increasing Douglas-fir but not with increasing Silver-fir proportion. Microbial community composition was also strongly affected by conifers species. Gram-negative bacteria (associated with labile carbon resources and high pH) were favored in European beech forests, while Gram-positive bacteria (associated with recalcitrant litter and high C/N ratio) were favored in Douglas-fir – beech mixed forests. Overall, the results stress the critical role of tree species identity and their proportion in shaping soil microbial community structure and functions. In particular, plantation of Douglas-fir – beech mixed forests may detrimentally affect the functioning of microbial communities, but this may be mitigated in plantations with low Douglas-fir proportion.

Patterns and drivers of post-fire tree regeneration in the Western Himalayan Region

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The Western Himalayan Region(WHR) is a distinct mountain landscape where forest fires are key in shaping forest succession, ecosystem services, and socio-cultural practices. In particular, the middle elevations(1,000-2,000 metres) are marked by high fire incidences and intense human-nature interactions. Forest regeneration is a key indicator of forest resilience, which is impacted by management practices, forest fires, human disturbances, and inherent biophysical settings. However, the combined influence of these factors on post-fire forest regeneration is relatively under-explored in the WHR.

Therefore, this study explores patterns and factors influencing post-fire tree regeneration across diverse ownership types, forest composition and fire histories in the Indian state of Uttarakhand, which lies in the WHR and is characterised by frequent man-made forest fires and a multi-ownership forest landscape. We conducted a tree and regeneration survey and assessed disturbances and biophysical site characteristics across 70 forest plots between March and November 2024. These plots were distributed across eight socio-ecological strata, categorised by ownership(reserve and community forests), forest composition(mixed and pine forests) and fire history(recently burnt and old fire forests).

Preliminary analysis indicated that the abundance of regenerating individuals and species richness were higher in forest stands with mixed forest composition and older fire histories. Further, inferential and multivariate statistics will be applied to understand the diversity, structure, and drivers of regeneration. The final results will be available by June 2025. In conclusion, the results would offer insights into the pattern of post-disturbance recovery and resilience of the Western Himalayan forests amidst recurrent forest fires, uncertain climatic future and changing human-forest relationships.

Let it grow - Post-disturbance recovery patterns of forest structure across Europe

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Forest disturbances play a major role in shaping the structure and growth of forests. Under ongoing climate change disturbance rates will very likely increase in the future. However, our quantitative understanding of how forests recover following diverse types of disturbances remains scarce, which limits our ability to project the long-term impacts of disturbances on ecosystem services and biodiversity.

Here, our objective was to quantify recovery trajectories of forest structure after disturbances in Europe. Specifically, we aimed (i) to identify differences in recovery trajectories between major biomes in Europe and (ii) contrast differences in recovery between major disturbance agents.

We analysed 125 aerial lidar scans (ALS) covering an area of 5541 km^2 across 15 countries, spanning the whole latitudinal range of Europe from boreal forests in north Fennoscandia to Mediterranean forests in southern Europe. Disturbed areas were identified using Landsat data, as recorded in the European Forest Disturbance Atlas. In total we analysed recovery for 31,034 disturbance patches covering 19,265 ha. We calculated complementary structural and recovery metrics that describe a full spectrum of post-disturbance forest recovery archetypes in Europe. Furthermore, we fitted a physiologically founded mathematical growth model to recovery trajectories, allowing us to compare post-disturbance development in a standardized way across different times since disturbance and forest types. First results indicate that, on average, human-induced disturbances result in more homogenized recovery trajectories across biomes compared to those following natural disturbance events.

Our study uses high resolution 3D remote sensing data to track forest recovery after disturbance, identifying areas where post-disturbance regeneration is delayed or failing. The findings help prioritize areas for restoration, adapt management to regional recovery dynamics, and improve predictions of forest responses under changing disturbance regimes.

Post-disturbance forest reorganization: a global synthesis

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Forest ecosystems are increasingly affected by climate change and disturbance activity, yet the outcomes of forest dynamics under these pressures remain uncertain. Traditional approaches often view forest change through resilience or regime shifts, a dichotomy that can obscure nuanced ecological transformations. Regime shifts occur when vegetation structure and composition are profoundly altered, leading to distinct ecosystem states. To better capture these dynamics, forest reorganization can be characterized along two dimensions: structure (e.g., tree number, size, and spatial arrangement) and composition (e.g., tree species identity and diversity). However, critical gaps remain in understanding the extent and prevalence of forest reorganization and the conditions driving structural or compositional changes. Here we synthesize knowledge of post-disturbance forest reorganization, focusing on disturbances as agents of change. We assess (i) the prevalence of structural and compositional changes following disturbance, and (ii) the frequency of specific reorganization patterns, including self-replacement, relay succession, novelty, and regeneration failure. A systematic review of studies examining post-disturbance forest structure and/or composition reveals structural changes dominate the literature (41%), followed by studies addressing both structure and composition (35%), and compositional changes (24%). Most studies, however, examine short-term effects (<10 years). Distinct patterns emerge across biomes: self-replacement dominates globally, except in boreal forests, where regeneration failure prevails. Novel ecosystems are most frequent in temperate forests, while relay succession occurs in temperate broadleaf, mixed, and boreal forests. The accelerating wave of global forest disturbances presents unique opportunities to advance research on forest reorganization, critical for informing ecosystem management under changing climates.

The Fate of European Strict Forest Reserves under Climate Change

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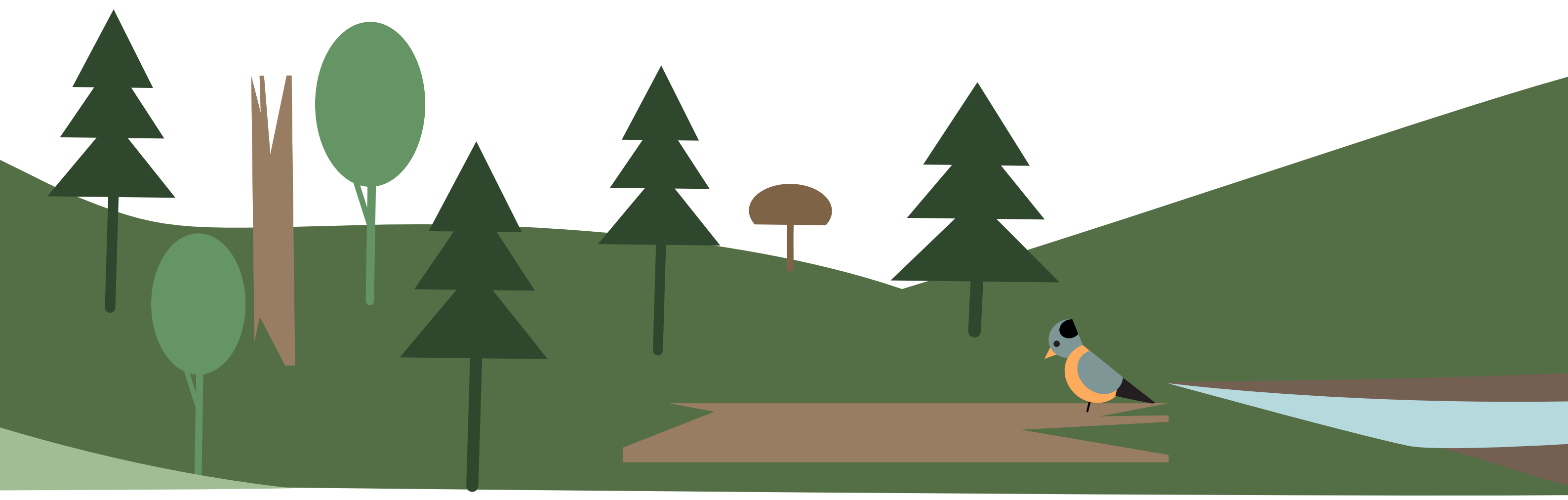
The EU has a net zero greenhouse gas emission target by 2050, and part of the Green Deal is to protect at least 30% of the EU's terrestrial area, including all primary and old growth forests. These forests play an important role in nature conservation, and there is a growing discussion about proforestation –i.e. the rewilding of managed forests– as a climate mitigation strategy. However, climate change will most likely lead to trajectories away from the originally protected forest structure, raising questions whether original conservation goals can still be met and the implications for proforestation.

The aim of our study, which is part of the EU project WILDCARD, is to address these knowledge gaps and to analyse the impact of climate change on strict forest reserves. We make use of the large and unique forest plot network EuFoRIa (European Forest Reserves Initiative). We will use these long-term forest inventory data to initialise and validate the forest model ForClim. Then we will simulate the development of the strict forest reserves under varying climate change scenarios until the end of the 21st century and beyond. We will assess the prediction uncertainty in our simulations and estimate how forest structure and composition will change under climate change.

Our simulations indicate that climate change leads to contrasting changes along the wide environmental gradient spanned by the EuFoRIa data. Forest reserves in warm-dry sites show substantial reductions in stand basal area, whereas cold-wet forests tend to benefit from climate change. Our results also suggest that climate change has the potential to significantly change the species composition of the reserves, depending on the severity of future climate change. We will discuss the implications for the forest reserve policy of the EU and for proforestation in general.

Session 14

Forest structure, dynamics and diversity



How do environmental filters shape seedling recruitment in a tropical dry forest?

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Seedling recruitment is a crucial step during plant regeneration, shaping the assembly of plant communities, forest regeneration and the recolonization of disturbed habitats. The recruitment of seedlings can be limited by both biotic filters such as seed dispersal and litter accumulation as well as by abiotic filters such as water or light. We conducted a one-year survey of natural seedling recruitment of woody plants in natural forests and silvopastures in a tropical dry forest in Southern Ecuador to identify limiting factors of seedling recruitment. Specifically, we assessed, 1) how seedling diversity changes between elevations and habitat types, and 2) how biotic and abiotic filters shape seedling abundance. Preliminary results show that seedling diversity is more than twice as high in forests compared to silvopastures, but it does not change between elevations. We will further test how seed rain, litter depth, soil temperature and moisture, as well as canopy closure jointly shape seedling abundance. Our study contributes to a mechanistic understanding of the limiting factors of seedling recruitment in tropical dry forests. The findings will help to predict seedling recruitment in these forests that are highly threatened and strongly modified by human activities.

Patterns and drivers of tree regeneration across temperate mountain forests with varying disturbance regimes

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Regeneration is a key process that determines the future of forest ecosystems for decades to centuries. Two broad spatio-temporal patterns of tree regeneration can be distinguished in temperate forest landscapes, i.e., continuous regeneration (where canopy openings and tree regeneration happen in small gaps that are frequent and ubiquitous across the landscape) and discontinuous regeneration (where tree regeneration happens following discrete pulses of high-severity disturbance). Climate change substantially alters tree mortality patterns, and disturbance pulses are increasing in many parts of the world. As a consequence, also the patterns of tree regeneration could change.

Our objective was to analyze patterns and drivers of tree regeneration across temperate mountain forest landscapes with widely differing disturbance regimes. We sampled tree regeneration in a total of 227 plots (681 regeneration transects) across Grand Teton National Park (USA, representing a strongly disturbance-driven system), Berchtesgaden National Park (Germany, a system with both disturbance-related and gap-type canopy openings) and Shiretoko National Park (Japan, a system driven solely by small canopy gaps).

We will investigate how regeneration density and diversity (alpha, beta, and gamma) vary depending on the dominance of continuous and/or discontinuous regeneration processes. Furthermore, we aim to identify whether consistent drivers—such as light availability and deadwood presence—shape regeneration patterns across different systems.

Synthesis: By comparing forest regeneration across ecologically diverse landscapes, we seek to understand general processes and potential shifts under changing disturbance regimes. This may provide insights into how forest composition and structure could respond to ongoing environmental change.

Tree regeneration patterns and drivers in a degraded temperate floodplain forest

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Floodplain forests are biodiversity hotspots and provide key ecosystem services. However, their dynamics have been profoundly altered by river regulation, land-use change, and climate impacts. Along River Isar (S Germany), decades of hydrological modification and forest management have created a transformed system that is best described as 'novel floodplain forests'. Since its designation as a forest reserve in 2020, this area offers a rare opportunity to investigate natural regeneration under heavily altered but unmanaged conditions.

We assessed tree regeneration across 122 stratified permanent plots to understand the trajectories and drivers of forest regeneration. We focused on abiotic factors (forest light, moisture, structure) and biotic interactions (understory competition, coarse woody debris). Our objectives were (i) to establish a baseline for regeneration dynamics and (ii) to identify key site-specific controls on species-specific regeneration success.

Preliminary results reveal distinct species-specific patterns. *Fraxinus excelsior* predomianantly regenerated under heterospecific canopies, whereas *Alnus incana* showed strong site fidelity, appearing even in the absence of nearby mature trees. *Acer pseudoplatanus* occurred across both conspecific and heterospecific stands, particulary in lower height classes. Contrary to expectations, overall light availability seems not to influence regeneration, though species-specific responses varied across height classes. Regeneration density was negatively correlated with ground cover (herbs, shrubs, and coarse woody debris), with interspecific differences. Notably, abundance of *F. excelsior* declined with height, while *A. pseudoplatanus* increased, indicating diverging recruitment trajectories.

These findings provide new insights into regeneration in novel floodplain forests and offer a basis for more nuanced conservation and restoration strategies under changing climatic and hydrological conditions.

Impacts of Forest and Game Management on Natural Tree Regeneration: What Is urgent, what matters, and what really counts?

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Natural tree regeneration is influenced by local environmental conditions, forest structural attributes, and game management practices. Forest management directly influence establishment conditions. In contrast, game management indirectly impacts regeneration by moderating browsing pressure on young seedlings.

Understanding these variables and their interactions is crucial for developing effective forest management strategies. Specifically, forest management interventions typically produce gradual, cumulative effects, whereas game management strategies often yield immediate ecological responses.

We aim to disentangle the combined effects of coordinated management between foresters and hunters on natural tree regeneration. We analyzed both direct and indirect influences of game management, forest management, local environmental conditions on natural tree regeneration to identify management scenarios with high probabilities of success.
We evaluated natural tree regeneration diversity, assessing both species richness and abundance in young, middle age and old seedling in 868 plots across all Austria . We used Bayesian Networks to examine the direct effects of 12 predictors grouped into forest management, environmental conditions, and game management categories. Following the Bayesian network fitting, we conducted sensitivity analyses for each predictor. Finally, we assessed scenarios aimed at intensified forest and game management to determine their probabilities of enhancing natural tree regeneration.

Our results revealed that environmental conditions, forest management, and game management exhibit varying impacts on species richness across different developmental stages. Seedling abundance captured a greater proportion of ecological variation compared to species richness alone. Moreover, we found a progressive increase in explanatory strength from young through middle-aged to old seedling classes.

Post-harvest environmental and community compositional heterogeneity in the understory level following experimental forestry treatments in an oak-dominated stand

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Due to potential ecological advantages, continuous cover forestry (CCF) is increasingly considered an alternative to conventional rotation forestry (RF). This study, based on the Pilis Forestry Systems Experiment in Hungary, compares the ecological impacts of five silvicultural treatments—clear-cutting, retention tree groups, partial cuts, gap-cutting, and control—in a replicated block design in an oak-dominated forest. Understory vegetation, soil moisture, and relative diffuse light were monitored in 20 circular plots from the 2_{nd} to 8_{th} year post-intervention using fine-scale grid sampling. Clear-cuts showed the most pronounced vegetation turnover, initially the highest diversity, abundance, and compositional heterogeneity, which later declined. Gaps maintained comparable diversity and heterogeneity, but greater compositional stability over time. Retention and partial cuts caused moderate or minimal changes. The heterogeneity of light and soil moisture varied: gaps showed high initial soil moisture heterogeneity, while clear-cuts were most variable in light. By year 8, the highest mean number of sessile oak saplings appeared in preparation cuts, followed by gaps. Overall, gap-cutting combined high understory diversity and regeneration potential with pronounced micro-environmental heterogeneity and temporal stability, highlighting its potential as a resilient silvicultural approach under changing environmental conditions.

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Decoupling of overstory and understory composition suggests declining tree diversity in an African tropical rainforest

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Understanding forest dynamics in the face of global change is one of the most pressing issues in ecology research. The extent to which tree community composition and tree diversity are undergoing shifts in tropical forests remains largely unknown. This knowledge gap is particularly pronounced in Afrotropical forests. We analyzed relationships between forest overstory and understory composition of tree species in Budongo, an East African rainforest, to assess the potential for change in tree species composition and diversity. We utilized a community-level forest inventory dataset covering 40.3 ha on tree overstory-understory relationships. We contrasted taxonomic diversity by developing two ratios linking overstory and understory richness and diversity. Our findings revealed a strong decoupling between the forest overstory and the understory, i.e. the regeneration layer. Taxonomic diversity, at alpha and gamma levels, was lower in the tree regeneration layer compared to the overstory layer. Species composition differed between these layers, with only a subset of overstory tree species found in the regeneration layer. Some dominant species in the overstory were poorly represented as seedlings in the regeneration layer. Our findings suggest a decline in tree diversity and a temporal species turnover. We hypothesize that the reported decline in fruit and seed production of overstory trees limits recruitment of some dominant trees in Budongo Forest and will eventually lead to fundamental forest change. By analyzing tree overstory-understory relationships, our study provides early indications of potential forest change, that could be counteracted by forest management. We recommend applying a similar approach in other tropical forests lacking long-term data to determine whether the observed pattern is a global phenomenon.

Temporal stability of Collembola in different forest types and regions of central Europe

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Land use intensification and climate change have led to alarming declines in the biomass and diversity of central European aboveground arthropods. Although the key ecosystem services provided by the soil fauna are increasingly recognized, the temporal stability of dominant belowground microarthropods such as springtails (Collembola) remains poorly understood. We analyzed 240 soil cores collected at three-year intervals (2008–2020) from 48 forest sites representing a management gradient spanning from unmanaged beech forests to managed age-class beech forests and conifer plantations in northern, central and southern Germany. We collected 18,617 Collembola, identified them to 101 species, and quantified changes in diversity, stability, synchrony and community composition in response to forest management and climate.

Linear mixed-effects models revealed that species richness varied significantly between regions and was closely linked to interannual variation in spring precipitation, with strong declines during dry years in northern sites with sandy soils. Stability was similar across forest types but was lowest in northern sites, coinciding with significantly higher population synchrony, suggesting more uniform species responses to environmental variation. In contrast to the well-documented biodiversity-stability relationships for aboveground taxa, we found no positive correlation between species richness and stability, due to strong dominance of a few highly abundant species driving overall community dynamics. However, communities in coniferous forests differed from those in beech forests and showed higher compositional variation over the years.

Our results show that Collembola community stability is primarily driven by climate rather than forest management and may be decoupled from local species richness due to strong dominance structures. This highlights that the temporal dynamics of soil arthropods may be fundamentally different from those of aboveground arthropods.

Recovery of tree-related microhabitats in a tropical rainforest after agricultural abandonment

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The restoration of degraded tropical forests is a global priority to halt terrestrial biodiversity loss. However, the complexity and hyperdiversity of tropical forests challenge the quantification of their recovery status. Unlike temperate forests, where tree-related microhabitats (TreMs) have been established as a surrogate for habitat diversity, TreMs have received little attention in the tropics. Here, we investigated the recovery of TreM profiles along a chronosequence of forest recovery ranging from active cacao plantations and pastures to abandoned agricultural land (2 to 38 years), and old-growth forests in the Ecuadorian lowland Chocó forest. Our analysis accounted for sample incompleteness and different abundance weightings using Hill numbers. Based on 57 TreM types, we identified an overall increase in diversity over time. Former pastures, exhibited a steeper and more continuous shift of TreM diversity and composition as forests age, due to remnant trees which retain TreMs, compared to Cacao plantations. Diversity, community composition and numerous indicator TreM types (b*uttressroots, semi-open trunk rot-hole, insect galleries, broken stiltroot, heavy resinosis, chimney trunk base rot-hole*, and *dead lianas*) show that old-growth forests maintain distinct TreM profiles. Using multiple regression in distance matrices we identified tree species richness and light availability as the main drivers of TreM composition. Our TreM results call for a strategy of protecting old-growth forests with their unique and diverse TreM profiles and of favouring agricultural sites with remnant trees for restoration due to faster achievements in habitat diversity.

Identifying Forest Structure-Biodiversity Relationships in the Context of Experimental Silvicultural Treatments Based on Multi-source Remote Sensing and Multi-taxa Biodiversity Data

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Enhancing the structural complexity of forests has been identified as a key management technique to increase biodiversity, support multifunctionality and strengthen the resilience towards disturbances. In the context of the interdisciplinary research project BETA-FOR, experimental silvicultural treatments with increased variety of light structures (distributed and aggregated cuttings) and deadwood features (no deadwood, downed and standing structures, habitat trees) have been implemented in central European broad-leaved forests. For continuous, cost-effective, and across-scale monitoring of forest structure, remote sensing offers complementary perspectives to local measurements. In the present study, multi-source remote sensing analyses comprising in-situ (mobile and terrestrial laser scanning) and spaceborne data (Sentinel-1, Sentinel-2, GEDI) were conducted to investigate enhanced forest structural complexity in BETA-FOR treatments. We found strong correlations

among in-situ and spaceborne data on structural complexity after carrying out different analyses (bi- and multi-variate correlations, unsupervised clustering). In addition, multi-taxa biodiversity data was considered for analysis to study forest structure-biodiversity relationships. Linear correlations of taxonomic diversity of birds, gastropods, hoverflies, insects, and tree species to spaceborne indicators of forest structure amount to greater than 0.4. Our findings demonstrate the great potential of multi-source remote sensing to monitor forest structure and biodiversity along different gradients (light conditions, deadwood structures) of enhanced structural complexity. We identified several indicators of forest structural complexity from spaceborne remote sensing that accurately bridge in-situ remote sensing measurements, and hold moderate correlations to multi-taxa diversity data.

Fighting Biodiversity Decline: Enhancing Structural Beta Complexity Boosts Hoverfly Diversity in Temperate Forests

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The loss of forest biodiversity due to structural homogenization is a major concern in intensively managed landscapes. While the value of local heterogeneity is well known, experimental evidence on how increasing structural variation at the landscape scale affects insect communities remains scarce. In a large-scale field experiment across 11 temperate forest sites in Germany, we tested whether enhancing structural beta complexity (ESBC)—through interventions such as modifying deadwood and canopy cover—can increase hoverfly (Diptera: Syrphidae) diversity.

We compared hoverfly communities in 234 forest patches (50 × 50 m) within 22 forest districts, half of which received ESBC treatments. Using standardized sampling across three seasonal sessions and a meta-analytic framework accounting for sample completeness, we assessed changes in taxonomic, functional, and phylogenetic α-, β-, and γ-diversity.

Forests with higher structural complexity consistently supported greater diversity across all metrics, particularly taxonomic richness. Effects were strongest for rare species, suggesting that ESBC counteracts biotic homogenization by maintaining species turnover.

Our study provides experimental evidence that forest management enhancing structural beta heterogeneity can effectively promote insect diversity at the landscape scale, offering a practical approach to counteract biodiversity loss in temperate production forests.

Experimental enhancement of structural beta complexity in forests alters the taxonomic and phylogenetic diversity of insects

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European forests have historically been structurally homogenized due to timber-oriented management. However, increasing climate-driven disturbances, such as drought-induced tree mortality, but also forest management may promote structural heterogeneity by creating canopy gaps and deadwood. We stablished a forest experiment across 11 landscapes dominated by European beech (*Fagus sylvatica*) in Germany. In each landscape, one forest district was experimentally manipulated to enhance structural beta complexity (ESBC) among 50 × 50 m patches by varying canopy openness and deadwood presence. A second, unmanipulated district served as a homogeneous control. Insects were sampled from all 234 forest patches using Malaise traps in 2022 and 2023. Species identification was performed via metabarcoding, and a unified phylogeny was constructed for all ~25k insect operational taxonomic units (OTUs). We assessed the effects of heterogeneous (ESBC) versus homogeneous forest structure on insect taxonomic and phylogenetic alpha-, beta-, and gamma-diversity using a novel meta-analytic framework that accounts for sample completeness and analyzes diversity across Hill numbers. Preliminary results suggest higher insect diversity in structurally heterogeneous forests, highlighting the potential of forest heterogenization—through both management and natural disturbances—to support biodiversity.

The Invisible Heterogeneity of a Forest – Beta Diversity of Volatiles

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Management and disturbance fundamentally alter forest structure and ecosystem functioning, yet their impacts on the invisible ecological dimension of scent (volatile organic compounds, VOCs) remains largely unstudied. In this study, we investigate how changes in forest structure in managed temperate beech forests influence scentscapes, potentially affecting ecosystem processes in previously overlooked ways. As part of the DFG-funded BETA-FOR project, we collected VOCs across 234 forest patches with treatments manipulating light and deadwood in a gradual way. We calculated a patch-level structural multifunctionality index using the Hill-Chao framework, combining various structural metrics, and analyzed its relationship to VOCs. Our analyses reveal patterns where forest structure correlates with patch VOCs and shows spatial associations with herb-layer composition and treatments. This approach offers new insights into forest ecosystem processes and biodiversity, with the potential to inform future forest management strategies that take these invisible ecosystem dimension into consideration.

Heterogeneous forest structures for diverse future forests: Experimental silvicultural interventions enhance beta and gamma diversity of natural regeneration

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Tree species diversity of forests contributes to their consistent provision of ecosystem services. Hence, with future forests presumably being subjected to increased climatic and biotic stressors, tree species diversity is a crucial forest management target. The key to predicting and managing diversity of future forests is the current tree regeneration. Natural regeneration is usually initiated by opening the canopy of mature stands. However, even though the enhanced light availability universally promotes understory plant growth in forests, tree sapling diversity is not necessarily increased: single tree species can become dominant, selective browsing by large herbivores can homogenize the community, or herbs and shrubs can out-compete the trees. Depending on the complex interactions of many biotic and abiotic factors, the individual fate of regenerating communities is challenging to predict.

However, so far species diversity of natural regeneration has always been measured as α species richness at local scales. We propose that, independent of the local context, a management approach that produces a heterogeneous mosaic of different light availabilities will increase the β-, and consequently γ-diversity of natural regeneration on larger spatial scales, potentially leading to increased tree species diversity in future forest landscapes.

In a manipulative experiment in broad-leaved forests throughout Germany, we created 11 pairs of forest districts, each pairing a homogeneous control district with a structurally heterogeneous forest district comprising canopy gaps, thinned patches and closed canopies. The study sites vary strongly in terms of site conditions, stand structure, tree species composition, management regimes and browser communities. Using a meta analysis approach, we can show that there are general positive effects of the experimental

Old growth attributes by chain saw: how between-patch heterogeneity changes the metacommunities of beetles in temperate forests

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Metacommunity theory has expanded our conceptual understanding of how spatial dynamics and local interactions influence the structure and diversity of species communities. Different assembly archetypes, reflecting different roles of species differences, habitat differences, and dispersal have been described, but we lack empirical studies specifically in terrestrial habitats testing which archetype is most important. In a replicated design (BETA-FOR) we experimentally enhanced structural between-patch heterogeneity in homogeneous production forests and developed a statistical framework controlling for sample incompleteness to detect different metacommunity processes. Metaanalyses on >100K individuals of >1.3K beetle species showed an increase of ~60 species in heterogenized forests at γ-level promoted by an increase in α-diversity supporting the mass-effect archetype and an increase of β-diversity by ~10% supporting species-sorting. Additionally, we tested β-deviations from null-models generated by random neutral processes. Results suggest that metacommunities in homogenous forests are dominated by patch-dynamics, while those in heterogeneous forests by mass-effect and species-sorting.

Two-decade changes in temperature buffering and their relationship with forest characteristics across biomes in Europe

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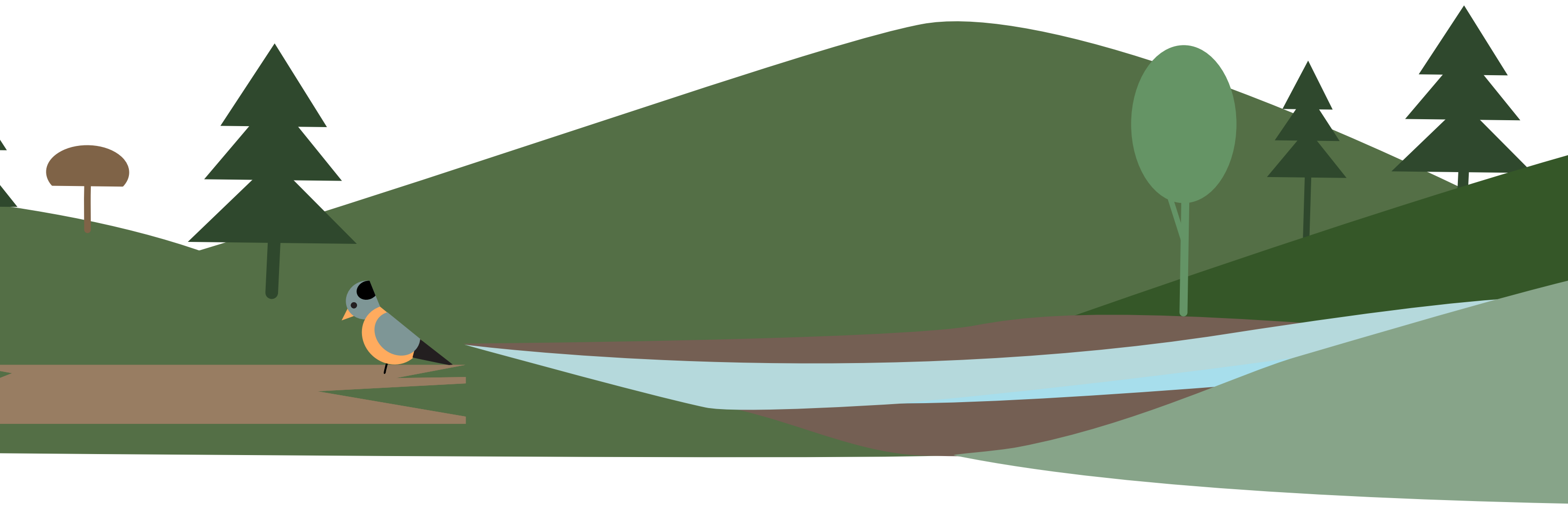
Tree canopies create understory microclimatic conditions by buffering extreme fluctuations of macroclimate temperatures as recorded at weather stations. Despite growing interest in temperature buffering, assessing buffering capacities over longer temporal scales (e.g., more than 20 years) is unstudied, resulting in gaps of understanding if and how buffering capacities change with forest tree characteristics in time. Our study aimed to detect temporal changes in temperature offsets—defined as the difference between micro- and macroclimate temperatures—across six European biomes and to explore their relationships with tree characteristics over time. Specifically, we used the ICP Level II database which provides over two decades (1996–2020) in-situ daily forest microclimate temperature data across Europe. We observed a general trend of increasing summer maximum offsets over time, while winter minimum offsets showed no significant temporal change. At the biome level, summer maximum offsets increased over time in the Mediterranean and Continental biomes but decreased in the Atlantic, Boreal, and Pannonian biomes, with little change observed in the Alpine biome. Winter minimum offsets showed slight increases across all biomes except the Boreal, though the magnitudes were relatively small. Among the four most dominant forest types, summer maximum offsets decreased over time in Quercus petraea and *Pinus sylvestris* forests but increased in *Fagus sylvatica* and *Picea abies* forests. In contrast, winter minimum offsets slightly increased over time in all four dominant forest types. Among the macroclimate variables (temperature and precipitation) and forest characteristic variables (tree cover, community-weighted mean traits, and diversity), both macroclimate temperature and community-level traits—specifically leaf dry matter content and specific leaf area—affected summer maximum offsets. For winter minimum offsets, microclimate conditions were of principal importance. The effects of these factors on offsets did not vary with year. Our findings reinforce that macroclimate temperature remains the primary driver of both maximum and minimum buffering, but selecting tree species based on functional traits may mitigate future declines in forest microclimate buffering capacity.

Session 15

Forest dynamics under pressure: from ecosystem processes to species responses



Have trees become more likely to die over time? - Insights from decades of European forest reserve data

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Over the past few decades, anthropogenic climate change has exerted substantial pressure on forest ecosystems, primarily through increased frequency and intensity of biotic and abiotic disturbances, such as insect outbreaks and wildfires. At the same time, a global rise in background tree mortality has been documented, likely caused by more frequent and prolonged droughts in combination with elevated temperatures. However, distinguishing background mortality from disturbance-induced mortality remains a critical challenge for understanding the observed rise in tree mortality rates worldwide. This task is complicated by the confounding influence of forest management, which typically aims to reduce background mortality. Notably, recent studies based on data from European old-growth forests have not detected a consistent increase in mortality over time.

In this study, we draw on a pan-European dataset from long-term monitoring of unmanaged forests to investigate patterns of background mortality across eight major European forest types. The dataset comprises approximately 1.5 million individual tree records from plots covering a total area of 853.7 hectares. We estimate background mortality rates, assess temporal trends, and explore the relationship between species-specific habitat suitability and mortality probability.

Mortality rates increased in spruce- and oak-dominated forests, whereas beech-dominated forests showed a significant decline in recent years. We identified three patterns in the relationship between habitat suitability and mortality probability: increasing, decreasing, or no clear effect of habitat suitability on tree mortality. This suggests no consistent response across species to habitat suitability. Overall, contrary to previous findings, our results indicate no consistent increase in background mortality in recent years.

Forest functionality under drought: Can beech-Douglas fir mixtures be a solution for Central European forests?

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Drought poses a growing threat to forest ecosystems, reducing tree performance and impairing key ecological functions. Temperate forests are particularly vulnerable. Between 2018 and 2022, Germany experienced severe droughts, leading to large-scale forest damage: bark beetle outbreaks and dieback in Norway spruce, defoliation and mortality in beech, and even growth decline in drought-tolerant species such as Douglas fir. These impacts highlight the need for adaptive forest management strategies that enhance resilience. Mixed forests, especially those combining broadleaved and coniferous species with complementary traits, are increasingly promoted as a solution. A promising combination for Central Europe is European beech and Douglas fir, which may offer an alternative to drought-sensitive spruce stands. However, their ecological performance and stability remain insufficiently studied. Within the framework of the RTG 2300 EnriCo, we investigated ecosystem functioning across five forest types in Lower Saxony: pure beech, pure spruce, pure Douglas fir, and their mixtures. We evaluated indicators of tree growth (measured with high-resolution dendrometers), and stand-level water retention (relative extractable water) and nutrient cycling (litter production, nitrate leaching and soil microbial biomass) from 2018 to 2022, a time period including several drought-affected years, to test whether mixed stands offer greater performance and stability under climate stress. Overall, for all forest types tree growth and ecosystem processes significantly declined in dry years; in particular during the severe drought of 2022, the impacts were similar in pure and mixed forests. These effects were only partially mediated by site conditions. Our findings aim to inform forest management strategies for resilient, multifunctional forests in the face of increasing pressure from climate change.

Tree-water relations in pure and mixed forests: drivers of root water uptake depth, stem water and growth dynamics

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As forests face increasing pressure from climate change and growing water limitation, understanding how tree species access and use water has become crucial for predicting ecosystem resilience and guiding sustainable forest management. In this context, mixed-species forests are considered a key strategy to foster resilient and multifunctional forest ecosystems. However, tree-water relations as determined by species-specific functional traits and their interaction with neighboring trees, site conditions, and water availability remain poorly understood. Connecting above- and belowground traits and processes, we investigated root water uptake depth, daily stem rehydration, sap flow and growth dynamics, comparing pure and mixed stands of European beech, Norway spruce, and Douglas fir – three major tree species in Central Europe. Our study demonstrates that tree-water relations are driven by an interaction of species identity, tree neighborhood, site conditions, and drought, with trait-based results offering a clearer mechanistic understanding of species-specific drought resistance. In summary, mixtures of European beech and Douglas fir emerge as a promising option to complement European forest management strategies.

How structural traits of forests modulate vapor pressure deficit during drought

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Temperate forests face increasing drought risk, with longer and more frequent drought events further limiting water resources in already dry regions. A climate-adaptive management strategy is to remodel forests towards greater structural complexity. Three-dimensional forest attributes are known to shape a distinct microclimate near the ground. However, a comprehensive understanding of the structural drivers behind vapor pressure deficit (VPD) buffering under drought remains limited. Can (a combination of) specific traits mitigate the increase in VPD caused by hot and dry macroclimatic conditions?

To answer this question, we established 40 plots in a managed, conifer-dominated forest in Brandenburg, a region considered to be one of the driest in Germany. Plot selection was based around a structural gradient, ranging from single layered pure Scots pine (*Pinus sylvestris*) stands to multilayered mixed stands (pine with various hardwood species). Forest structural traits were quantified using hemispherical photography and mobile laser scanning. Microclimatic conditions - temperature, humidity, and soil moisture – were monitored over two vegetation periods.

We found that mixed stands effectively reduced subcanopy VPD during dry periods without accelerating topsoil moisture loss compared to pure pine stands. Understory vegetation - acting as a protective near-ground layer – was shown to buffer against high VPD exposure in sparse stands. At a finer structural level, VPD reduction during dry periods was best explained not by any single complexity metric, but by a combination of specific structural metrics capturing vertical stratification and horizontal arrangement in 3D space. These structural attributes partially offset the effects of hot and dry macroclimatic conditions. Based on these insights, we propose a conceptual model outlining how structural traits can be strategically enhanced through forest management to improve drought resilience.

Loss of Resilience and Diversity: Vegetation Shifts in Ash-Dominated Forests after Dieback

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For more than two decades, the ash dieback disease has been responsible for a significant decline in the number of living and healthy trees of European ash (*Fraxineus excelsior L.*) across its entire distribution range. Many studies focus on the origin of the disease as well as on potentially more resistant ash genotypes. However, there are conflicting views about the impact on the forest ecosystem — in particular on the potential changes in the herb layer vegetation of ash-rich forests.

We hypothesized that altered conditions in light and nutrient availability, along with disturbance and structural changes, will significantly affect the herb layer and initiate a long-term transformation of ecosystem functioning in formerly ash-rich forest stands. As part of the FraDiv project, we used a monitoring approach involving 114 study plots across different forest types all over Schleswig-Holstein. Vegetation surveys, conducted in 2019 and 2023, and repeated measurements of abiotic factors such as light and soil conditions, form the basis of our analysis. In addition, we assessed the infection symptoms of ash trees on the plots.

First results show an advanced and non-linear dieback of ash trees, which is more pronounced on drier and phosphorus-poor soils. Around 34% of mature ash trees died within five years. These dynamics induce changes in the light availability in the forest stands. NMDS analyses show the consequences for the understory vegetation: indicator species of ash-rich forests are declining, and floristic distinctions between forest types are diminishing. The regression of both rare and widespread, shade-tolerant, and poorly dispersing species suggest that ecosystem degradation extends beyond species loss to functional decline. We conclude that structural and functional characteristics of ash-rich forests are being lost, with transitions underway towards less diverse, more homogenised forest types with reduced ecological resilience.

Impacts of bark beetle control strategies on avifauna in the management zone of the Bavarian Forest National Park and Šumava National Park

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In recent decades, European spruce forests have experienced extensive bark beetle outbreaks, primarily involving *Ips typographus*. These outbreaks, often combined with other natural disturbances, have led to widespread tree mortality with far-reaching economic and ecological consequences for some regions. To mitigate further infestations, forest managers employ various strategies, including debarking, bark scratching, and complete removal of affected trees. However, such interventions can affect other forest-dwelling organisms. As part of the BeetleTrees project, we assess the impacts of these management strategies on forest bird assemblages. Our study was conducted in bark beetle-affected areas of the Bavarian Forest National Park (Germany) and the Šumava National Park (Czech Republic). We deployed autonomous sound recorders across plots subjected to six different treatments: (1) salvage logging, (2) debarking, (3) scratching, (4) creation of high stumps, (5) no intervention, and (6) undisturbed spruce forest. Bird activity was acoustically monitored from April to June. Here, I present preliminary findings from this acoustic monitoring and discuss the potential implications for forest conservation management.

Ecosystem function of insectivorous songbirds in forest habitats

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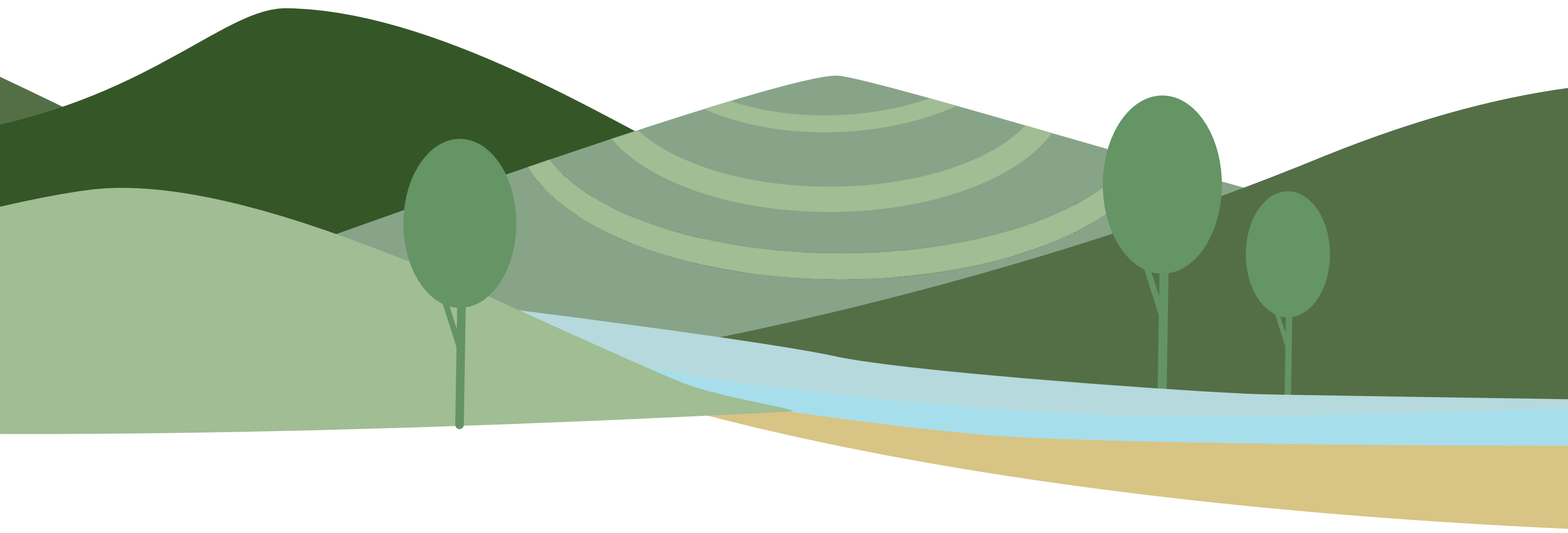
Forest ecosystems are more and more impacted by increasingly frequent weather extremes due to climate change, such as drought or heavy rain events. This makes forests more vulnerable to further impacts such as consumption by insects. Ecosystems naturally consist of self-regulating components that balance the system and thus keep it in equilibrium. If self-regulation is disturbed or significantly reduced, the system can become unbalanced and less resilient. In this context predators take on a regulating function. Insectivorous bird species are essential parts in forest ecosystems. Their abundance is negatively impacted by the intensity of forest management, but what effect a reduced predator abundance has on the ecosystem is unclear.

In this study, we aim to analyse the potential of insectivorous songbirds as a natural pest control by regulating herbivorous arthropods and thereby place their ecosystem function. We measured breeding phenology, lepidoptera larvae biomass and diversity, leaf damage and tree growth in areas with artificially increased bird abundance (experimental plot) and unmodified bird abundance (control plot) in two forest areas. The Results show a high overlap between breeding phenology and abundance of lepidoptera larvae, a reduced biomass of lepidoptera larvae in experimental plots and a higher leaf damage in control plots. Arthropod diversity tended to be higher in experimental plots. Trees in the experimental area have shown relatively higher growth rates than trees in the control area since the nest boxes were installed.

The results indicate a stabilising function of insectivorous songbirds along the trophic cascade in forest ecosystems by regulating herbivorous lepidoptera.

Session 16

Grasslands: conservation, management, restoration



Key challenges for conservation of biodiversity, species interactions and ecosystem functions in European calcareous grasslands

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Calcareous grasslands arise from a unique heritage of traditional land use in European cultural landscapes and are one of the continent's most species-rich habitat types. However, they are nowadays often threatened, mainly by abandonment of traditional practices. In the InterRest project, we investigate biodiversity, species interactions, and ecosystem functions in calcareous grasslands across Germany, Spain, and Estonia, along a local management gradient from abandonment to active conservation and across contrasting landscape contexts. Moreover, we analyse the social contexts of conservation management and restoration programs based on interviews with key stakeholders in the three study regions.

First results show that local management and the landscape-scale availability of calcareous grasslands were important drivers of pollinator species richness and predation functions. Agri-environment schemes in the surrounding landscapes enhanced in some cases bee species richness and pollen richness collected by bumblebees, but decreased predation functions by birds and arthropods. In our integrated analysis of socio-economic and ecological factors, we identified five key challenges for the successful management of semi-natural grasslands: (1) profitability, (2) competition for space, (3) policy fit and interplay, (4) climate change and (5) changing rural societies.

The preliminary findings show that local and landscape management drive biodiversity, species interactions and ecosystem functions although effects often differ between countries. Our social science analysis illustrates the need to widen the angle on grassland conservation from a narrow technical-administrative view to also include contextual social-ecological factors, which determine whether effective site- and landscape-level management strategies can be applied successfully. We discuss leverage points derived from good-practice-examples for future pathways to achieve more successful conservation outcomes.

Heterogeneity of the Mowing Regime in Grasslands and Impacts of Agri-Environmental Schemes in Bavarian Landscapes (Germany)

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Grasslands are multifunctional components of Bavarian landscapes, and their management requires balancing trade-offs between different ecosystem services, such as fodder production, habitat provision, and biodiversity conservation. One ecologically important aspect of grassland management is the mowing regime, including the timing of cutting events. The timing of cuts in neighboring fields affects the extent of habitat disruption; therefore, identifying homogeneously managed grassland areas is important. To maintain agricultural productivity while supporting biodiversity, agri-environmental schemes (AES) aim to encourage environmentally friendly farming practices.

This study combines remote sensing data with AES monitoring data to examine spatial autocorrelation in mowing events across Bavarian grasslands from 2018 to 2020. Additionally, we explore the spatiotemporal autocorrelation between enrollment in mowing-related AES and the timing of the first cut. The results reveal areas with statistically significant clustering of first cut dates across Bavaria and regions where AES-enrolled fields are specifically clustered in space and time.

These findings suggest that AES may contribute to management and habitat homogeneity, potentially reducing landscape multifunctionality. The results may inform biodiversity advisors and farmers in making management decisions and aid in the application and design of AES in Bavarian grasslands.

The effect of grassland management and landscape structure on arthropod communities

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Insect diversity is declining globally, driven largely by habitat loss and agricultural intensification. Landscapes with low biodiversity offer fewer ecosystem functions and are less resilient to climate extremes. Grasslands can serve as biodiversity hotspots within agricultural areas, but not all are species-rich or multifunctional. Management practices strongly influence grassland species composition, including insect biodiversity, as well as ecosystem functioning. However, it remains poorly understood how specific management practices and use intensity levels affect diverse insect taxa on broad scales. Here, we analyze the effects of grassland management and landscape structure on arthropod diversity in Bavaria, Germany. Most German grasslands are regularly mown, with mowing times varying across parcels. To capture this, we used a high-resolution mowing dataset derived from satellite time series. We also included a hedgerow map for Bavaria, generated from orthophotos using deep learning. This data was linked to a large arthropod dataset (~12,000 BIN species across 450 families), sampled throughout Bavaria. The spatial data were intersected with the point data by calculating spatial statistics (e.g. mean, variance) for hexagons (200 m edge length) surrounding the points. Using Generalized Linear Mixed Effects Models (GLMMs), we analyze the influence of variables related to grassland mowing dynamics as well as landscape features on insect diversity. First results show that the mean mowing frequency has a significant negative influence on the arthropod diversity over all orders. Further analyses focus on the contribution of e.g. early mowing, variance in mowing dynamics or hedges for overall arthropod diversity and various subgroups such as flying or red list insects. With this analysis, we aim to expand our understanding of how grassland management and landscape structure influence insect diversity across a broad range of grasslands.

Woody encroachment effects on biodiversity and carbon storage of mountain grassland ecosystems

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Mountain pastures are centuries-old cultural landscapes, harbour unique biodiversity and deliver important ecosystem services for society. Socio-economic changes and climate change have increased the vulnerability of mountain pastures to abandonment and ecological succession.

In this project we explore how woody encroachment affects biodiversity and soil carbon storage. We selected eight mountain pastures along an elevational gradient in the Berchtesgaden biosphere region (Bavaria, Germany), within Berchtesgaden National Park (Northern Limestone Alps). Within each pasture, we sampled two strata: control (<3% shurb cover) and woody-encroached (>20% shrub cover). Three 15 m transects were randomly placed within each stratum. **Soil.** We sampled soil (topsoil 0-10 cm and subsoil 10-30 cm) at six locations along the transect to analyze soil biogeochemistry and follow changes in carbon, N and P stocks. **Vegetation**. We recorded vascular plant species composition and functional parameters in three 1 m² plots per transect. For invading trees, we recorded cover, abundance, annual shoot length and browsing damage. **Insects.** To estimate abundances of local insect fauna in the vegetation plots, we used suction sampling. Grasshoppers were identified on-site in each plot.

We found that soil organic carbon was significantly higher in shrub-encroached transects. Plant species richness per plot (alpha-) was higher in control plots, but the total species richness (gama-diversity) was higher in woody-encroached plots. Moreover, the specialisation of grasshopper-plant networks decreased with increasing encroachment. Overall, coppice shots of sycamore (*Acer pseudoplatanus*) were identified as the main source of woody-encroachment in the studied mountain pastures. Our holistic approach provides insights into how woody encroachment affects the interplay between below and aboveground ecological processes and biotic communities.

Adapting grassland management to ecological needs – Wet grassland conservation benefits from by site-specific biomass removal

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In temperate Europe, semi-natural wet grasslands are biodiversity hotspots and conservation targets, yet typical species continue to decline. Efficient conservation requires understanding which environmental factors threaten target species within protected sites and how current management can be improved.

We studied 95 protected wet grasslands in Germany to identify climatic and site-specific factors that jeopardize habitat specialists despite conservation management. The orchid *Dactylorhiza majalis* was chosen as a model species. We also evaluated factors for successful grassland management by synthesizing findings from 60 studies and comparing them to current practices.

Climatic effects were relatively weak, and considerable variation among populations underscored the role of site-specific conditions. Elevated nutrients and tall vegetation threatened *D. majalis* even under regular conservation management. Scientific and practical literature concurred that two annual cuts benefit species-rich, meso- to eutrophic wet grasslands, while a single cut suits less productive types. Extensive grazing was considered as a suitable alternative, if well-managed through timing, fencing, and close monitoring.

Our findings suggest that *D. majalis* tolerates moderate climate change, provided water levels are maintained sufficiently high— pinpointing that conservation hinges on local site management. However, given that a single annual cut is the dominant practice in European wet grasslands, our results indicate a mismatch between current regimes and ecological needs. Thus, we suggest increasing biomass removal in meso- to eutrophic wet grasslands by a second cut or by adjusted grazing, with some spatio-temporal variation. Where feasible, combining mowing and grazing offers the highest conservation potential, as it supports greater diversity and buffers regime-specific limitations.

Traditional pasture use of local herders in Great Gobi B Strictly Protected Area in Mongolia

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In Mongolia, nomadic pastoralism is practiced by one-third of the population under socio-economic and climate change. In the Dzungarian Gobi, 280 pastoralist families with around 120,000 livestock have seasonal access to Great Gobi B Strictly Protected Area (GGB) which aims to protect a diverse desert ecosystem with several iconic wild ungulates. While pastoralists' mobility is key in this arid landscape, little is known about livestock movements and whether pastoralist livelihood trends are compatible with protected area goals nowadays. To understand herder and livestock mobility patterns, we linked GPS collar tracking data of 19 small livestock herds, monitored over 20 months, with remotely sensed environmental parameters. Our results show that local herders frequently change camp sites and depending on location, move 70–123 km between summer and winter camps. Camps were located in the nutritious plant communities, and season and available biomass were key for herder's decisions to move camps. Whereas grazing time increased with increasing biomass and rising temperatures, daily walking distance and maximum distance from the herder camp increased with camp use duration. We only found limited evidence for pasture degradation yet. We conclude that herders have optimized pasture use by reacting to changes in biomass availability at landscape and local scale through high mobility and flexibility. However, local livestock trends and interviews showed that herders want to further increase livestock numbers. This will ultimately threaten pasture health and conservation goals and requires sustainable pasture management and control of livestock numbers within GGB and its buffer zone.

MERLIN enchants the Emscher-region

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The Emschergenossenschaft/Lippeverband (EGLV) is Germany's largest water management association, playing a pivotal role in enhancing biodiversity through restoration measures in and around watercourses. EGLV is ideally situated to contribute to blue-green infrastructure in the urbanized Ruhr area of western Germany. The EU research project, MERLIN (Mainstreaming Ecological Restoration of Freshwater-related Ecosystems in a Landscape Context), is a multidisciplinary initiative that aims to promote the ecological restoration of freshwater ecosystems within the context of landscape management. Innovation, upscaling and transformation provide a framework within which EGLV's objectives are supported and supplemented by means of specific measures, thereby facilitating tangible advancement in this field. These measures include the large-scale conversion of mowing to extensive, biodiversity-promoting management of grassland along watercourses and on operational facilities. Extensive mowing also includes the removal of the mown material, which is to be utilised as biomass for economic and value-adding purposes. The overarching objective of the MERLIN project is to identify and implement holistic and economically viable solutions for various mown material utilisation methods. In addition to conducting concrete investigations on a pilot plant scale to produce biogas from mowed material, other utilisation methods were analysed and the advantages and disadvantages identified. In this context, a digital tool for decision support (GrasslandTool) was developed that shows new ways by spatially optimising maintenance processes and identifying economically sustainable utilisation strategies for the mown material. In addition to the establishment of flowering meadows on operational facilities, the GIS-supported grassland tool also makes a substantial contribution to the conservation of biodiversity in the Emscher-Lippe region.

Maintenance of different types of grasslands - approaches and challenges: a perspective from the nature conservation point of view

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The differences of grassland types within Germany result in various management requirements. Many of these grassland types host specific plants or animals which contains rare species and are partly protected. Furthermore, some of these habitats are listed within various NATURA 2000 habitat types protected by the European Union and are subject to the prohibition of deterioration.

Examples for these protected habitats ranges from the European dry heath, calcareous grasslands, semi-natural dry grasslands, hydrophilous tall herb fringe communities, extensively managed hay meadows or alkine fens.

The majorities of these open land habitats have developed by historical forms of utilization and need recurring maintenance such as mowing or grazing to avoid natural succession into scrubland or forests. These management approaches are within the tension field of the preferable nature conservation aspects and the practical implementation according to modern agricultural management. For example, larger mowing machines increase the effectivity but often conflicts with soil conserving or insect-friendly utilization.

Therefore, nature conservation needs special attention within the agricultural usage of specific grasslands to maintain the characteristic diversity. Focusing on soil-friendly mowing techniques, the removal of the cut plant material or the establishment of landscape conservation herds explicitly for nature conservation are presented and chances as well as challenges are shown. Often the nature conservation management lead to higher costs due to special technology and a high amount of additional manual work to maintain the cultural landscape which needs specific funding beyond the agricultural subsidies.

Here, the close interrelationship of agriculture and nature conservation is crucial for the success of the maintenance of these protected habitat types.

Experimental reduction of land use increases invertebrate abundance but not diversity in grasslands

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Grasslands are diverse ecosystems that are increasingly threatened by intensive land use. Restoring grasslands by reducing land-use intensity may support insect abundance and diversity, helping to halt insect declines. To test for the effect of reduced land use on invertebrates, we studied an experiment (established 2020) at 45 sites across three regions of Germany. We hypothesized that reduced land use increases invertebrate abundance and diversity, with larger effects in less intensively used grasslands. Using suction sampling, invertebrates were quantitatively sampled in May 2021 and May 2023, with 2021 samples identified by DNA meta-barcoding. Reducing land use to a single late mowing increased invertebrate abundance by 41% after one year and 99% after three years. However, species richness, Shannon diversity, and Simpson diversity did not differ between treatments and controls. Finding more individuals in grasslands with reduced land use suggests that species already present benefit, rather than additional species being recruited from the surrounding area. The effect of land-use reduction on abundance was consistently influenced by land use in the surrounding matrix, with larger positive effect sizes at grasslands with lower mowing frequency but higher fertilization. In spite of these local differences in the magnitude of restoration effects, the consistent increase in invertebrate abundance suggests that reducing land-use intensity can enhance invertebrate populations with potential benefits for ecosystem functions. It will be important to study how outcomes of land-use reduction develop over time, as land-use reduction is likely more successful when implemented permanently

Increasing plant diversity on former intensively used grasslands: invasive versus non-invasive soil preparation techniques in mesic grassland restoration

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Semi-natural grasslands are the most species-rich habitats in Central European cultural landscapes. Nevertheless, their conservation status detoriated significantly due to agricultural intensification, resulting in a loss of plant biodiversity. Today, species-poor intensively managed grasslands are widespread, but less resilient to increasingly frequent climate extremes such as droughts. Diversification and extensification of formerly intensively used grasslands can help to enhance the resilience, productivity and multifunctionality, which in turn would contribute to solving both the climate and biodiversity crisis.

Since the introduction of native seed mixtures after ploughing significantly disturbs the soil structure, we are testing non-inversive techniques for soil preparation in grassland restoration. With the aim of developing a lowland hay meadow (habitat type 6510), site-adapted target species were sown in spring 2021 on a formerly intensively used, ryegrass-dominated grassland, using various soil disturbance and seeding methods (milling, milling grooves, slit seeding and overseeding).

In this study, we present the successes in establishing a species-rich grassland over a period of four years. We show the establishment of target species and the effect of varying soil disturbance intensities before sowing on vegetation assembly, above ground biomass and fodder quality. Our results demonstrate that intensive soil disturbance is a key factor for species-rich grassland restoration.

Grassland fertilization in the interface between nature conservation goals and farmers' demands

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European semi-natural grassland area suffered a significant decline and the ongoing grassland improvement leads to a shift in vegetation composition, coupled with a massive impairment of plant species diversity. Precisely because grassland is use-dependent, the question of how the conservation of species-rich grassland or its restoration can be reconciled with the fodder production is of fundamental importance for the future. To explore the trade-off between farmers' and conservationists' interests, two field experiments were conducted in Eastern Germany. The Dessau grassland experiment evaluated the influence of fertilizer variants on the vegetation assembly and fodder quality of an alluvial meadow in favorable conservation status on a P-poor site over eight years. The Hayn grassland experiment determined how fertilizer levels and drought conditions affect target species performance and biomass production in the medium-term development in mesic grassland restoration over eight years. In both experiments, the target species persisted despite 120 kg N ha^{-1} yr^{-1} application. However, fertilization resulted in higher cover of grasses as nitrogen intake increased, and forb cover as well as the legume cycle benefited from the absence of N supply. Fertilization with 60 kg N ha^{-1} yr^{-1} represents a compromise. However, on nutrient-poor sites, this should be combined with an application of P and K, as this compensated for the loss of forb cover. The forage quality could hardly be improved and the biomass could only be increased by the highest N fertilizer rate of 120 kg N ha^{-1} yr^{-1}. Interestingly, the forb biomass of the first cut increased in the non-nitrogen and the 60 kg N ha^{-1} yr^{-1} fertilized treatments despite drought, which is one of the key results in terms of climate adaptation. Six of 44 sown plant species appear to be particularly suitable for sustaining productivity over several drought years and should be part of high-diverse native seed mixtures.

Grassland restoration in practice: The fragile path of phosphorus depletion from nutrient-rich soils

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Restoration of nutrient-poor grasslands on formerly fertilized land requires substantial abiotic and biotic change. Elevated soil phosphorus (P) concentrations particularly impede *Nardus* grassland restoration. Common restoration practices aimed at reducing P, such as biomass removal via unfertilized mowing or more intensive P-mining (i.e. fertilization with nitrogen (N) and potassium (K) to stimulate growth, followed by harvest), often conflict with the protection of local meadow bird populations. In the LIFE *Nardus & Limosa* project, we aim to harmonize grassland restoration with meadow bird conservation. Since 2021, we monitor nutrient removal via biomass from 105 field measuring points across four locations in Belgium and one in the Netherlands. We assessed four management types: (i) postponed mowing without fertilization, (ii) intensive P-mining with early fertilization and cutting, and (iii) two bird-friendly P-mining variants with postponed fertilization and cutting and reduced NK-inputs. P-removal is significantly highest in intensive P-mining plots, removing twice as much P in the most optimal circumstances compared to postponed mowing. However, P-removal varies strongly between locations and years. Adding complexity, one site hosts a growing goose population, which appears to influence outcomes. These findings highlight the ecological and operational uncertainty of long-term nutrient depletion. Weather extremes, shifting biotic pressures and management inconsistencies—such as miscommunication with site managers or machine operators—can disrupt outcomes. As modest nutrient inputs may undo years of removal effort, restoration success depends on a fragile alignment of ecological processes and management precision. Understanding such uncertainties offers both a scientific challenge and an opportunity to improve adaptive strategies in nutrient-enriched grasslands.

Reintroducing Fire for Grassland Management

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Semi-natural grasslands are biodiversity hotspots that provide essential ecosystem services, but they are increasingly threatened by land-use changes such as agricultural intensification and land abandonment. Ongoing abandonment or insufficient management often lead to the structural degradation of these grasslands. These pressures highlight the urgent need for effective management strategies. Revisiting historical land-use practices may offer valuable solutions for modern conservation. Here, we revisit prescribed burning (PB) – the controlled application of fire – as a management option.

In an eight-year experimental study between in the Rhön Mountains (Germany), we applied PB at three frequencies (annual, biennial, and triennial) to species-rich and species-poor *Nardus* grasslands, with unmanaged fallows as controls. We evaluated fire effects on vegetation structure, plant species composition and diversity, and soil parameters.

We showed that soil parameters remained largely unaffected by fire. PB however had a strong effect on variables of vegetation structure, resulting in a reduced vegetation height and a more patchy vegetation structure compared to fallows. Further, PB caused a substantial reduction in moss cover. We showed that effects on vegetation structure increased with increasing fire frequency. While frequent burning reduced species richness and evenness, lower frequency (particularly triennial) fire mitigated negative effects of fire on diversity. Further, the effect of fire differed between species rich and species-poor grasslands, indicating that the initial community composition also mediates fire effects. We showed that PB effectively prevents structural degradation caused by ongoing ecological succession in *Nardus* grasslands, and therefore maintains favourable conditions for grassland specialist species, highlighting PB as a valuable management option for montane *Nardus* grassland.

Restoring plant and pollinator diversity in lowland grasslands using different seed addition methods

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The biodiversity of semi-natural grasslands has dramatically declined over the past century, largely due to the intensification of management practices. In this study we experimentally tested the efficacy of different assisted (active) restoration methods to increase plant and invertebrate biodiversity in relatively species-poor extensively managed Swiss lowland meadows. Four restoration treatments and a control were randomly established in 2019: 1) hay transfer from a species-rich donor meadow to a harrowed receiver meadow; 2) the same as 1), but to a ploughed meadow; 3) sowing a directly harvested native seed mixture originating from a species-rich donor meadow to a ploughed meadow; 4) sowing a propagated native mixture on a ploughed meadow; 5) control, with no soil disturbance and no reseeding. The experiment was conducted at field scale and replicated 12 times across the Swiss Plateau. Vegetation surveys were performed before (2018) and after the restoration (2021–2024). Pollinators were sampled in 2022 (wild bees and hoverflies) and 2024 (butterflies). After a marked increase in 2021, plant species richness stabilised in 2023 in most treatments with on average 29% more species compared to 2018 and 16% more species in restored compared to control meadows in 2023. Moreover, in 2023, 90% of the restored meadows qualified for the result-based payment scheme (whereas none qualified before restoration). Harrowing before sowing was found to be as effective as ploughing. Wild bees and butterflies responded positively to the restoration treatments, though not consistently across all treatments. Hoverflies showed no response. This real-scale study provides evidence-based recommendations for restoring grasslands through various methods (with pros and cons) that are both financially viable and practically feasible for farmers to implement.

Exploring the multifunctionality of restored grasslands

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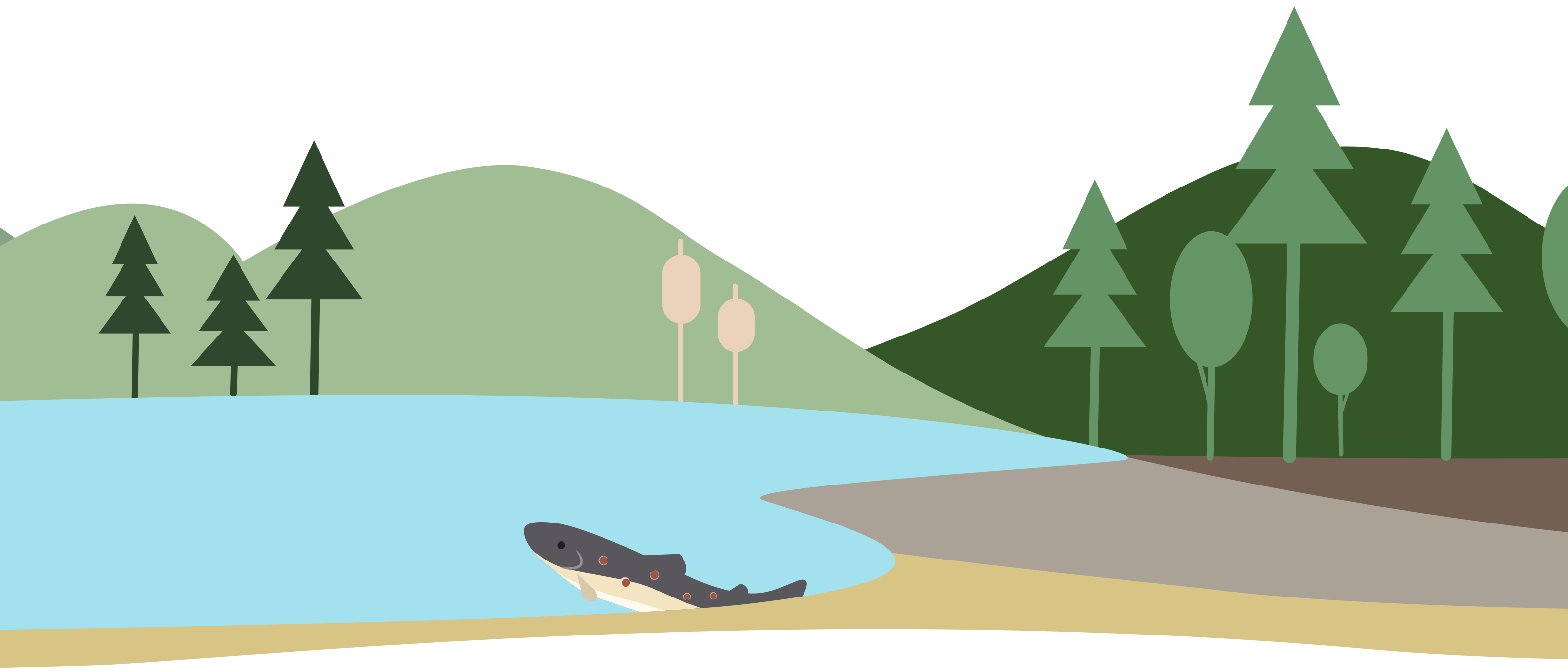
Grassland restoration can help to bend the curve of biodiversity loss and thus secure ecosystem functioning. However, when restoring grasslands in order to improve multiple ecosystem functions simultaneously, i.e. to foster multifunctionality, the goals are often not achieved because trade-offs between different functions may affect the outcome. As different methods with varying levels of intensity have been applied to restore grasslands, analysing which restoration method enhance multifunctionality of grasslands may reduce the effects of trade-offs. Within the *Grassworks* project, we sampled 121 restored grasslands that cover a wide gradient of site characteristics and restoration methods (i.e. cultivar or regional seed mixture seeding, management adaptation, and the seeding of directly harvested material) in three regions across Germany. The restored grasslands were compared with 33 positive and 33 negative reference sites. We characterized grassland multifunctionality using 12 indicators of ecosystem functions. We analyzed the differences among restoration methods for all single functions and for multifunctionality using the (i) averaging and (ii) Hill-numbers (effective number of functions) approaches. Our results indicate that ecosystem multifunctionality increased when high-quality restoration methods such as the sowing of regional seed mixtures or direct harvested material were applied. A comparison of the averaging approache and the Hill-numbers led consistently to the same results. Understanding and evaluating how restoration enhances biodiversity and provides multifunctional ecosystems is the key driver for sustainable land use while maintaining food production.

Session 17

Landscapes and habitat features for biodiversity conservation



Disentangling Landscape Heterogeneity: Integrating Compositional, Configurational, Vertical, and Temporal Heterogeneity Across Land-Cover Types

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Landscape heterogeneity plays a central role in shaping biodiversity, ecosystem functioning, and resilience. While compositional and configurational heterogeneity are widely studied, less is known about how these components relate to vertical and temporal heterogeneity—particularly across different land-cover types and at large spatial scales. In this study, we quantified multiple components of landscape heterogeneity across Germany using high-resolution, publicly available geospatial datasets. We assessed heterogeneity within and across forests, croplands, and grasslands based on land-cover types, management practices, and structural features using 3 × 3 km^2 grid cells.

Using correlation analysis and Structural Equation Modelling (SEM), we investigated interdependencies among heterogeneity components: (i) compositional vs. configurational heterogeneity (Shannon diversity vs. edge density), (ii) configurational heterogeneity vs. connectivity, (iii) horizontal vs. vertical and temporal heterogeneity, and (iv) heterogeneity across different land-cover types. Our findings reveal that while compositional and configurational heterogeneity are generally correlated, their relationship is strongly mediated by land-cover proportions. Contrary to common assumptions, configurational heterogeneity did not enhance connectivity; instead, it showed a negative partial association when controlling for land-cover proportions. Vertical and temporal heterogeneity appeared largely independent of horizontal heterogeneity, indicating that they represent distinct aspects of landscape heterogeneity. Principal Component Analysis revealed that landscape heterogeneity was primarily shaped by heterogeneity in forests and across all land-cover types (e.g., edge density of dominant tree species), whereas cropland heterogeneity (e.g., crop type diversity) showed a negative contribution.

This work emphasises the importance of considering land-cover proportions and multi-dimensional heterogeneity in ecological analyses. Since patterns of landscape heterogeneity are influenced by land-use decisions, history, and socio-ecological contexts, cross-national and cross-administrative studies are essential for drawing generalizable conclusions.

Insights on the distribution of hedgerows in Bavaria by means of remote sensing

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Natural hedges and other woody vegetation fulfill a variety of environmental functions. They constitute important habitats for flora and fauna, provide forage, shelter and breeding grounds. In addition, their importance for biodiversity is closely tied to their distribution and interconnectivity as they function as migration corridors for numerous species. Besides, hedges structure and diversify the landscape and positively influence fluxes of nutrients, carbon and water as well as the microclimate and control erosion.

For an extensive analysis of the occurrence of hedgerows over large areas, comprehensive and up-to-date datasets are needed. Traditional methods, such as field observations or reporting, are still necessary but no longer sufficient to meet this demand. In this context, Earth Observation technologies offer a powerful solution for assessing environmental indicators across large areas efficiently. We therefore rely in this study on the first remote sensing-based hedgerow map of Bavaria, Germany, to examine the heterogeneity of hedgerows in agricultural landscapes. The hedgerow map was derived from orthophotos using a Convolutional Neural Network and provides information on the precise location and extent of hedgerows. The map is integrated with other sources such as Small Woody Features from the Copernicus Land Monitoring Service as well as crop type maps derived from Sentinel-1 and -2 imagery. These datasets enable detailed spatial and statistical analyses to assess regional variations of landscape heterogeneity.

Our results show that there are significant regional differences in landscape heterogeneity, revealing hotspots of woody landscape features with a strong habitat connectivity. At the same time, we could identify areas with a low hedgerow density. Our findings provide valuable insights to policy makers for achieving environmental objectives through more targeted interventions and can be used for carrying out large scale biodiversity assessments.

Local habitat quality and generalist species are key to restoring plant-pollinator meta-networks in calcareous grasslands

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Biodiversity conservation must include agricultural landscapes to be effective. Current agricultural intensification and abandonment is causing the extinction of species due to habitat loss. Thus, restoring semi-natural habitats in agricultural landscapes has become a target of many international policies. Nevertheless, restoration goals often focus on simple attributes, like local taxonomic richness or abundance. Yet, restoration efforts should go beyond species-centered approaches and target the restoration of species interactions to preserve ecosystem functioning. Besides, at the landscape level, it should be promoted that interactions remain spatially redundant, so ecosystem processes are maintained across space. Here, we used a novel approach, meta-networks, to study crucial aspects to restore species interactions across habitat patches embedded in agricultural landscapes. We focused on plant-wild bee interactions over two years across 96 calcareous grasslands in three countries, along a restoration-abandonment gradient. To guide restoration practice, we analyzed the structure of the meta-network by examining the ecological strategies of interacting species —classified based on their interaction breadth (generalists vs. specialists) and their spatial occurrence (ubiquitous vs local)—, as well as the influential role of each grassland within the meta-network. For the latter, we assessed how habitat quality, both at local and landscape scale, influenced the role of grasslands within the meta-network. Generalist and ubiquitous species played a key role connecting the meta-network. Local habitat quality increased the number of interactions in calcareous grasslands, while woody succession led to more uniform interaction patterns across sites. Calcareous grassland landscape cover did not significantly affect how influential a given grassland was. Results show that restoring local habitat quality is essential to promote plant pollinator interactions across space.

How landscape structure and disturbance shape dispersal strategies in natural and fragmented metacommunities

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The modification of natural landscapes by land use activities reduces the amount of natural habitat, disrupts habitat connectivity and alters ecological processes. Dispersal plays a key role in shaping the distribution, abundance, and persistence of species in such altered landscapes. While previous research has focussed on the evolution of dispersal strategies at the species level, community-level dynamics and patterns remain less understood. Furthermore, it is still unclear how multiple interacting drivers influence the selection of dispersal strategies in natural versus modified landscapes.

Two opposing hypotheses exist: Either, land use change may favour short-distance dispersal to reduce mortality in hostile environments, or it may favour long-distance dispersal to enhance (re)colonization rates of isolated and/or disturbed habitat fragments. To investigate these dynamics, we use an individual-based metacommunity model to explore how habitat heterogeneity, habitat amount, and fragmentation per se influence the identity and diversity of dispersal strategies as well as biodiversity. We also consider the role of spatially correlated disturbances - such as fires, or pest outbreaks - and compare outcomes for continuous natural landscapes and fragmented modified landscapes.

Using detailed simulation experiments, we analyse how landscape properties and disturbance regimes jointly affect the community-weighted mean dispersal distance, functional diversity in dispersal, and species richness in the metacommunity. Our findings show that the landscape characteristics prior to land use change strongly determine the adaptation of dispersal strategies in the metacommunity towards the consequences of land use change.

Ecological boundaries between crop fields & dry grasslands: Small-scale patterns of plant diversity

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To mitigate the ongoing biodiversity loss in Central European agricultural landscapes, we need a comprehensive understanding of spatial patterns in biodiversity, and their drivers. Cultural landscapes consist of habitat patches, which are connected through boundaries, making boundaries an omnipresent and fundamental component. Here, we address the surprising scarcity of studies on small-scale plant diversity patterns across habitat boundaries. We therefore sampled vegetation and soil along transects extending from crop field interiors into adjacent dry grasslands in two German landscapes, the Eifel and the Uckermark. For plant species diversity, we could show strong impacts of land use extending deeply into neighboring habitats, and we also found effects of general landscape context associated with farming practices. Due to land use, following natural conditions, the boundary between crop fields and dry grasslands is primarily characterised by differences in nutrient load and disturbance regime. Ecological boundaries are those landscape components where characteristics change most strongly, while the existence, strength, and spatial dimension of these changes are perspective-dependent, varying for species functional groups. Beyond alpha diversity, we developed and confirmed a model for beta diversity across boundaries. Finally, we synthesize existing and our new concepts into a comprehensive model for ecological boundaries, integrating multiple layers of driving, mediating, and responding characteristics. This model links small-scale patterns of these characteristics, from underlying environmental conditions shaping resource distribution and habitat quality, through species abundances, to species richness, composition, and functional traits.

Biodiversity contribution of quartz habitat islands in a summer rainfall region, South Africa

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One of the main goals of conservation ecology is to understand the spatial distribution of biodiversity and its environmental drivers. We studied the vegetation of quartz habitat islands in South Africa's Nama Karoo drylands—floristically unique systems increasingly threatened by global warming and habitat degradation. The studied quartz islands lie in the summer rainfall zone near Pofadder, but their plant communities show strong affinities to the Succulent Karoo biome. We investigated whether these islands represent embedded Succulent Karoo elements within the Nama Karoo. We asked: (1) How do quartz islands contribute to alpha and beta diversity? (2) How do plant functional traits differ among habitat types? (3) Which environmental factors drive these diversity patterns?

We sampled 30 plots (5 × 5 m) in quartz islands, surrounding zonal habitats, and their transition zones. Alpha diversity and beta diversity components (turnover, nestedness) were analyzed among habitats. In addition, 10 transects crossing habitat boundaries (15 plots each, 1 × 5 m) were used to study fine-scale changes in beta diversity, traits, and environmental variables.

Species richness peaked in the transition zone, while the Shannon index was highest on quartz habitats. Beta diversity was highest between quartz and zonal habitats, driven mainly by turnover. Quartz habitats had significantly more nitrogen, organic carbon, and sand, but less silt. Along transects, succulents and nano-chamaephytes increased towards quartz habitats, while hemicryptophytes and non-succulents decreased. Sand, clay, quartz cover, and vegetation cover were key drivers of transect-diversity.

Quartz islands harbor distinct plant communities and make a strong contribution to regional (gamma) diversity. Their conservation is important for protecting succulent-rich dryland flora.

Time and distance to forest shape plant community recovery in a landscape under assisted an natural restoration

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Optimizing tropical forest restoration requires a better understanding of how assisted and passive restoration strategies contribute to the recovery of native vegetation. Evidence on the effectiveness of both strategies is mixed, as each contributes to vegetation restoration in different ways and could be complementary. In this study, we evaluated how plant abundance and diversity vary across a chronosequence of restored tropical montane forest sites in southern Ecuador, where restoration strategies include both assisted (active) and natural regeneration. Our results reveal that plant abundance is primarily driven by elevation, with lower elevation sites supporting higher abundance, regardless of the restoration strategy. Species richness (q0) increased with restoration age and was also higher at lower elevations, indicating that time since disturbance and environmental gradients are key drivers of species richness. Both strategies converged over time, leading to similar richness levels in older sites. Shannon diversity (q1) increased with restoration age and distance to remnant old growth-forest, but declined with elevation, suggesting that forest aga and proximity to forest remnants support more even plant communities. In contrast, Simpson diversity (q2) was influenced by distance to old-growth forest, with more isolated sites showing lower dominance, likely due to limited seed input and the proliferation of pioneer species. Lastly, plant community composition across both restoration strategies became more similar over time, with older sites approaching the species composition of old growth-forest. These findings highlight the critical role of restoration age, proximity to forest remnants and elevation in shaping plant community recovery of both assisted and passive strategies in a tropical cloud forest.

Do local site conditions (quality & heterogeneity) outweigh landscape effects on biodiversity in Central European high-value grasslands?

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Habitat deterioration, habitat loss and climate change synergistically pose major challenges to biodiversity in Central European landscapes. Even in the few remaining high-value habitats, biodiversity is jeopardized by the homogenization within habitats and the simplification of entire landscapes. Nutrient deposition, encroachment due to abandonment, and the rise in temperatures are further changing habitat conditions for open habitat species. While several studies address these threats separately, mainly in agricultural contexts, we now shift the focus to some of the biodiversity hotspots and refugia in Central Europe, 75 nutrient-poor calcareous grasslands within matrices of intensively used farmland or forest, distributed between the colline and the alpine elevational zone in Germany. Here, we recorded four groups of conservation-relevant insect taxa - butterflies, grasshoppers, hoverflies and wild bees - alongside vascular plant assemblages occurring at the grassland study sites. We characterized local habitat conditions and their spatial heterogeneity by using plant indicator values and plant cover as well as their variation between plots within a grassland, while also assessing the landscape composition. Species richness, abundance and community composition were strongly affected by habitat quality and heterogeneity and to a lesser extent by habitat amount. Temperature, nutrient scarcity, and light availability had varying impacts on the different taxa and facets of biodiversity, shedding light on possible explanations for diversity declines during global change. Especially red-listed species responded most severely to local conditions. Our results indicate that apart from stopping landscape simplification, safeguarding, restoring and improving habitat quality even within high-value habitats are crucial steps in order to fight the loss of diversity.

Assessing the effects of landscape diversity and flower fields on farmland bird species richness

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Agricultural intensification threatens bird populations across Europe. One proposed countermeasure is the diversification of agricultural landscapes through agri-environment-climate measures, such as flower fields. In this study, conducted in Central Germany, we examined the combined effects of landscape diversity and flower field area on total and farmland bird species richness, as well as on the Sørensen-based beta-diversity components (turnover and nestedness) of bird communities across landscapes. We sampled 37 agricultural landscapes spanning two independent gradients of landscape diversity and flower field area. Bird communities were monitored in April and May 2024 using AudioMoths. Recordings were analysed using BirdNET, and 37 hours of April recordings were manually identified to assess BirdNET precision.

We recorded 132 species (after excluding waterbirds and retaining BirdNET confidence > 0.5), of which 33 were farmland species. Both total and farmland species richness were higher in May than in April; yet neither metric was significantly affected by landscape diversity or flower field area. Landscape diversity negatively affected several farmland species—skylark (*Alauda arvensis*), kestrel (*Falco tinnunculus*), yellow wagtail (*Motacilla flava*), and grey partridge (*Perdix perdix*)—while flower field area had a negative effect on the rook (Corvus frugilegus). Landscape diversity promoted species turnover but not nestedness; flower field area had no significant effect on either beta-diversity component. Average BirdNET precision was 0.45 for all species and 0.77 for farmland species.

Farmland bird communities may rely more on specific habitat types than on general landscape diversity. However, species richness may not be a sensitive enough metric to detect positive effects of landscape diversity and especially of flower field area, highlighting a main limitation of acoustic monitoring, namely that activities or densities cannot be reliably estimated.

From Forest to Field: The Role of Habitat Complexity in Bat Foraging Dynamics

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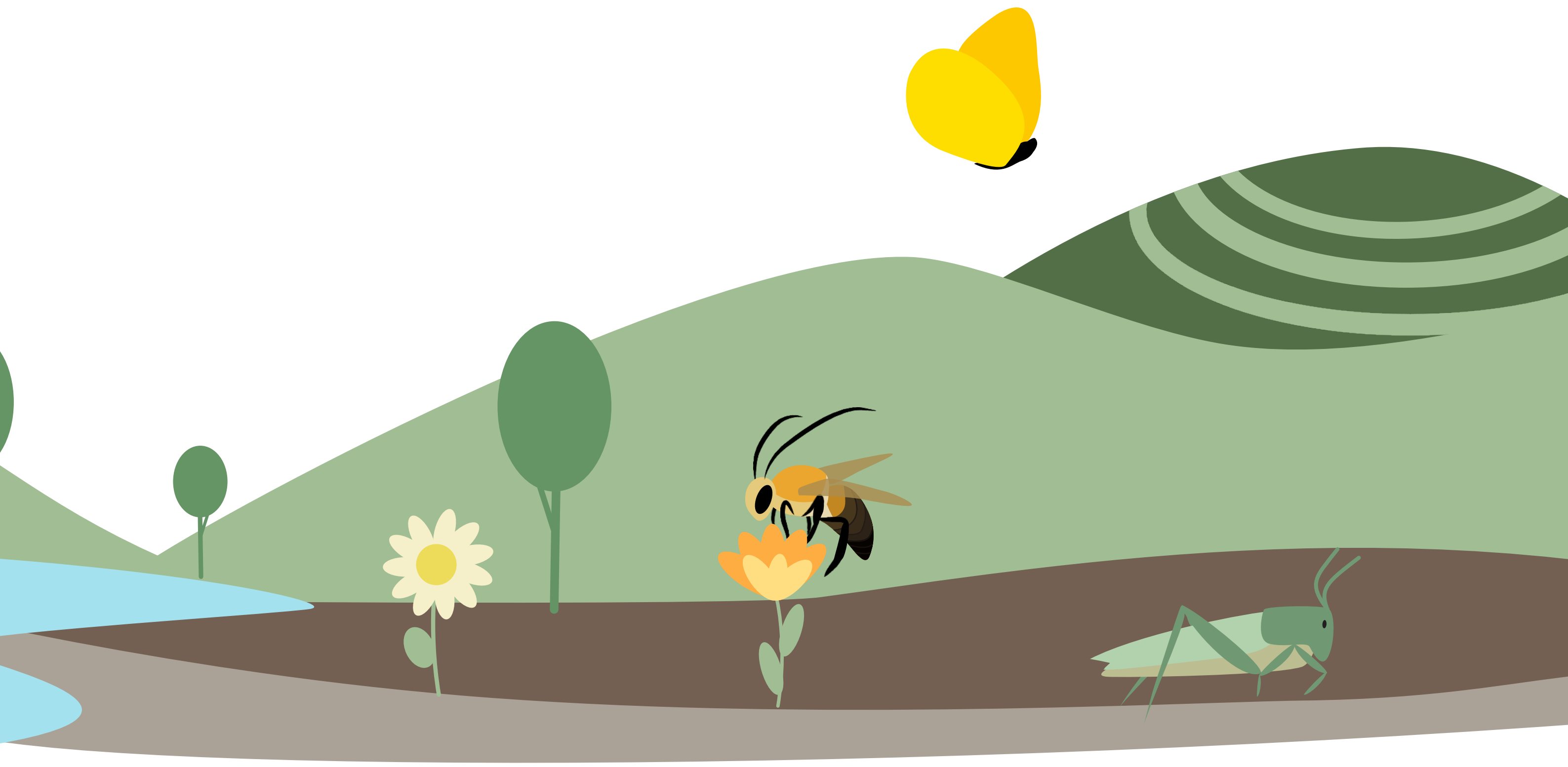
The structure and complexity of landscapes are pivotal in shaping bat biodiversity and the ecological services they provide, such as pest control, seed dispersion, and pollination. However, a key factor contributing to the ongoing decline in bat populations is the simplification in landscape heterogeneity due to ongoing agricultural intensification. Here we study how bats of different foraging guilds respond to changes in landscape complexity. We monitored bats across 14 distinct landscapes (1x1 km) with 16 recording devices each, covering all habitat types proportionally (arable land, grassland, orchards, and forest). After automated filtering of over 650 h of recordings we manually classified 13,059 bat call sequences into three ecologically distinct foraging guilds: narrow space, edge space, and open space foragers. We found guild-specific responses to both landscape-scale and local-scale (within 100 m of each recorder) habitat complexity, as well as to habitat type. The activity of narrow space hunting bats increased significantly with increasing landscape complexity, while the activity of open and edge hunting bats was not affected. However, open space foraging bats responded positively to increased local-scale habitat complexity. Furthermore, although foraging activity over arable land was consistently lowest across all foraging guilds, only edge space foraging bats exhibited significantly higher activity in forest habitats. We found no effect of hedge length on bat activity across all foraging guilds. However, only open-space foragers showed a significant decrease in foraging activity with increasing tree density. These findings underscore the distinct habitat preferences among foraging guilds and emphasize the role of structurally diverse landscapes in supporting bat activity and pest control services. Maintaining heterogeneity at both local and landscape scales is therefore crucial for conserving functional bat diversity across agricultural environments.

Session 18

Dynamics in insect ecology



Home advantage: species-specific insect survival and phenology beyond their local climate

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Temperatures beyond the local climate are expected during insect diapause. Differences in survival and phenological responses may indicate a lower adaptation potential in certain species.To test this, we reared two wild bees (*Osmia bicornis* and *Osmia cornuta*) and a butterfly (*Pieris nap*i) over the summer. We used a space-for-time approach to evaluate the impact of a strong climatic gradient on insect survival and phenology. The pupae were sent to 16 European locations, spanning a fall and winter mean temperature gradient from -2 °C to +15 °C, allowing the pupae to experience different natural conditions in standardized insect "hotels". At the end of winter, all pupae were sent back to a central location. We also tested the influence of winter warming only, keeping a separate set of pupae under controlled conditions in climate chambers. A cold (-3.3 °C), a mild (+2.6 °C) and a warm (+8.6°C) winter relative to the local temperatures were simulated. We monitored the timing of insect emergence, percent survival and weight loss under standardized greenhouse conditions.

Across species, the highest insect survival after overwintering in European locations was found where conditions matched the climate of origin, i.e. home advantage. *P. napi*´s survival was reduced the most by warmer temperatures in both experiments. *P.napi* also experienced higher weight loss at warmer winter temperatures compared with the bee species. Interestingly, female insects` emergence was delayed in *P. napi* and advanced in *O. bicornis* after overwintering in warmer locations. The chamber experiment also showed a delay in the female phenology of *P. napi*, whereas *O. cornuta* advanced its emergence after warmer winter temperatures.

Warming during insect diapause is thus likely to cause species-specific and sex-specific changes in insect abundance and emergence timing, potentially modifying insect competition and pollination interactions in the spring.

Taxonomical Community Composition of Emerging Aquatic Insects of the Oder River and its Floodplains after the 2022 Catastrophe

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A sudden bloom of the toxin-producing, brackish-water golden alga *Prymnesium parvum* in summer 2022 caused a massive die-off of fish, aquatic molluscs, and likely other aquatic invertebrates (www.oder-so/info). However, how the algae bloom affected the aquatic insect communities is currently unknown. The alga bloom less severely impacted many adjacent floodplain water bodies since they were not connected to the river in the summer. Therefore, we investigated their role in the recovery of aquatic insect communities in the river after the environmental disaster.

We deployed floating insect emergence traps at six sites on the German side of the Oder to monitor spill-over effects. At three of the sites, we also sampled adjacent permanent floodplain waterbodies connected to the river during the spring flooding. We compared the taxonomic community composition of adult insects in both habitats weekly from March until November 2023 and 2024 to investigate differences in the seasonal dynamics of the insect communities.

Preliminary results from 2023 show that the average insect abundance per trap was highest in June and lowest in November and in general, considerably higher in the river groynes (June versus November: river groynes: 1041.8 ± 1187.7 (mean ± SD) vs. 6.8 ± 9.1, floodplains: 79.4 ± 75.2 vs. 2.4 ± 3.2). Furthermore, 96.6% of all collected insects were Chironomids, the remaining insects belonged predominantly to Ephemeroptera (1.8%), aquatic parasitoid wasps, such as chalcid wasps (0.5%), Chaoboridae (0.4%) and Trichoptera (0.4%). Furthermore, the results show so far that Chaoboridae only occur in the floodplains, Ephemeroptera were 116 times (River groynes vs. Floodplain: 0.01 ± 0.3 vs. 6.3 ± 30.0), and the parasitoid wasps were 7 times (0.2 ± 0.9 vs 1.4 ± 13.8) more common in the Floodplains. In contrast, Chironomidae were 5 times (170.9 ± 405.2 vs. 33.1 ± 57.0) and Trichoptera were 2.5 times (0.6 ± 1.4 vs. 0.4 ± 1.0) more common in the river groynes.

Landscape context, plant diversity, habitat openness and raw substrate drive insect diversity of extraction sites

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Extraction sites represent exceptional habitats within the intensively used landscapes of Central Europe. Characterized by high disturbance levels and low nutrient availability, they support low-competition conditions that are favourable to a variety of specialists across multiple taxonomic groups. The variability in extraction practices and resulting site conditions contributes to a high degree of habitat heterogeneity. We investigated biodiversity patterns in extraction sites of the building materials industry across Germany. Specifically, we assessed vascular plant and insect diversity in relation to multiple environmental gradients, distinguishing between site-level and plot-level effects. We surveyed vascular plant diversity on 124 plots (5 × 5 m) across 12 extraction sites of limestone, gypsum, gravel and sand. Insect diversity was recorded through transect walks for Lepidoptera and Orthoptera, and via eDNA metabarcoding from trap samples for Hymenoptera, Diptera, Coleoptera, and Hemiptera.

Our results show that site-level factors accounted for the largest proportion of variability in insect diversity, indicating that geographic location and surrounding landscape context primarily drive the patterns within extraction sites. At the plot level, soil pH and plant diversity were key predictors of overall insect diversity. Similarly, the richness of endangered plant species positively affected the diversity of endangered insect species, highlighting the role of plants as effective indicators for insect diversity in this context. In terms of management implications, we found that high herb cover positively influenced insect diversity, while extensive shrub cover had a negative impact, indicating the importance of maintaining open habitats in extraction sites. Notably, the presence of raw, unmodified substrate was essential for supporting the diversity of endangered insects, while site age had a generally positive effect but was not among the strongest predictors.

Tree evolution explains effects of forest uniformity on insect diversity

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Forests harbour an exorbitant diversity of insects. Humans threatens this diversity by warming climate and rendering forests increasingly uniform. These impacts so far have been studied as direct impacts on insects. However, warming and forest uniformity may also drive tree evolution, which may in turn may affect insects. First, warm climate and uniform forests may represent specific selection pressures. Warm climate and competition in uniform forests might select for tree traits such as early budburst, to the advantage of many herbivorous insects. Inversely, abundant specialist herbivores in uniform forests might select for late budburst. Second, uniform forests may foster genetic drift and thus decrease genetic distance between trees and heterozygosity within trees.

We studied how the evolution of Sessile Oaks (Q*uercus petraea*) mediates the effects of climate and phylogenetic uniformity of forests on insect diversity. We used a provenance experiment with trees descending from 30 provenances differing in climate and in phylogenetic uniformity (i.e. the phylogenetic distance of the ambient trees to sessile oaks). We used fogging to sample 24 000 insects from 120 30-years old trees. We also recorded the within-tree heterozygosity of these descendants and the genetic distance to their neighbours.

We found overall species richness of insects to be highest in descendants from phylogenetically uniform forests (reflecting high abundance of insects). Moreover, diversity of Hemiptera was highest in trees with genetically proximate neighbours.

Increased abundance and diversity on descendants from phylogenetically proximate parental neighbourhoods provides an evolutionary explanation for a pattern so far explained by direct, ecological mechanisms such as resource concentration. Evolution of long-lived trees may be quick enough to interfere with the assembly of short-lived insects.

Satellite data and metabarcoding provide new insights into the consequences of tree mortality and clearing on taxonomic and phylogenetic insect diversity

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Tree mortality has increased in recent decades, raising concerns about its ecological consequences, including potential impacts on insect diversity. While natural forest disturbances can promote insect habitats by creating structural complexity, such as deadwood accumulation, post-disturbance interventions like salvage logging may alter these outcomes. Yet, the mechanisms linking disturbance, forest structure, and insect diversity remain insufficiently understood.

In this study, we investigated how natural disturbances and subsequent logging affect insect diversity in forests across Bavaria, Germany. Our design included replicated triplets of undisturbed, naturally disturbed, and post-disturbance cleared patches across forests dominated by spruce, beech, pine, and oak. Central to our approach was the integration of satellite-derived data to quantify canopy openness. This enabled us to further analyse the effects of canopy openness, which varied within our treatments, while deadwood accumulation or removal were standardized within our factorial design.

Insect communities were assessed using DNA metabarcoding and a newly developed phylogeny, allowing us to analyse both taxonomic and phylogenetic diversity across thousands of operational taxonomic units from 347 insect families and multiple feeding guilds.

While our findings show complex and varied responses to disturbance, especially across different insect guilds, canopy openness emerged as an important factor associated with changes in insect diversity. By combining remote sensing with high-throughput biodiversity assessment, our approach offers new insights into how small-scale forest disturbances and management decisions influence insect communities in temperate forests.

Flying beetle species abundance distribution and body size distribution react to changes in forest characteristics

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Extreme weather events and changes in precipitation or temperature patterns are strongly affecting both near-natural and managed forests, leading to changes in the characteristics of forest ecosystems. Many studies have analysed the effects of changing forest characteristics on beetle community composition and diversity, but knowledge of the underlying mechanisms is lacking. Species Abundance and Body Size Distributions can disentangle such changes by explaining why communities change and how the environment filters for different body size classes.

We studied beetle communities and forest characteristics on 49 forest plots in western Germany that varied in canopy openness, deadwood volume, proportion of non-native trees, mean DBH and tree diversity. We analysed the effects of forest characteristics on community composition and structure using three parameters describing Species Abundance Distributions: decay rate, dominance and rare species richness. In addition, we tested for effects on the skewness of the beetle community Body Size Distributions.

Beetle community composition varied with all included forest characteristics except tree diversity. Canopy openness affected both decay rate and rare species richness, indicating a less even community with fewer rare species in open forest plots. The skewness of the body size distributions increased with decreasing mean DBH and increasing proportion of non-native trees, indicating a lower occurrence of larger beetles in these communities.

The results of our study show that changes in the beetle community due to a more open canopy are explained by responses in Species Abundance Distributions, whereas changes due to mean DBH and proportion of non-native trees are related to effects on the community Body Size Distribution. Our results emphasise the importance of underlying community structures for understanding patterns of biodiversity and community assembly in the context of structural changes in forest ecosystems.

How land use impacts insect biomass by altering spatio-temporal vegetation dynamics: a remote sensing approach

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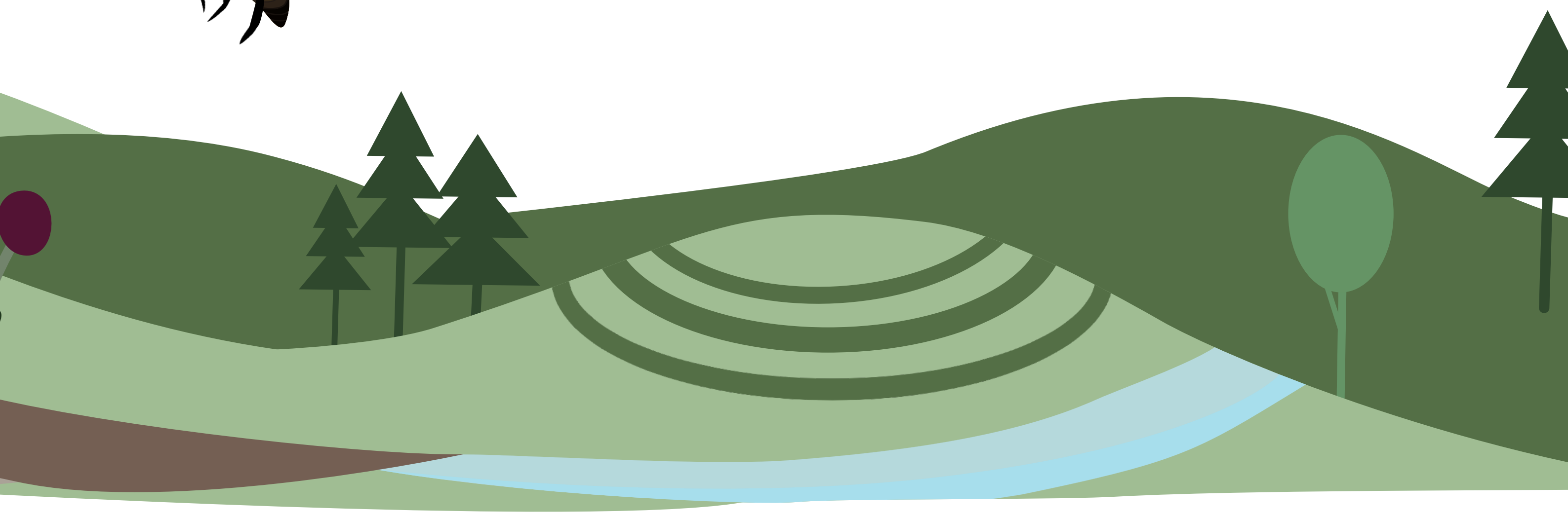
Insect biomass has declined drastically in recent decades, raising concerns about biodiversity loss and ecosystem stability in agricultural landscapes. While it has been postulated that increasing productivity and homogeneity of agricultural landscapes may contribute to this decline, it remains poorly understood how land use change impacts insect biomass by altering the spatiotemporal vegetation dynamics. To close this gap, we investigated the relationship between remotely sensed vegetation characteristics and long-term trends in insect biomass. We related published insect biomass data (including data from the Krefeld study) to satellite-derived NDVI metrics within a 1 km radius around sampling sites. Specifically, we calculated indices of vegetation productivity and its spatial-temporal variability for the three years preceding each sampling event. To extend the analysis beyond the original sampling locations, we examined vegetation trends at 500 randomly selected sites across Germany. Using the same NDVI-derived metrics, we assessed long-term changes in vegetation dynamics, stratified by major land cover types: arable land, grassland, and forest. Generalized Additive Models (GAMs) revealed that higher productivity and spatial homogeneity of vegetation reduced insect biomass. Across Germany, mean NDVI increased steadily over time across all land cover types. In contrast, spatial homogeneity increased only in arable and grassland areas, while remaining stable in forests. These findings suggest that agricultural intensification impacts insect biomass by altering vegetation productivity and its spatial-temporal dynamics. The observed increase in vegetation homogeneity may reduce habitat quality and resilience, thereby contributing to long-term ecological degradation. Our results underline the need for land use policies that address not only habitat quantity but also its spatio-temporal configuration.

Session 19

Macroecology and biogeography



Spatio-temporal patterns in biodiversity and linguistic diversity

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Spatial patterns in the diversity of biological species and human languages are astonishingly similar on a global scale. Higher diversities are found towards the tropics, on islands and in certain hotspot regions. Previous studies have, in isolation, related linguistic diversity and biodiversity (of certain taxa) to environmental factors. However, an integrated approach is still lacking. In my PhD dissertation, I would like to fill this gap — exchanging data and methods in a common evolutionary framework and leveraging interesting differences between diversity patterns that can be seen upon a closer look.

Employing statistical models on a global scale, I am linking diversities to the environment, identifying the relative importance of variables such as bioclimate, landscape, biogeography/ paleoenvironment and human history (e. g. land use). With my results, I want to contribute to a more general understanding of diversity systems, identifying common hotspots as well as system-specific differences between the distribution of biological taxa (vertebrates, invertebrates, plants) and human languages. For my talk, I would like to present the conceptual framework, methodology and the first results of the mapping and modelling process. A first outlook into future models, providing a more mechanistic approach that includes time, are also given.

Anthropogenic and climatic factors as co-determinants of fungal diversity worldwide

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Anthropogenic factors disrupt global diversity and ecosystems. However, a comprehensive assessment of anthropogenic effects on fungal diversity is lacking. Here, we use a global high-throughput sequencing dataset and test the relative importance of human factors on taxonomic and phylogenetic diversity. The anthropogenic predictor set significantly influenced fungaldiversity, partly even stronger than climate. Pollution increased, and climate change decreased phylogenetic alpha diversity. Climate change further affected between-site phylogenetic composition, suggesting global lineage homogenization. This study highlights human factors as amajor driver of worldwide fungal diversity besides climate, soil, and vegetation. Our analysis suggests continuing regional loss of phylogenetic diversity, a recently discovered important aspect of ecosystem stability.

Changes in Fungal Phenology Patterns in Europe

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The worlds ecosystems are altered by climate change. The timing of recurrent biological events responds sensitive to climatic changes in many organism groups, but evidence for fungi is limited. While small-scale studies show significant changes in fungal phenology, the generality of the observed patterns is still unknown, i.e. the effects of spatial extent, spatial grain and spatial resolution. We study the spatial variability of changes in fungal fruiting phenology using 7.6 million fruiting events across Europe. Preliminary results indicate that the autumn peak, the start and the end of the main fruiting season in autumn have become later over time. We suggest that these changes are a result of a decrease in environmental constrains in the winter months (freezing) and an increase in environmental constrains in the summer months (heat, drought).

Global hotspots of butterfly diversity are threatened in a warming world

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Insects are in decline and threatened by climate change, yet lack of globally comprehensive information limits the understanding and management of this crisis. Here we uncover a strong concentration of butterfly diversity in rare and rapidly shrinking high-elevation climates. Integrating comprehensive phylogenetic and geographic range data for 12,119 species, we find that global centers of butterfly richness, range rarity, and phylogenetic diversity are unusually concentrated in tropical and sub-tropical mountain systems. Two thirds of the assessed species are primarily mountain-dwelling and mountains hold 3.5 times more butterfly hotspots (top 5%) than lowlands. These hotspots only partially overlap with those of ants, terrestrial vertebrates and vascular plants (14%-36%), while butterfly diversity is uniquely concentrated above 2,000 m elevation. We project that 64% of butterflies' temperature niche space in tropical realms will erode by 2070, with the geographically restricted temperature conditions of mountains potentially turning these from refugia to traps for butterfly diversity. Our study identifies critical conservation priorities for butterflies and underscores the need for quantitative global assessments of at least select insect groups to help mitigate biodiversity loss in a rapidly warming world. [OA article: Pinkert et al. 2025, Nat Ecol Evol]

Global human impact on the functional and phylogenetic diversity of island birds

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Islands are globally important for biodiversity, but their ecological communities are increasingly shaped by human activities. While dispersal limitation and environmental conditions have long been recognised as key drivers of island community assembly, the role of anthropogenic influences is less well understood in a global context. Here, we analyse functional and phylogenetic diversity (FD and PD) in avian community assemblages on 2,719 islands to quantify the relative importance of dispersal, environmental and anthropogenic drivers.

We combine global trait and phylogenetic datasets with Bayesian multivariate models to assess how FD and PD respond to geographic isolation, island environmental conditions, and anthropogenic pressures such as human land cover diversification, introduced predators, and human appropriation of productivity. FD and PD are positively correlated overall, but respond differently to specific drivers. While island area promotes higher phylogenetic diversity, functional diversity is more variable and often constrained by contemporary pressures.

Among all predictors, anthropogenic drivers - particularly introduced predators and landscape modification - exert strong, consistent effects, clustering both FD and PD and contributing to biotic homogenisation. These effects are particularly pronounced on remote and tropical islands, where distinctive bird communities are being reshaped. In some cases, human pressures override or reverse patterns expected from classical biogeographic theory.

Our results highlight that anthropogenic filtering plays a central role not only in shaping species composition, but also in structuring the functional and phylogenetic dimensions of island community assembly. These findings underscore the importance of integrating human impacts into biodiversity theory and conservation strategies, especially in vulnerable island ecosystems.

Bioenergetic Theory of Island Biogeography - Mechanistic Predictions Across Taxa

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The Theory of Island Biogeography provides a framework for understanding how island area and isolation shape species richness, with broad relevance to all spatially structured ecosystems and patchy environments. Recent extensions have moved beyond classical equilibrium theory that assumes functional equivalency among species by incorporating body mass and trophic interactions. Here, we further advance the theory by integrating energetic constraints on dispersal and minimum viable population thresholds to determine whether species can arrive, survive, and persist on islands. We compare model predictions with global distributions of island birds and reef fishes across 2,608 islands and 366 reef sites, respectively. The model accurately captures observed patterns in species richness, while also predicting local food-web structure and community dynamics. Our framework offers a testable, trait-based model for understanding how mechanistic constraints shape biodiversity patterns across isolated ecosystems and diverse taxa.

Biodiversity modulates the size-abundance relationship in changing environments

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Organismal abundance tends to decline with increasing body size. Metabolic theory links this size structure with energy use and productivity across levels of biological organization, predicting a size-abundance slope of -0.75 that is invariant across environments. We tested whether the size-abundance relationship is robust to a gradient of protist species richness (1 to 6 species), temperature (15 to 25° C), and time. Our results support the expected slope of -0.75 for the size-abundance relationship, but we found interactive effects indicating that the size-abundance relationship is not invariant. In high-richness communities, temperature increased the abundance of small protists more than that of the large protists, leading to a steeper size abundance slope. Temperature and size-dependent species interactions were identified as potential drivers. Understanding variation in size-abundance relationship hence provides novel insight into the underlying mechanisms shaping the size structure of ecological communities under environmental change.

Trait evolution in invasive plants with residence time: a meta-analysis

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The success of invasive plants is often attributed to rapid post-introduction evolution, due to novel selection pressures at the introduced range. However, increasing number of studies suggest that evolutionary shifts in invasion-promoting traits can also take place within the introduced range over time. Here, we performed a meta-analysis aimed at providing a general overview of current knowledge on trait evolution with time since introduction. We predicted that invasion promoting traits, including growth, competitive ability and dispersal ability, will decline in more established populations with a longer invasion history due to the attenuation of selection pressures, such as enemy release or interspecific competition, while herbivore defence will increase. Our results reveal a general indication for the evolution of invasive plants with residence time for most of the studied traits. However, this divergence did not have a consistent direction in most traits, except for growth, which, in contrast with our prediction, increased with residence time. The general temporal effect found in our meta-analysis stresses the need to consider population age when comparing attributes of invasive plants between native and invasive ranges. Moreover, the increased size of invasive plants in older populations, suggests that the dominance of these plants might not attenuate with time since introduction, thus highlighting the need to further explore the long-term dynamics between invasive plants and their recipient native communities.

Climatic niche conservatism in non-native plants depends on introduction history and biogeographic context

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Niche conservatism is a key assumption in predictive models for preventative management of non-native species, but its generality has been questioned as previous research yielded contradictory results. We hypothesize that variations in niche conservatism can arise from context dependency related, for example, to differences in dispersal limitations, which can be studied in species that have been introduced to multiple regions of the world. Here, we used an ordination-based approach to quantify the climatic niche changes (stability, unfilling, expansion) occurring in 1566 plant introductions across eight study regions, including the Pacific Islands with extreme isolation between island groups. We performed multiple phylogenetic regressions to assess how the regional context and species' characteristics affect niche dynamics. Many species exhibited high variation in niche conservatism but no niche switching. While niche expansion into previously unoccupied conditions was overall low, unfilling varied strongly across regions. Species' biogeographic attributes and region-specific introduction time were more important for explaining niche changes than ecological traits. Niche unfilling decreased with residence time, potentially due to dispersal limitations. Our results underscore that niche conservatism is context-dependent and highlight the unique nature of each regional introduction. Importantly, a lack of niche conservatism might be a transient phenomenon, which should be accounted for in risk assessments of non-native species.

The disruption of the global plant biogeography

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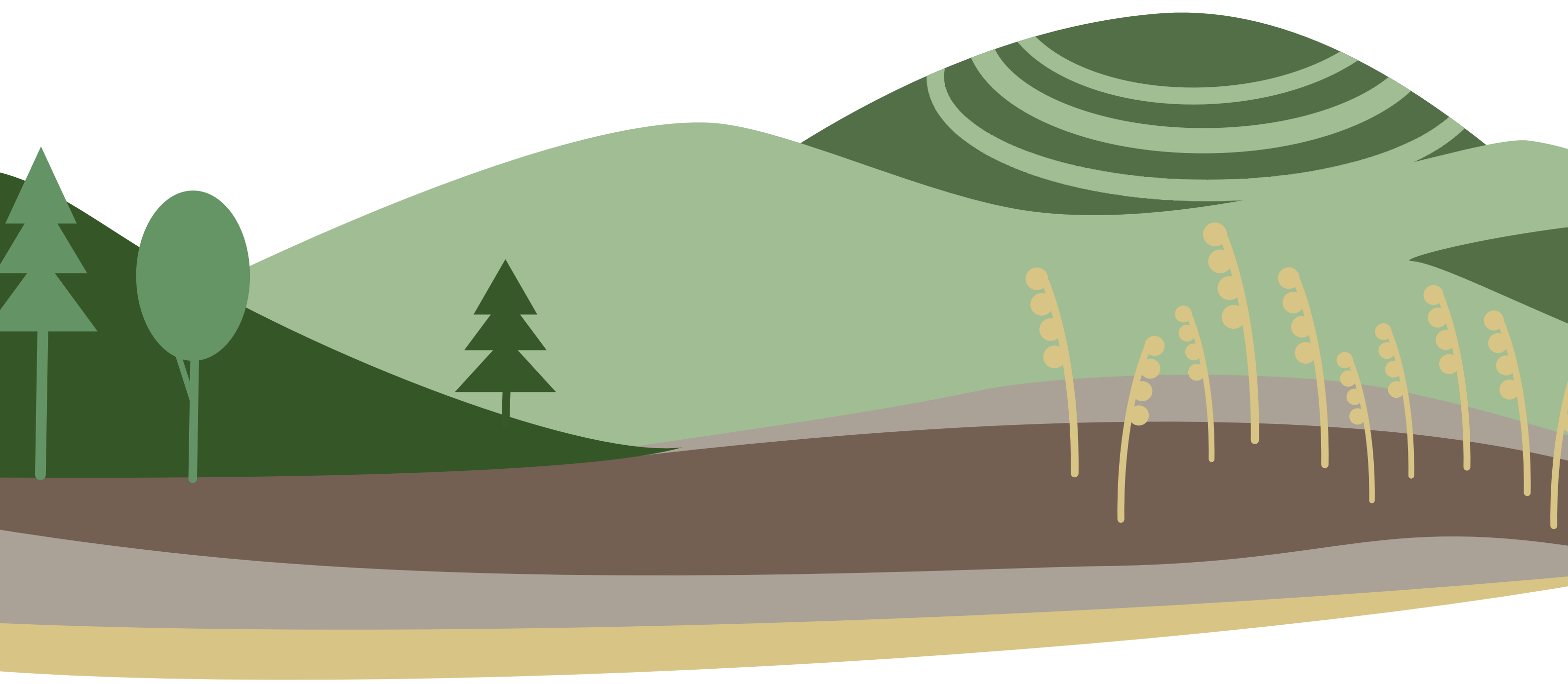
Human activities have altered the composition of biotas worldwide by introducing non-native species, breaking down biogeographical boundaries. Here I present a collaborative study to assess the effects of plant invasions on the natural global biogeography of plants, using floristic kingdoms. Using a unique and most comprehensive data set on the global distribution data of ~300.000 native and >10.000 non-native seed plant species, we analyzed the impact of species introductions on natural biogeographic boundaries based on taxonomic and phylogenetic compositions of 548 regions.

We found that the plant invasions reshaped natural biogeographical patterns, leading to a reduction of floristic kingdoms. Based on taxonomic dissimilarity, eight natural floristic kingdoms broke down into tropical, non-tropical and Australian regions after species introductions. Geographical distances, accounting for dispersal barriers including water, mountains, or unsuitable climates, important in explaining natural patterns, lost their importance when including non-native species. However, environmental factors consistently exerted a strong influence on native and non-native species. Our findings show that human-mediated plant invasions lead to the breakdown of biogeographical barriers and redefines the global biogeography of plants.

Session 20

Management and restoration in agricultural landscapes



Ecosystem and Landscape Restoration for Climate Resilience and Biodiversity Enhancement

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Global change strongly affects biodiversity and ecosystem functionality in agricultural landscapes through climate change, land use intensification and habitat degradation. To counteract these negative impacts, various ecosystem and landscape restoration (ELR) measures have been developed. However, the effectiveness for enhancing biodiversity remains unclear. Our research project “AgriRestore” (2024-2029) aims to address some of these deficiencies using an interdisciplinary approach that combines both real-world observations, long-term experimental monitoring, and knowledge synthesis. At the landscape scale, we assess the effectiveness of wildflower strips as temporary ELR measures and hedgerows as permanent ELR measures along a landscape complexity gradient. For this we compare restored sites with conventionally managed margins in the agricultural landscape of Saxony-Anhalt, Central Germany. While to advance the development of wildflower strips in relation to climate change adaption, a mesocosm experiment has been set-up to study the vegetation development of various seed mixtures. Furthermore, we use remote sensing to up- and downscale patterns, and synthesize the existing evidence base through meta-analyses and data-driven predictive analyses (e.g. restoration archetypes). First results focusing on wildflower strips show that these enhance wild bees and natural enemies compared to conventionally managed margins, while there was no effect on soil nutrient content and enzyme activity as well as pest species. Plant communities strongly differ between wildflower strips, grassy margins and agricultural fields, which underlines their importance for overall farmland biodiversity. Finally, we will give an outlook for the next four

Restoring Resilience: The Role of Wildflower Strips and Hedgerows for Promoting Pollination and Pest Control in Agricultural Landscapes

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Agricultural intensification threatens biodiversity and ecosystem functions by changing land use and fragmenting habitats. This reduces food and nesting sites for insects and disrupts ecological stability. Insects are crucial in agroecosystems through pollination and natural pest control. To support these services, ecosystem and landscape restoration measures like wildflower strips and hedgerows are implemented by the Common Agricultural Policy, both of which provide resources and corridors for insects, with their effectiveness depending on their structure and complexity of the landscape. Little is still known about the interplay between temporary and permanent measures. This study aims to understand and improve ecosystem and landscape restoration measures, enhancing the support of wild bee populations as well as biological pest control in degraded landscapes.

In 2024, wild bees were surveyed in 12 wildflower strips established in 2022 next to winter wheat and compared with conventionally managed grassy margins as control sites along a landscape complexity gradient in an intensively farmed, dry agricultural area of Saxony-Anhalt, Germany. We sampled 100 m transects along three distances from wildflower strips and control sites into the crop (2 m, 12 m and 15 m) using sweep nets, followed by vegetation surveys. Pest insects and their antagonists were counted on 100 crop stalks per distance. Abundance and species richness of wild bees was higher at sites with wildflower strips (437 individuals, 70 species) than at controls (206 individuals, 55 species). Bee numbers declined with distance into the field. Unexpectedly, aphid densities were higher near wildflower strips, while ladybugs were more abundant on control sites. Our initial results show that wildflower strips can enhance bee abundance and diversity, though their role in biological pest control remains unclear. Experiments in 2025 will examine the impact of hedgerows and wildflower strips as restoration measures.

Landscape-level synergistic and antagonistic effects among conservation measures drive wild bee densities and species richness

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Pollinators are experiencing a significant global decline, largely driven by agricultural intensification. In response, local conservation measures (CMs), such as annual flower fields, organic crop fields, or perennial semi-natural habitats (SNH) are employed to counteract these trends, though their success varies. Local CMs often fail to support ecological processes at landscape scales, a limitation that can be addressed by implementing conservation strategies across larger areas. These landscape-level CMs may include multiple agricultural fields with a specific CM or a combination of different CMs, but their combined effects can be complex and not always beneficial.

It remains unclear whether multiple combined landscape CMs can be more efficient than single landscape CMs (synergistic effect), reduce each other's effectiveness (antagonistic effect) or sum together (additive effect) to promote biodiversity. To investigate this, we studied how three landscape CMs, organic crops, annual flower fields, and perennial SNH interact to influence wild bee species richness and population densities. Using data from wild bee surveys conducted across multiple transects in 32 different landscapes, we scaled bee densities to the landscape level.

Our results revealed that organic crops and perennial SNH had a synergistic effect on non-*Bombus* wild bee densities, likely due to complementary resources. Bumblebees showed an additive benefit from both CMs, regardless of their availability. In landscapes with few annual flower fields, wild bee densities and species richness increased with organic crop cover. However, antagonistic effects among CMs were also observed e.g. organic farming did not increase wild bee biodiversity in sites with abundant annual flower fields, which provided similar resources as organic crops, suggesting context-dependent outcomes of CMs.

These findings emphasize that combining landscape CMs effectively requires providing complementary resources while avoiding redundant ones. Future bee conservation strategies should focus on a mix of CMs that meet the specific habitat needs of different bee species.

Towards optimal locations of perennial wildflower strips for wild bees, pollination service, and supported by farmers

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Perennial wildflower strips have been introduced as agri-environmental measure to help reverse widespread pollinator loss. However, incentives are largely based on the size of wildflower strips, missing critical aspects to optimise their effectiveness to promote pollinators and their service to increase yields. Our aim was to evaluate how landscape context, the presence of pollination-dependent crops, and farmers' support and reservations can be integrated into decision-making to optimise the placement of perennial wildflower strips in agricultural landscapes.

We took the example of the federal state Saxony-Anhalt, Germany, and analysed potential wild bee habitats in agricultural landscapes based on species-specific requirements and a map of biotope types. Moreover, we developed a classification to determine the extent to which cultivated crops depend on insect pollination and applied it to arable lands using IACS data. Finally, we used interviews with farmers to explore their motivations and experiences in managing perennial wildflower strips.

First results show that large parts of the agricultural landscape would be suitable for wildflower strips to provide resources for wild bees. The potential for wildflower strips to locally support crop pollination appears less, due to the overall small area of pollination-dependent crops. Motivations of farmers to establish wildflower strips and promote biodiversity are generally high, especially on areas difficult to manage or to fulfil legal obligations.

We demonstrate two applications of our analyses: (i) to assess the suitability of the locations of already established wildflower strips and (ii) to detect potentially suitable locations before wildflower strips are implemented. Thus, our study provides a starting point beyond individual farmer decisions to promote perennial wildflower strips at the landscape scale for the biodiversity and functionality of agricultural landscapes, without neglecting practical requirements.

Synergistic enhancement of wild bees at the landscape scale through multiple types of agri-environmental interventions

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The current biodiversity crisis and land pressure call for efficient strategies to promote biodiversity and functional ecosystem services while minimizing trade-offs with opportunity costs. In this study, we examined how the concurrent implementation of two agri-environmental interventions—flower strips and extensively managed meadows—can synergistically enhance the promotion of wild bees in agricultural landscapes. We sampled plant-bee networks and nest-site availability across all major habitat types to assess landscape-level spatiotemporal resource distribution and bee community composition. The turnover of bee species was higher between different intervention types than between patches of the same type across different landscapes, resulting in greater species richness in landscapes combining both interventions. These landscapes also showed a synergistic increase in wild bee abundance, including key crop pollinators. In landscapes with concurrent implementation of agri-environmental interventions, bees benefited from broader diets and lower extinction risk, likely due to the complementarity of floral resources and different temporal flowering patterns in flower strips and extensively managed meadows. Bee communities in landscapes with flower strips included smaller and more oligolectic species, while high proportions of extensively managed meadows alleviated environmental filters resulting in a more balanced bee community composition. Our findings demonstrate that combining different agri-environmental interventions can enhance wild bee promotion through habitat heterogeneity, resource complementarity, and reduced extinction risk. A better understanding of how these mechanisms shape wild bee communities may offer strategies to reduce trade-offs between biodiversity conservation and agricultural production by increasing the land-use efficiency of agri-environmental interventions and improving ecosystem services.

Establishment of flower fields with a regionalized native seed mixture

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Perennial flower fields applied through EU agri-environment schemes (AES) are often used to counteract biodiversity loss in agricultural landscapes. However, it is largely unknown whether the successful establishment of sown flowering plant species depends on the sowing period, previous land use and landscape diversity. Moreover, there is a lack of knowledge whether these factors influence further spontaneously emerging plant species or agronomically problematic weeds.

We studied the vegetation of 29 flower fields sown with a high-diversity seed mixture with 33 native plant species regionalized for southern Lower Saxony, Germany. The flower fields were sown in autumn or spring, differed in their previous land use (annual crop or AES) and were located along a landscape diversity gradient. The fields were sampled over the first two years after establishment.

From the first to the second year the sown species cover tripled, spontaneous species cover almost halved, and problematic weed cover decreased to one fifth of the cover in the first year. In the first year, autumn sowing increased sown species cover, while spring sowing led to higher problematic weed cover. Flower fields with previous land use as annual crop field had less than half of the problematic weed cover and spontaneous species cover respectively compared to flower fields established on AES fields. Sown species established better in low-diversity landscapes, whereas spontaneous species established better in high-diversity landscapes.

We found that the native and regionalized seed mixture with perennial plants established very well and suppressed spontaneous species, including weeds. Successful establishment was facilitated by sowing on previous annual crop fields and by autumn sowing. We conclude that regionalized seed mixtures with native plants are highly promising for the establishment of perennial flower fields that can provide valuable habitats for a wide range of species in agricultural landscapes.

Assessing Biodiversity Outcomes of Farming Practices: Insights from the Landscape experiment patchCrop

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Agricultural biodiversity is among the central components of sustainable agriculture.

However, the focus of conventional agriculture on maximizing yields in recent decades led to a sharp decline in associated agricultural biodiversity. While efforts are made to halt this decline, knowledge gaps still exist as to which extent different management practices affect these dynamics, which are also a subject to specific environmental conditions.

Carabid beetles (Coleoptera: Carabidae) are considered to be a good indicator of biodiversity, due to their ecological relevance and sensitivity to environmental changes and management practices, while also relatively easy to collect.

The ecology of these insects is shaped by a complex interplay of multiple factors within agroecosystems, though more comprehensive studies in real-world agricultural landscapes are needed to unravel this complexity and quantify the effects of individual practices.

Landscape experiments (LE) are suited for this task as they are explicitly designed to gather empirical evidence on multiple processes and mechanisms within an agricultural landscape and offer a valuable platform to explore these interactions. patchCROP is an example of LE by ZALF, which is aimed among others at promoting biodiversity while minimising trade-offs with other production and environmental goals in farming systems.

This however reaches the limitations of the current mainstream methods used to analyse of agri-ecological data, characterised by complex and often non-linear relationships, especially with respect to effect size estimation.

To address this, we tested methods from the Propensity score analysis group - which remain unutilized in ecological studies - using carabid abundance and diversity data from the patchCrop experiment to evaluate the effects of specific management practices. We present both our results and reflections on the method's usability in ecological contexts.

Restoration and rodents: How habitat improvements shape rodent occurrence and their role as agricultural pests?

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Agricultural intensification negatively affects biodiversity and ecosystem functions. Small rodents can be both pests of crops and important elements of food webs. To balance their opposing ecosystem functions and improve acceptance of restoration measures, it is essential to study how such measures affect this underrated species group.

At the landscape scale, we investigated the effects of wildflower strips, whereas at the local scale we studied interrow seeding of wildflower mixtures on the occurrence of rodents and associated crop damage in winter cereals.

Our landscape-scale assessments show that rodent-related crop damage was very low in 2024 (0.2% on average) and was similar between fields adjacent to wildflower strips and conventionally managed grassy field margins. Damage was highest (0.5%) near the wildflower strip edge (3 m), but was nearly undetectable further inside the field (12–150 m). These patterns align rodent activity, with 0.65 burrows/ha near wildflower strips and 0 near conventional margins. In the field center, rodent activity also approached zero.

In interrow seeding trials, crop damage peaked at 8.4% in 2022 but was nearly undetectable in 2023 and 2024 (0.1 and 0.8%, respectively). Damage was slightly lower in plots wildflower-seeded interrows (3.3%) compared to conventionally managed plots with bare interrows (3.8%). Rodent captures indicated a temporal dynamic, with very low densities of wood mice and field voles in 2022–2023, increasing slightly in 2024 (7.7 animals/100 trap nights). Rodent densities did not differ significantly between interrow treatments.

In conclusion, our firs results suggest that wildflower sowing, whether at along field margins and between crop rows, can be a valuable restoration measure to support biodiversity without increasing the risk of crop damage through rodents. Future research needs to investigate restoration approaches in relation to rodent populations, dynamics, and crop impact.

Eco-Agrivoltaics: Integrating Biodiversity and Related Ecosystem Services into Agrivoltaics

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Given the rapid expansion of agrivoltaics (Agri-PV) installations, there is a timely opportunity to develop ecological design principles. Therefore, we propose eco-agrivoltaics as a framework that integrates biodiversity to enhance related ecosystem services, such as pollination, natural pest control, and soil health. This framework aims to mitigate practical challenges as operators and farmers face arising issues from spontaneous succession under PV modules, the risk of weed proliferation, and shading of PV modules by tall vegetation.

Our framework demonstrates how PV system design and arrangement, vegetation composition, structural habitat diversity, adaptive management, and landscape connectivity can optimize the output of biodiversity-mediated ecosystem services across various agricultural systems. Furthermore, we present promising results of seed-based restoration methods applied under vertical PV modules on arable land. These results reveal significant potential for promoting pollinators but also raise questions regarding their transferability to different Agri-PV system configurations and agricultural settings. Consequently, we outline research needs for shade-adapted plant communities in eco-agrivoltaics.

We present seven key planning parameters for eco-agrivoltaics shaping biodiversity-mediated ecosystem services : (1) climatic context defining ecological feasibility, particularly under climate change, (2) system design influencing microclimatic niches, (3) soil characteristics affecting vegetation establishment, (4) landscape context determining connectivity, (5) ecological infrastructure supporting insect life cycle needs, (6) land use compatibility affecting management options of habitats, and (7) economic and regulatory settings influencing feasibility and acceptance.

Climate protection through dual land use? The effect of solar modules on the restoration of drained peatlands

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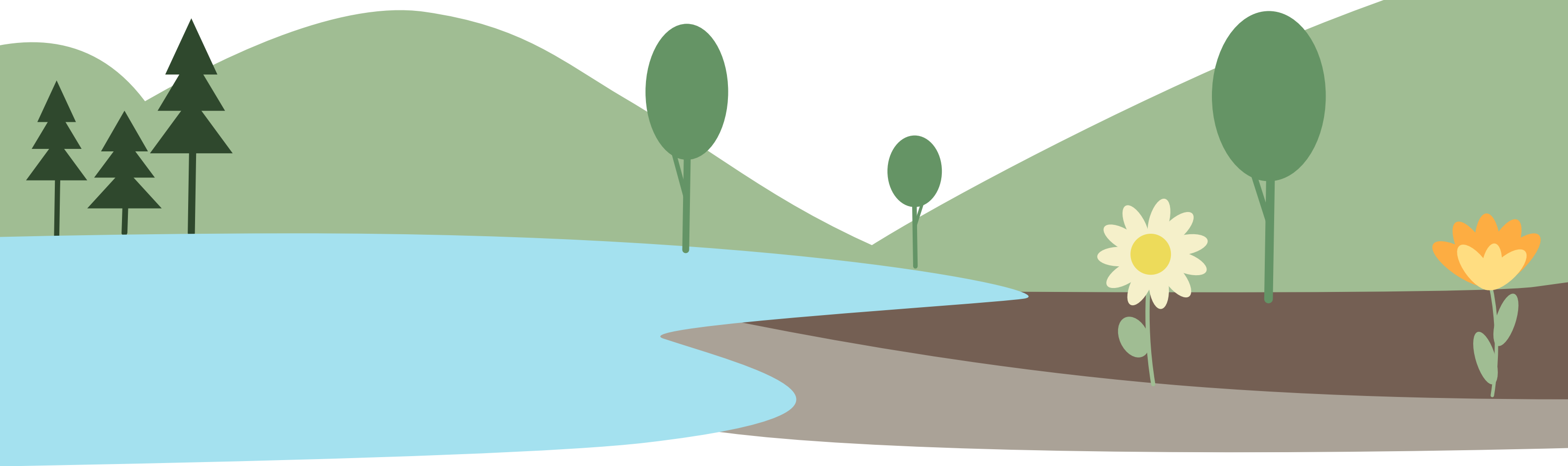
Peatlands cover only 3% of the Earth's surface but store ~30% of global soil carbon. Their carbon storage ability depends on stable, waterlogged conditions that limit decomposition. However, drainage for agriculture and peat extraction has transformed many peatlands into major carbon sources. Hence, rewetting is essential to mitigate GHG emissions, yet it is accompanied by challenges. Restoring a near-surface and stable water table is difficult due to altered soil structure and increased evapotranspiration. Further, re-establishment of key peat-forming *Sphagnum* is hindered due to the altered hydrological conditions and the competition with vascular plants. In addition, the socio-economic perspective has to be considered too, as a major part of drained peatlands are in use for agriculture. Restoring these peatlands to a pristine state would lead to a loss of income, therefore limiting the social acceptance of rewetting programs. Installing photovoltaic systems on rewetted peatlands is one approach to address this conflict.

The aim of this study is to identify the effects of solar modules on the microclimate and the establishment of *Sphagnum*. For that, we extend and apply the process-based LiBry-Model, to simulate the long-term effects of these modules on the challenges of rewetting. With a field experiment in the solar park Lottorf the model will be parametrized and validated. Finally, we run an optimization to determine the optimal size and distribution of modules to maximize both renewable energy and rewetting success.

First results show that the water tables under the modules fluctuate less and that surface temperatures are lower during hot days. Both could be beneficial for *Sphagnum* re-establishment and is supported by an increased biomass gain of *Sphagnum spp*. under the modules, despite reduced light availability. This indicates that, in addition to their socio-economic benefits, solar modules may also have positive effects on other facets of peatland rewetting.

Session 21

Novel methods in monitoring



Balancing birds and beef: examining sustainable land use in Australia

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Australia supports a rich avifauna of over 850 species; nearly half of which are endemic. Many of these species face threats from land-use pressures, notably domestic livestock grazing, which spans 43% (3.3 million km2) of the continent and contributes substantially to land degradation. Grazing impacts on birds are highly variable and influenced by stocking rate, vegetation, grazer species, and grazing regime. Ground nesting and foraging birds are often presumed to decline within increasing grazing intensities (i.e., stocking rate), yet empirical evidence remains limited. As global demand for meat is projected to rise 70% by 2050, identifying optimal grazing intensities that support avian conservation is urgent. Here, we deployed time-lapse camera traps at 30 waterpoints over two years, combined with semi-automated AI image recognition, to continuously monitor avian activity across a gradient of cattle grazing intensities. Generalised linear mixed models revealed ground-nesting bird abundance – including the nationally threatened squatter pigeon (Geophaps scripta scripta) – was highest at sites with intermediate to high cattle grazing intensities, irrespective of environmental factors in remnant habitat. Seasonal fluctuations in squatter pigeon presence were also positively correlated with cattle grazing pressure. These findings suggest that balancing intermediate cattle grazing intensities and squatter pigeon conservation is feasible under sustainable management practices.

A Trait-Based Comparison of AudioMoth Passive Acoustic Monitoring and Point Counts for Bird Community Detection in Agricultural Landscapes

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Agricultural intensification negatively impacts farmland birds, making effective monitoring crucial for evaluating mitigation strategies such as Agri-Environment Schemes (AES). Traditional Point Counts have limitations including observer bias, temporal coverage, and potential disturbance. In comparison, Passive Acoustic Monitoring (PAM) by AudioMoths offers standardized data but requires validation and understanding potential trait-mediated detection biases. We conducted a trait-based comparison of Point Counts and PAM effectiveness for bird community assessment in agricultural landscapes. During the breeding season 2024, we performed bird observations using a paired design across 11 AES sites with no pesticide use vs. conventionally managed winter wheat sites in Saxony-Anhalt, Germany. We concurrently performed standardized 5-min Point Counts throughout three visits and deployed AudioMoths. PAM data and Point Counts surveys were processed using BirdNET with a species-specific filtering pipeline. We compared differences in community composition and identified key species traits (e.g., hand-wing-index, habitat) and environmental factors (e.g., landscape diversity, management). Preliminary results indicate notable differences: PAM detected higher species richness per site, whereas Point Counts uniquely identified certain species. Community composition also differed significantly between methods. Multivariate analyses revealed that detection differences were significantly influenced by the species' Hand-Wing Index (HWI), with PAM demonstrating enhanced detection of species with higher dispersal capability. These findings confirm PAM's strength in detecting a broader species pool but underscore the complementarity of the methods. Understanding these complex, trait-mediated nuances and environmental interactions is crucial for optimizing monitoring protocols and developing robust ecological indicators for farmland bird conservation.

Acoustic Indices Predict Bird Community Recovery in Tropical Forest Restoration

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Tropical forests are still increasingly threatened by deforestation and degradation, with severe consequences for carbon storage, climate regulation and biodiversity. In response, the United Nations has declared the Decade on Ecosystem Restoration, which has triggered a global wave of restoration initiatives. Yet, monitoring the effectiveness of these efforts, particularly in terms of biodiversity recovery, remains a major challenge. Traditional expert-based biodiversity assessments, while accurate and granular, are often resource-intensive and difficult to scale.

We present a new approach that integrates expert-annotated bird community data with acoustic indices derived from passive acoustic monitoring. Our study was conducted in Canandé, a lowland tropical forest region and biodiversity hotspot in northwestern Ecuador. We analyzed 2380 two-minute audio recordings and calculated five well-established acoustic indices that capture key aspects of the acoustic environment. A stratified subset of the recordings was manually annotated by ornithologists, who identified 334 bird species. The community composition was assessed by considering different frequency distributions and controlling for incomplete sampling.

We found that acoustic indices reliably predicted bird community shifts along a recovery gradient, spanning pastures, cacao plantations, regenerating forest, and old-growth forest. Importantly, the indices captured not only taxonomic but also functional and phylogenetic diversity, including both rare and dominant species. These findings highlight the potential of acoustic indices – once validated by stratified ground-truth data – as a cost-effective, scalable tool for monitoring ecological restoration and biodiversity recovery over large tropical areas, capturing even the functional composition of rare tropical birds.

Wind energy and roding activity of the European Woodcock: an acoustic monitoring approach

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Wind energy is vital for reducing carbon emissions, yet its installation in forests poses challenges for species like the European Woodcock (*Scolopax rusticola*). It is a nocturnal forest bird that performs roding flights at twilight to mark territories and attract mates. Despite evidence suggesting potential impacts on the species, details regarding the effects of wind energy in forests on the habitat use of Woodcocks remain unclear. We compared the vocal activity of Woodcocks at 15 windfarms scattered throughout Hessen, Germany. We used passive acoustic monitoring in a paired design, with control sites, situated 3 km from active wind turbines. We recorded for three hours at dawn and dusk over ten days in June 2023 during the peak of roding activity. We validated presumed Woodcock matches by BirdNET to assess precision for the species accompanied by a stratified screening to estimate recall rates. We compared true vs. false positive BirdNET hits in relation to the twilight periods during dawn and dusk respectively. We also compared the presence of Woodcocks as well as their continuity throughout the recording period, separately for dusk and dawn. We found that the Woodcocks' roding activity was confined by darkness and by the vocal activity of other species (mainly Thrushes), which during the morning/evening chorus partially overlapped with the acoustic niche of the Woodcocks. Detection probabilities of BirdNET were not affected by differences in soundscapes with and without windfarm instalments. Likewise, species' presence did not change between windfarm and control sites. However, we found that roding activity of Woodcocks was significantly reduced at wind power sites by around 59% (95%CI = 40%-75%). We discuss our findings with regards to environmental management of the species for windpower planning and the use of passive acoustic monitoring for elusive species.

Microclimate and Seasonal Dynamics of Bird Communities in Temperate Forests: Insights from Acoustic Monitoring

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Bird diversity and community composition in temperate forests are well studied during the breeding season, but much less so at other times of the year. To inform management that support birds throughout the year, it is important to understand which environmental variables influence bird diversity and community composition in different seasons, and how their importance may shift over time. In addition to variables related to vegetation structure, our study places a strong emphasis on microclimate, specifically air temperature, relative humidity, and light intensity.

While previous research has identified species-specific effects of microclimate on birds, there is limited knowledge on how these relationships vary across seasons at the daily scale. We conducted a study at 20 forest sites around Jena, Thuringia, in spring, summer, autumn, and winter 2024. Bird data were collected using passive acoustic monitoring with AudioMoths, and species were identified using the BirdNET software. We are examining the effects of abiotic and biotic factors, including vegetation structure and daily microclimate data, on birds. Our analysis focuses on both seasonal patterns and how these relationships change between seasons.

We hope our findings will contribute to a better understanding of the seasonal drivers of bird communities and provide insights into how microclimate influences birds throughout the year, which is especially relevant in the context of climate change.

Rare bird species exhibit greater post-disturbance specialisation compared to sympatric common species

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Understanding faunal responses to disturbance is a core component of disturbance ecology. This understanding is often achieved by collecting and analysing faunal occurrence data across vegetation that varies in post-disturbance age, allowing ecologists to investigate the ecological role of disturbance and predict the ecological impact of future disturbances. Rare species are often excluded from such analyses due to insufficient data. In such cases, results are reported for more common species and presented as the best information available on the effect of disturbance on fauna in that ecosystem. However, what if the disturbance responses of common species are not representative of the disturbance responses of rare species? We tested whether the fire responses of rare bird species were distinct from those of common species in a 670,000-ha reserve network in a fire-prone part of south-eastern Australia. For common species, we used published fire responses of 20 bird species, based on 125 x 2-ha sampling sites (total: 250-ha; 227-hrs). For rare species, we increased our sampling to 413 x 25-ha sites (total: 10,325-ha; 1,652-hrs), targeting seven threatened species that were excluded from analysis in the initial study due to insufficient data. Both studies sampled the same 70-yr post-fire chronosequence in the same region. Using Generalised Additive Models, we found that most common species preferred late successional vegetation or had a null response to fire (80%). By contrast, most rare species (86%) preferred early or mid-successional vegetation. Rare species also had narrower post-fire time-windows of occurrence, making them more susceptible to the impacts of altered fire regimes. Our results indicate that the disturbance responses of common species do not represent those of rare species, which have greater specialisation. We highlight the systematic ways in which common sampling strategies exclude rare and specialist species and how such biases can misrepresent the post- disturbance needs of faunal communities.

Evaluation of the use of detection dogs for reptile surveys – wildlife detection dogs versus traditional transect surveys

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The use of dogs to detect cryptic species has increased over the past decade. However, for many species, there is insufficient data on detection accuracy. This is the main reason why the detection of reptiles using dogs is not yet a generally accepted method in planning projects and monitoring. The aim of this study was therefore to investigate the accuracy of wildlife detection dogs in detecting sand lizards (Lacerta agilis) under various conditions. In addition to the suitability of molts and swab samples for use as odor samples, the detectability of various target odors was investigated depending on their age and their differentiability from other reptile species. Furthermore, the extent to which the depth of odor samples in the substrate can influence the detection probability was tested. For this purpose, various experimental approaches were conducted in the field under controlled conditions in 2023 and 2024. A total of eleven dog teams participated in the experiments. The results showed that the wildlife detection dogs were capable of detecting both swab and molt samples. Although swab samples hidden beneath track ballast were less likely to be detected by the dogs, the sensitivity did not decrease with increasing hiding depth, so that samples were still found with a 74% probability even at a depth of 80 cm beneath the track ballast. The dogs were also able to distinguish swab samples from different reptile species native to Germany with a high sensitivity of 96% and were both more effective and efficient in the field compared to experienced persons.

Overall, the study shows that the use of trained dogs is a valuable addition, as they make previously inaccessible data available for planning and monitoring projects, independent of the reptiles' daily and weather-related activity patterns.

Development of a standardised method for recording raccoon distribution in Northrine-Westphalia (NRW)

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The impact of neozoa on biodiversity is currently one of the greatest challenges in conservation biology. The German Federal Agency for Nature Conservation also sees a need for action regarding alien species, as these can lead to changes in the functional processes of ecosystems. However, in order to assess neozoa's actual impact on ecosystems and possible threats to them, more precise knowledge of their distribution and the establishment and optimisation of monitoring measures are required in order to be able to assess the population development of these species and the resulting consequences.

The raccoon (*Procyon lotor*) has recently been the centre of public attention. As a hemerophile, it often lives in close proximity to humans. At the same time, as a potential predator of birds and amphibians, among others, it is seen as a threat to biodiversity and is perceived ambivalently as adorable by large sections of the population due to its appearance and behaviour.

In order to be able to better assess the ecological impact of raccoons in the future, a standardised method for recording their distribution is to be developed. The method is currently in the stage of development and trial for the raccoon population in NRW. Central elements of the method are the inclusion of citizen science data, the examination of points selected on the basis of raccoon-specific ecological criteria for traces and eDNA as well as other indications for raccoon presence.

The aim is to improve the utilisation of citizen science data in particular when assessing the distribution. This should enable us to better assess the dispersal potential and the local ecological impact of the raccoon in the future.

The scientific concept for a National Biodiversity Monitoring of Forests (NaBioWald) in Germany

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Monitoring forest biodiversity, its changes and dynamics is the aim of the NaBioWald initiative. It is the result of a perennial process by a group of people from institutions working on forests and nature conservation, universities and additional experts for specific topics. During this process six species groups (vascular plants, bryophytes and lichens, birds, bats, insects and spiders, and soil organisms) were selected and addressed. In addition, genetic studies on intraspecific variation of five vascular plant and insect species were suggested. Drivers of biodiversity such as the intensity of forest management, and indicators for climate change, air pollution and pesticides complement the data selection.

The concept combines existing forest and nature conservation surveys with new elements to build a cost-efficient monitoring system; enabling detailed analyses on the relationships between diversity of species groups and drivers. This aims at gaining comprehensive information at different spatial and temporal scales.

Understanding regional biodiversity variation: combining Citizen Science and professional monitoring for better data coverage

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Monitoring programs covering large spatial and temporal scales provide valuable data on species occurrences. However, designing and implementing such programs is resource-intensive, and historical data cannot be retroactively collected once a reliable and structured monitoring program is initiated. Citizen science initiatives, in particular, can yield large-scale data across space and time, offering unique insights into species occurrences.

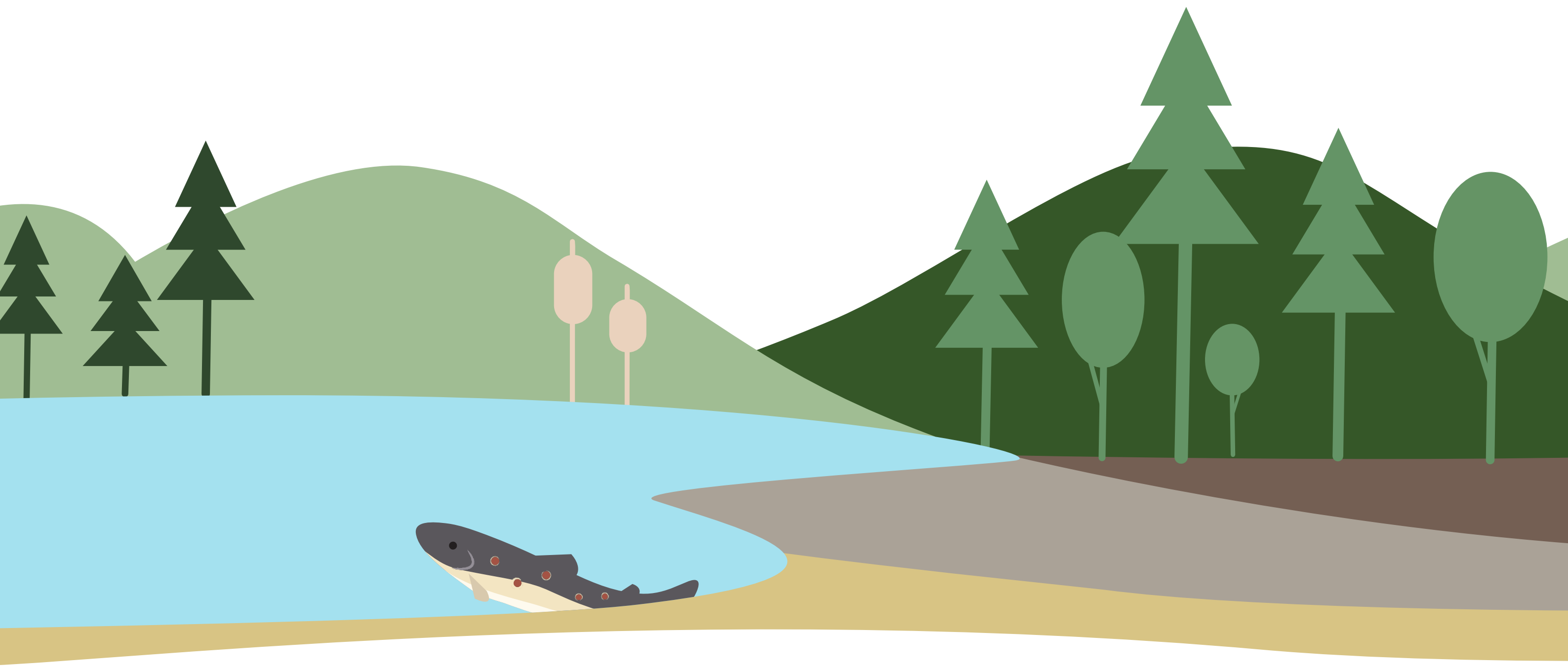
However, these data aren't without their shortcomings. Citizen science observations tend to cluster in areas where people live or travel, and seasonal patterns may cause certain species to be missed entirely. While statistical methods can correct for some of these issues, a good understanding of data quality and coverage remain critical for robust results.

A promising approach is to combine citizen science data with structured, professional monitoring. Guided by the gaps left by citizen observations, professionals can be strategically deployed in a resource-efficient way to under-sampled regions or time periods.

In this study, we analyse insect occurrence records collected over the past 40 years in a typical Central European region, based on a state-owned dataset that integrates both citizen science contributions and various state-organized monitoring programs. We investigate observations to identify spatial and temporal gaps in citizen science data that could be addressed through targeted professional efforts. We also compare the citizen scientists' records with existing professional datasets to assess whether some gaps have already been filled and where they remain. This assessment of monitoring efforts can offer valuable guidance for optimizing current and future biodiversity monitoring in a resource-efficient manner.

Session 22

Multi-trophic interactions under stress



Multitrophic interaction networks mediate biodiversity effects on ecosystem multifunctionality

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Biodiversity loss threatens the multifunctionality of ecosystems on which human well-being ultimately depends. Although beneficial effects of biodiversity on ecosystem functions have been widely documented across ecosystems and trophic levels, we still lack a comprehensive mechanistic understanding of the underlying forces. Multitrophic species interactions are key to predicting real-world consequences of biodiversity loss. However, studies explicitly linking species interactions and ecosystem multifunctionality remain rare and limited to few types of interactions, making generalizations on the mechanistic role of multitrophic species interactions difficult. Using comprehensive species interaction and ecosystem functionality data from a large-scale tree biodiversity experiment, we show that the structure of species interaction networks is a crucial driver of ecosystem multifunctionality across multiple types of antagonistic and mutualistic interactions. While positive effects of network size align with positive effects of multitrophic species diversity, the positive effects of niche overlap and negative effects of linkage density reveal additional, interaction-mediated drivers of multifunctionality. Specifically, niche overlap suggests benefits of functionally similar species, and linkage density underscores the importance of specialized interactions. These findings emphasize that to effectively safeguard ecosystem service provisioning, ecosystem management and biodiversity conservation need to explicitly account for species interactions across all trophic levels.

Tree diversity drives and stabilizes parasitism via bottom-up trophic pathways during early forest succession

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Plant diversity affects the functioning of ecosystem processes via bottom-up effects that propagate across trophic interactions. Yet, little is known about how diversity effects shape ecosystem functioning and stability at higher trophic levels as plant communities undergo succession. We investigated temporal dynamics of biodiversity-ecosystem functioning (BEF) relationships using a decade-long multitrophic dataset from a young regenerating experimental forest in southeast China. From 2014 to 2023, we monitored cavity-nesting bees and wasps and their natural enemies to assess the effects of tree, host, and parasitoid diversity on a key ecosystem function (parasitism) and its temporal variability during forest succession. We found that tree diversity had a positive and stabilizing effect on parasitism rates, mediated by functional diversity and accumulated stand volume that enhanced host and parasitoid diversity and stability over time. Moreover, tree diversity, stand volume, and age moderated the strength of trophic pathways themselves. That is, forest stand characteristics shaped parasitism not only by structuring host and parasitoid diversity, but also by modulating how these diversity patterns contributed to ecosystem functioning over time. As forests aged, tree diversity emerged as the key moderator of trophic interactions, suggesting a transition from biomass- and abundance-based regulation to diversity-driven mechanisms. Our results underscore the dynamic nature of biodiversity-ecosystem functioning relationships during forest succession. We show how the influence of tree diversity on multi-trophic diversity and ecosystem functioning strengthens as forest mature, highlighting the growing role of biodiversity in sustaining and stabilizing ecological processes through time.

Interactive effects of tree diversity, tree identity and management on generalist predator taxonomic and functional diversity

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Stand diversification increases structural and resource diversity, which can benefit multitrophic diversity and ecosystem functioning. However, for higher trophic level organisms such as spiders, tree diversity effects are ambiguous. Instead, tree species composition seems more relevant, especially in species-poor forests. Spiders might also benefit from management interventions directly targeting stand structure, but such interventions have rarely been studied together with the effects of tree diversity and identity.

In a temperate tree diversity experiment (BIOTREE-SPECIES) comprising four economically and ecologically relevant species (European beech, sessile oak, Norway spruce, and Douglas fir) we studied effects of tree phylogenetic and taxonomic diversity, tree identity, recent management (thinning with deadwood retention), and their interactions on epigeal spider activity density, taxonomic and functional diversity.

In our study, tree diversity had no direct effects on spider diversity. Instead, spiders in monocultures benefited the most from management, and some tree identity effects were only apparent in monocultures. Furthermore, tree species identity was a key driver: Sessile oak promoted spider activity density, while Norway spruce promoted diversity, likely due to differences in stand structure.

By comparing our study to results from sites of varying ages, we conclude that tree identity effects change with stand structural development. Thus, predators can benefit from tree species mixtures even in the absence of direct tree diversity effects, as mixtures can temper temporary negative tree identity effects. Considering the interplay of tree diversity, identity and forest management makes research from experimental (mixed) stands more transferable to real-world plantations. Concomitantly, our results urge for research on the temporal dynamics of this interplay for multiple taxa to provide a basis for sustainable forestry and ecosystem restoration.

Species-habitat networks reveal key habitats for landscape-level wild bee conservation

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Agricultural landscapes consist of multiple habitat types, but most studies focus on single habitats, overlooking species' use of resources across habitats. Species-habitat networks offer a promising approach to understand biodiversity loss, yet their structure and robustness to habitat loss remain understudied. Here we studied the structure and robustness of bee-habitat networks in agricultural landscapes of Southern Germany. We built these networks based on data from grid-based sampling covering all 224 locations across arable land, grassland, forest, and orchards. Orchards hosted more wild bees than expected purely from their proportional area in the landscapes. Particularly oligolectic (i.e., specialized) bees favored orchards, underlining their importance as extensively managed yet threatened habitat. Forests supported fewer species, and more social than solitary bees. Landscape diversity shaped the structure and robustness of bee-habitat networks to simulated habitat loss: Networks in more diverse landscapes exhibited higher modularity but tended to be less robust to habitat loss, indicating that landscape diversity and network modularity do not necessarily buffer against biodiversity decline. In summary, our study emphasises the value of species-habitat networks to identify key habitats and the importance of landscape diversity for species conservation. Traditional orchards are crucial for wild bee diversity, but all habitat types harbour a similar proportion of endangered species. Therefore, maintaining a diversity of habitats is essential. Effective conservation measures need to focus on landscape diversity and incorporate different, complementary habitats, including both extensively and intensively managed areas.

Multisensory pollution in multitrophic communities

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Industrial and agricultural activities introduce subtle disturbances, such as vibrations, noise, and synthetic scents, that alter the sensory landscape surrounding animals, plants and microbes. Unlike other threats such as habitat loss or pollution, these multisensory pollutants interfere with how organisms detect essential cues for communication, foraging, mating, and predator avoidance, impairing behavior without causing immediate physical harm or habitat destruction. To move beyond anecdotal evidence from natural ecosystems, we developed a systematic predator-prey model that incorporates the role of information flow and its disruption by sensory pollution for the prey detection and identification probabilities of predators. While fitting empirical data as well as existing models, it offers a novel explanation for the dynamically important shifts between type II and type III functional responses. Analyses of multi-trophic, complex food webs, including these information-based functional responses to model the strength of interactions, show systematic effects of sensory pollution on population dynamics. Ultimately, sensory pollution decreases the efficiency of predatory attack rates and thus limits their energy supply. Our simulations further reveal that sensory pollution disproportionately threatens species occupying higher trophic levels, endangering both biodiversity and ecosystem functioning. Together, these results not only reinforce empirical evidence that multisensory pollution poses a serious threat to natural ecosystems, but also highlight the need for more systematic studies that integrate multiple sensory pollutants and span populations across trophic levels.

Synergistic effects of climate warming and light pollution on trophic communities

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Climate warming and light pollution are among the most widespread and intensifying global change drivers, yet their combined effects on the dynamics and stability of multi-trophic communities remain poorly understood. Diurnal and crepuscular animals have been shown to adjust their diel activity patterns in response to light pollution to reduce competition or exploit the nocturnal niche. These shifts alter encounter rates and interaction strengths between predators and their prey, with far-reaching consequences for trophic interactions in ecological networks. Simultaneously, climate warming increases overall activity in ectotherms while also generally shifting activity patterns toward cooler periods, such as dusk and dawn. This overlap in behavioral responses suggests that warming and light pollution may interact in complex, non-additive ways. In this study, we model complex food web dynamics, spanning multiple trophic levels, across gradients of light pollution and temperature, incorporating empirically-derived effects on key biological processes, such as metabolism and activity patterns. We show that these interacting pressures influence community persistence and ecosystem functioning, highlighting potential risks to biodiversity and network stability under global change.

Assessing the effects of ozone pollution on a plant-aphid-hoverfly tritrophic interaction

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Tropospheric ozone pollution has been shown to affect plants, insects and the interactions between them. Aphids are important agricultural pests, and predatory hoverflies—such as the marmalade hoverfly—are considered effective biological control agents. Ozone can alter plant chemistry, including the nutritional quality and secondary metabolite profile, potentially affecting organisms at higher trophic levels. This study investigates whether ozone pollution affects the tritrophic interaction among broad bean plants (*Vicia faba*), black bean aphids (*Aphis fabae*), and the marmalade hoverfly (*Episyrphus balteatus*). Aphid-infested plants were exposed to two different ozone concentrations under controlled conditions. Aphid colony development, adult hoverfly oviposition preferences, and the survival and development of hoverfly offspring from egg to adult emergence are assessed.

Holo-omics disentangle drought response and biotic interactions among plant, endophyte and pathogen

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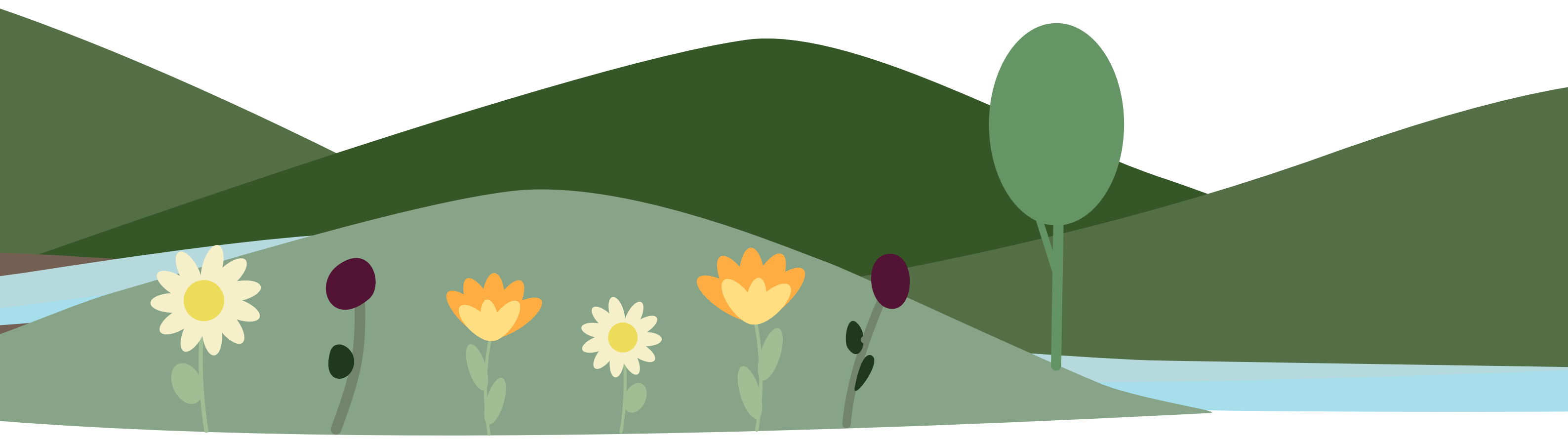
Holo-omics provide a novel opportunity to study the interactions among fungi from different functional guilds in host plants in field conditions. We address the entangled responses of plant pathogenic and endophytic fungi associated with sorghum when droughted through the assembly of the most abundant fungal, endophyte genome from rhizospheric metagenomic sequences followed by a comparison of its metatranscriptome with the host plant metabolome and transcriptome. The rise in relative abundance of endophytic Acremonium persicinum (operational taxonomic unit 5 (OTU5)) in drought co-occurs with a rise in fungal membrane dynamics and plant metabolites, led by ethanolamine, a key phospholipid membrane component. The negative association between endophytic A. persicinum (OTU5) and plant pathogenic fungi co-occurs with a rise in expression of the endophyte's biosynthetic gene clusters coding for secondary compounds. Endophytic A. persicinum (OTU5) and plant pathogenic fungi are negatively associated under preflowering drought but not under postflowering drought, likely a consequence of variation in fungal fitness responses to changes in the availability of water and niche space caused by plant maturation over the growing season. Our findings suggest that the dynamic biotic interactions among host, beneficial and harmful microbiota in a changing environment can be disentangled by a blending of field observation, laboratory validation, holo-omics and ecological modelling.

Session 23

Plant phenology



Relationships between phenological events, growth phenology and functional traits throughout the season - a case study with 29 perennial herbaceous species

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The seasonal dynamics of plant development and reproduction processes and their changes have recently been studied frequently. It has been shown that knowing the timing of important phenological events (such as leaf unfolding or the first day of flowering) and growth phenology is crucial for understanding the dynamic processes of plant growth during the season in a temperate climate. However, little is known about the connection between the timing of phenological events and growth rate and how plant leaf traits shape this.

Here, we explore the relationship between phenological events and growth rate and its association with functional leaf traits for 29 perennial herbaceous species in the botanical garden of the Friedrich-Schiller-University in Jena on the basis of weekly phenological observations, fortnightly growth measurements, and functional trait recordings six times throughout the growing season 2020.

The results show that the timing of growth (early vs. late species) and growth rate are independent dimensions. Later species necessarily have lower absolute growth rates, but the standardized growth rate is almost independent of these. Further, the final volume of the plant foliage was a particularly important predictor for generative phenological events. Most importantly, we show how the correlation between growth rate and specific leaf area, which is often used as a proxy for growth rate, changed across six measurements in the season with phenology from a positive to a negative relationship.

Our work contributes to a better understanding of the connections within and between phenological events, growth rate and leaf functional traits. For the first time, we showed the relationship dynamics between growth rate and leaf traits throughout the season. Therefore, further research is needed to identify whether and how this leads to changes in species abundances and competitive hierarchies, with consequences for biodiversity and ecosystem functioning.

Plant Phenological Responses to Climate Change in Mongolia: A Long-Term Study in Hustai National Park

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Mongolia is increasingly impacted by climate change, namely rising average temperatures and altered precipitation patterns. Plant phenology, which is highly sensitive to these climatic factors, serves as an important indicator of ecological responses to climate change. While remote sensing studies have shown a lengthening of the growing season marked by earlier onset and later end dates, species-specific phenological responses in Mongolia remain largely unstudied.

To address this gap, we conducted a 12-year long-term study in Hustai National Park, monitoring plant phenology in seven focal plant species on seven sites. In addition to analysing how changes in temperature and precipitation affect plant phenology, we measure plant functional traits - canopy height, plant width, individual aboveground biomass, chlorophyll fluorescence and specific leaf area - over two consecutive years, to assess their influence on phenological patterns as well.

While data analysis is still ongoing, preliminary results indicate an earlier start and later end of growth in most species, indicating an overall extension of the growing season. In contrast, flowering onset does not change signigicantly over time while the end of flowering is advanced. At the same time, spring temperatures tend to increase while spring precipitation decreases. In contrast, summer temperatures remain stable, but summer precipitation shows an increasing trend. While final analyses still have to be conducted, initial results suggest that temperature, rather than precipitation, is the primary driver of the onset of the growing season.

The final results of this study will give insights into which climatic drivers mainly impact plant phenology in Mongolian steppe ecosystems and to what extent. Furthermore, the study will show to which degree functional traits determine species-specific phenological responses to changing climatic conditions.

Space-for-Time substitution to study phenological shifts in herbaceous species is most reliable for early-flowering species

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Phenological events in plants are shifting worldwide due to climate change. By studying long-term shifts of phenological events in plants using historical data records, scientists gain a deeper understanding of potential further changes. However, conducting such Time-for-Time Substitutions (TFTS) remains sparse due to limited availability of long-term data. An alternative method is the Space-for-Time substitution (SFTS), in which the temporal gradient is reflected by a spatial gradient.

For this study, we used historical phenological records of 17 herbaceous species from botanical gardens in Vienna covering a period of 150 years and data from 11 botanical gardens covering a large spatial gradient to test the space-time equivalence. This is necessary to ensure that SFTS are applied reliably. We fitted a linear-mixed effect model to test for differences between the two approaches while analysing the associations between annual flowering onset dates and temperature. Additionally, we used a meta-analytical approach to examine species-specific suitability of SFTS in regard of the species' temporal niches.

We showed that the space-time equivalence is fulfilled for the present species and spatial gradient and found that for both approaches, flowering was advanced by 7 days when the temperature increased by 1°C. On the species level, however, we found that the known connection that early-flowering species are more temperature-sensitive cannot be confirmed for the SFTS dataset. Furthermore, the space-time equivalence is better fulfilled for early-flowering species than for late-flowering ones.

This study contributes significantly to phenological research, as it demonstrated that SFTS can be generally applied for herbaceous species monitored in botanical gardens. However, this method should always be used with caution for species-specific questions. In addition, it still remains unclear to what extent the patterns found can be confirmed in less-controlled habitats.

Effects of pre-industrial, ambient and future CO2 concentrations on interactions between plants, pollinators, herbivores, and the microbiome

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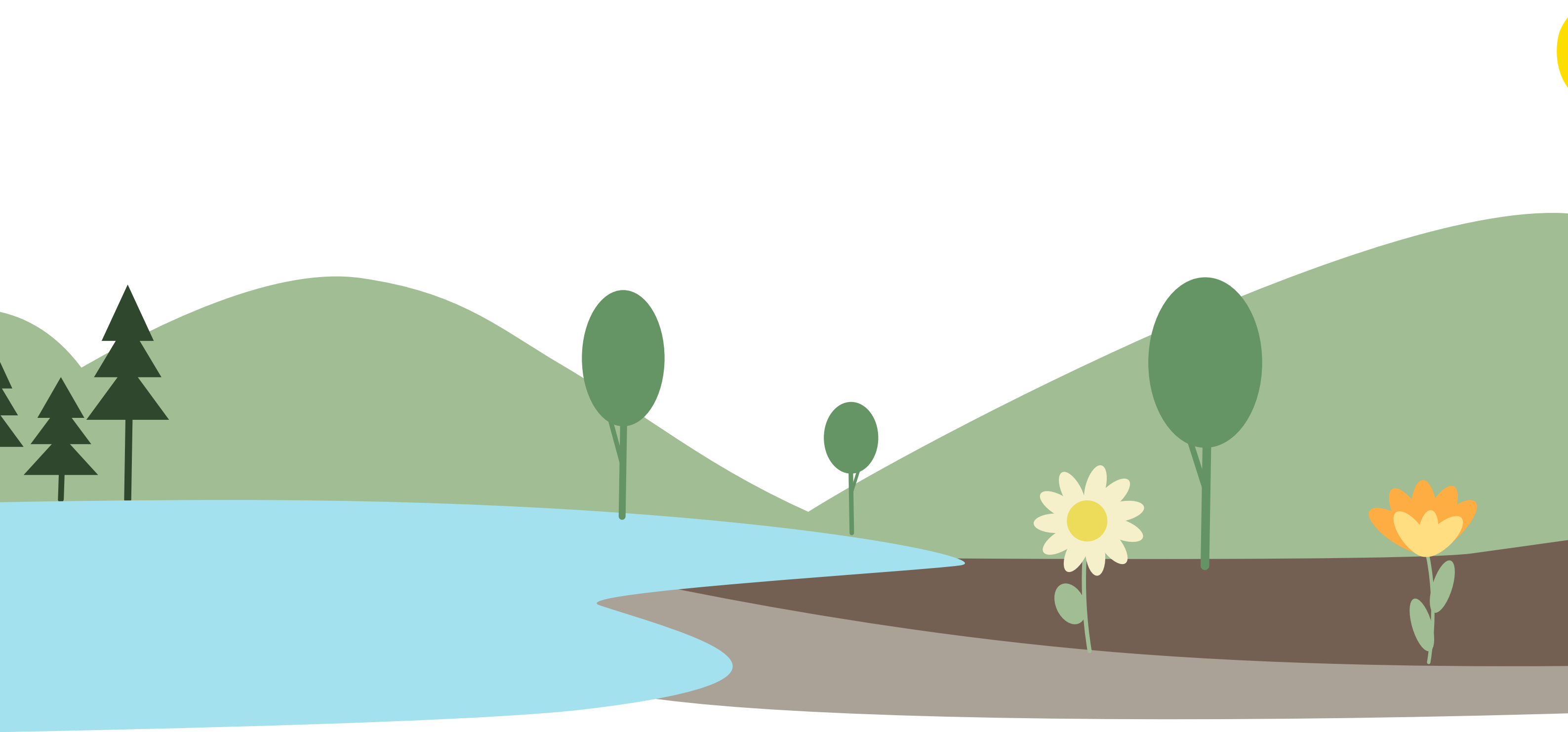
Global change threatens biodiversity and ecosystem functions, as demonstrated by numerous experimental studies simulating future environmental conditions. While biodiversity loss in plants and animals is regularly assessed, and conservation efforts often focus on these groups, our understanding of how anthropogenic disturbances affect interspecies interactions remains limited. Microbial communities, in particular, are still largely overlooked, leaving critical gaps in our understanding of microbiomes as key components of biodiversity. Furthermore, most experimental studies use current ambient conditions as a control, thereby failing to account for the extent of historical global change. To address these limitations, we are experimentally manipulating CO_2 and nutrient availability to simulate pre-industrial, ambient, and projected future environmental scenarios. We assess their effects on germination, plant physiology, floral reward traits, and reproductive success. Preliminary results suggest that elevated CO_2 affects some plant features and phenology. We also observed a combined effect of elevated CO_2 and nutrient availability. These environmental changes are likely to influence key biotic interactions and the composition of plant-associated microbiomes. The influence of CO_2 and nutrients is currently being tested in the context of ecological interactions, including plant–pollinator and plant–herbivore dynamics, herbivore performance, and microbiome shifts. We expect that changes in CO_2 and nutrient levels will alter floral traits, the quantity and quality of nectar and pollen, and plant defensive chemistry, with cascading effects on ecological networks.

Session 24

Plant traits



Global Change Factors differentially impact Floral and Leaf Economic Traits

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Since the Industrial Revolution, rising atmospheric CO_2 levels, increased temperatures, and frequent droughts have significantly impacted natural ecosystems. While many studies have analyzed the effects of these factors on plant functional traits, reproductive traits remain understudied, although they play a crucial role in the diversification and distribution of flowering plants globally. Using long-term (10 years) climate manipulation experiment, we examined how elevated CO_2, warming, and drought and their interactions influence floral and leaf traits of two grassland perennial herbs, *Lotus corniculatus* and *Crepis capillaris*. We also explored the level of trait coordination under different climatic conditions. The resource economics traits analyzed included traits relating to size, construction cost and dry matter content of leaves and flowers, as well as seed size and number. Our results indicate that floral traits, like leaf traits, exhibit trade-offs among themselves but are largely independent (orthogonal) of leaf traits. Trait responses to global change factors were inconsistent across species, with drought being the dominant factor affecting leaf traits in *L. corniculatus* and both floral and leaf traits in *C. capillaris*. Extreme global change conditions led to stronger trait coordination in *L. corniculatus*, while *C. capillaris* showed less coordination. Overall, our findings reveal that similarly to leaf economic traits, floral economic traits are also sensitive to individual and combined effects of global change factors. This highlights their importance in plant responses to environmental change and the need for better integration of floral economics into the whole-plant economic spectrum.

Are annual plants escaping the root economics space? Root functional traits in the annual model grass Brachypodium hybridum under increasing aridity

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Root traits play a central role in plant adaptation to drought as they are responsible for the uptake of water and nutrients. The theory of optimal resource partitioning predicts that root growth and subsequent belowground biomass production and root:shoot-ratio should increase when water is limited. However, intraspecific studies in annual plants reveal contrasting results in root biomass allocation, including the opposite pattern along aridity gradients, suggesting a conservative instead of an acquisitive strategy. Thus, intraspecific patterns in root investment may not be straightforward and need clarification.

Following the root economics space framework, we tested whether trade-offs in root system architecture, mycorrhizal colonization or root ontogeny influence root morphology from becoming more conservative instead of acquisitive in *Brachypodium hybridum,* an annual grass abundant in Mediterranean ecosystems.

For this reason, we collected seeds of 15 ecotypes of *B. hybridum* along a natural aridity gradient and corresponding north- and south-facing slopes in Israel. We grew them in a greenhouse under standard conditions to measure key traits of the root economics space and other relevant belowground traits. We hypothesized that arid ecotypes show a more conserving strategy under harsher conditions, i.e. towards the drier end of the gradient, with drought treatment, on south-facing slopes within sites and, in addition, harvested plants at three ontogenetic stages, hypothesizing that ecotypes switch from being acquisitive to conservative during their life cycle.

Preliminary results revealed that in the juvenile stage, plant roots have higher root diameter and reduced SLA with drought treatment, suggesting a plastic response and, eventually, an outsourcing of root functions to mycorrhizal fungi under higher aridity.

Tracing Drivers of Autumn Phenology: The Combined Effects of Climate, Soil, Leaf Unfolding, Stand Structure, and Topography on the Leaf Colouring of Temperate Trees

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Climate-driven shifts in leaf unfolding and leaf colouring in temperate trees impact key ecosystem processes and the terrestrial carbon cycle. While leaf unfolding is relatively well understood, the environmental drivers of leaf colouring are understudied and therefore poorly understood. Here, we assess how temperature, drought, soil characteristics, stand structure, topography, and the timing of leaf unfolding jointly affect the day of year of leaf colouring in mature beech, larch and lime across a large environmental gradient.

Using species-specific linear mixed-effects models and variable importance metrics, we show that growing degree days, climatic water balance, and the timing of leaf unfolding are highly important drivers of leaf colouring across species. High growing degree days, late leaf unfolding and high climatic water balance had delaying effects across species. Notably, climatic water balance exhibited the largest species-specific effects, particularly for larch, where interactions with available water capacity substantially shifted the effect of climatic water balance. Elevation and tree height showed moderate to limited importance depending on species, whereas topographic and stand structure parameters were consistently of low relevance.

Interestingly, cooling degree days — often used as a proxy for low temperatures in autumn — were not retained in any well-performing models, suggesting they may be of limited value when growing degree days and other variables are appropriately considered. This tentative result challenges common assumptions in phenological modelling of leaf colouring and highlights the need for further investigation.

Our findings underscore the importance of considering environmental factors beyond temperature — most notably drought, soil characteristics and phenological legacy effects — to avoid confounding and to robustly predict autumn phenology. This comprehensive approach reveals species-specific sensitivities and enhances the predictive accuracy of phenological models, with implications for modelling carbon uptake in temperate forests and other ecosystem processes.

LeafComplexR: A Spectral Entropy Framework for Quantifying Leaf Shape Complexity in Functional Ecology and Species Discrimination

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The complexity of a leaf's shape has a significant impact on its ecological and physiological processes as well abiotic interactions such as herbivory. However, traditional morphometric measures do not capture the subtle variations in these shapes that are critical to the functional responses of species and individuals. Here we present LeafComplexR, a novel framework for accurately quantifying leaf shape complexity from images based on spectral entropy. Our approach introduces a linearization approach and two highly complementary shape metrics: Leaf Macro Complexity (LMC) and Leaf Edge Complexity (LEC), designed to effectively distinguish between the overall shape structure and the fine-scale edge features, respectively.

We exemplify the capabilities of LeafComplexR with two case studies. Firstly, to investigate the individual-level differences in leaf shape, we sampled 1110 undamaged leaves from eight different individuals of *Quercus robur* - a species with substantial intraspecific variation in LMC - under similar environmental conditions. Using principal components of naive fourier morphometrics, we show that our entropy-based proxies better describe the overall shape space and differentiate between individuals than traditional proxies such as circularity or outline area ratios. Secondly, to investigate interspecific shape variation, we applied LeafComplexR to a sourced image dataset of Swedish tree species. Combining LMC (e.g. lobed and compound leaves) with LEC (e.g. entire and serrate margins), our approach demonstrates a strong taxonomic discriminative power. These results also provide a proof of concept that the vector-based linearizations central for our quantifications are readily applicable to a wide range of leaf shapes.

LeafComplexR advances functional ecology by providing a robust and automated way to quantify the complexity of leaves of different morphologies from leaf images. This creates new and easier means to analyse the relationship between morphology and the environment, and to capture the functional significance of morphological diversity across broad taxonomic, temporal and spatial scales.

Spatiotemporal and bottom-up effects on herbivore guild damage in pedunculate oak canopies

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Understanding the drivers of herbivory can provide insights into plant defense mechanisms and the resilience of forest ecosystems to herbivore pressure. In this study, we assessed the effect of canopy strata as a proxy for microclimatic variation, season, and leaf defense traits of pedunculate oaks on leaf damage by insect herbivore guilds, namely leaf chewers, miners, sapsuckers, and skeletonizers. We sampled 480 leaves from eight mature pedunculate oak trees in the Marburg Open Forest from spring to autumn 2024. We found that higher anthocyanin content was significantly associated with a reduced probability of damage by margin-feeding chewers and sapsuckers, but an increased probability of damage by leaf miners. The likelihood of damage by sapsuckers and miners was higher in shade leaves from the lower canopy than in sun leaves from the upper canopy. Skeletonizer damage was unaffected by leaf traits and was influenced exclusively by season, peaking in late summer and autumn. The probability of damage by sapsuckers increased from spring to autumn, while that of leaf miners peaked in late summer. Chewers causing hole damage showed no significant response to canopy strata, season, and leaf traits. Our findings highlight trade-offs in oak defenses, where traits that deter chewers and sapsuckers particularly promote leaf miners. Moreover, chemical defense traits contribute more to herbivory patterns than physical traits like leaf thickness. While microclimatic variation across the canopy appears to influence damage by certain guilds, seasonal effects seem to be a stronger driver for others.

The role of insularity: plants have few ornithophilous traits but are visited by morphologically more distinct hummingbirds in the Caribbean islands

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Functional traits shape interactions between plants and pollinators. To increase pollination efficiency, many plants evolve traits to attract specific pollinator groups. However, biogeographical setting may influence trait evolution and biotic interactions. For example, hummingbird-pollinated plants often have ornithophilous traits, i.e., elongated corollas, dilute nectar and red colors, but – due to colonization history, depauperate biotas and unstable environmental conditions – it may be disadvantageous for plants to rely on partners with specific traits on oceanic islands. Hummingbird-visited plants on islands are thus expected to have fewer ornithophilous traits and be functionally less diverse in their interactions with hummingbirds.

We compiled a large dataset of plant—hummingbird interactions (1,030 plant and 181 hummingbird species) and related functional traits. Data were divided into four biogeographical regions across the Americans to test whether regions differed in the proportion of ornithophilous floral traits, and functional diversity of plant—hummingbird interactions.

Plant communities of the Caribbean islands displayed the lowest proportion of traits typically associated with functional adaptation towards bird-mediated pollination, with the shortest corollas, highest nectar concentrations and largest proportion of non-red colors. Surprisingly, Caribbean plants interacted with more morphologically distinct hummingbird species than mainland plants.

We document a strong imprint of insularity on floral traits and hummingbird interactions. While native Caribbean plants displayed floral traits that support island theory, predicting less specific pollination systems on oceanic islands, functional diversity of plant—hummingbird interactions in the Caribbean communities were higher than on the mainland, possibly driven by competition over resources. These results highlight the influence of insularity on functional traits and plant—pollinator interactions.

Chemodiversity as part of the Plant Economics Spectrum

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Chemodiversity, the richness, relative abundance, and chemical disparity of compounds produced by plants, is an underexplored but important component of the plant phenotype. While certain phenotypic traits have well-established ecological functions and form the basis of the Plant Economics Spectrum, it remains unclear whether and how the chemical properties of plants align with this framework. Here, we test whether floral and leaf chemodiversity of volatile organic compounds is integrated into the major dimensions of the Plant Economics Spectrum or represents an independent axis of a plant’s ecological strategy. Through an exhaustive literature search, we compiled a global dataset of floral and leaf volatile organic compounds for more than 1,000 plant species and calculated metrics of their scent chemodiversity. We combined these data with established trait datasets of the Plant Economics Spectrum to evaluate the positioning of chemodiversity relative to other key traits. Our results reveal that floral and leaf scent chemodiversity are independent dimensions of plant functional variation. The independence of chemodiversity from resource-use traits suggests that it reflects a different aspect of a plant’s ecological strategy, shaped by distinct ecological and evolutionary drivers. Our work advances the understanding of trade-offs and constraints in the ecology and evolution of the plant phenotype. It demonstrates that chemodiversity constitutes a complementary axis of the Plant Economics Spectrum and may offer additional explanatory power for plant ecological research beyond traditional trait frameworks.

Root carboxylate-exudation phosphorus-mining strategies and trait diversification of eucalypti forests in global biodiversity hotspots in south-western and south-eastern Australia

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Australia's severely phosphorus (P)-impoverished soils have driven extraordinary evolutionary innovations in plant nutrient acquisition, exemplified by non-mycorrhizal species from Proteaceae and Cyperaceae, which release root carboxylates that mobilise poorly-available soil P. In contrast, the P-acquisition strategies of mycorrhizal species in the dominant family Myrtaceae remain poorly understood.

We conducted field surveys in two global biodiversity hotspots—south-western and south-eastern Australia, by collecting leaves and soils from 98 eucalypt species at 72 sites spanning diverse habitats and soil P concentrations. Leaf [Mn], total P, and stable isotope nitrogen and carbon ($\delta^{15}N$, $\delta^{13}C$) were analysed to assess nutrient-acquisition strategies and environmental adaptations. Complementing field data, we selected 10 representative eucalypt species for hydroponic experiments, quantifying root carboxylate exudation in nutrient solutions with 0.5 and 50 µM P.

Our findings reveal that high leaf [Mn] (a hallmark of carboxylate exudation) is widespread but not universal in eucalypts, with field [Mn] similar to those in non-mycorrhizal carboxylate-releasing Proteaceae. This challenges the paradigm that carboxylate-mediated P mining is restricted to non-mycorrhizal lineages, suggesting convergent evolution of this trait in mycorrhizal taxa. Hydroponic experiments confirmed significant root carboxylate release. Strikingly, interspecific variation in leaf [Mn] and [P] highlighted divergent strategies among genera such as Angophora and Eucalyptus, implying genus-specific trade-offs between carboxylate exudation and alternative P-acquisition mechanisms.

We conclude that root carboxylate exudation is a critical yet overlooked mechanism underpinning the dominance of mycorrhizal Myrtaceae in Australia's P-impoverished ecosystems. These results redefine our understanding of plant-soil feedback in mycorrhizal systems, emphasising the synergy between carboxylate exudation and fungal partnerships in nutrient acquisition.

Molecular Ecology – Challenges and opportunities for research through New Genomic Techniques (NGT)

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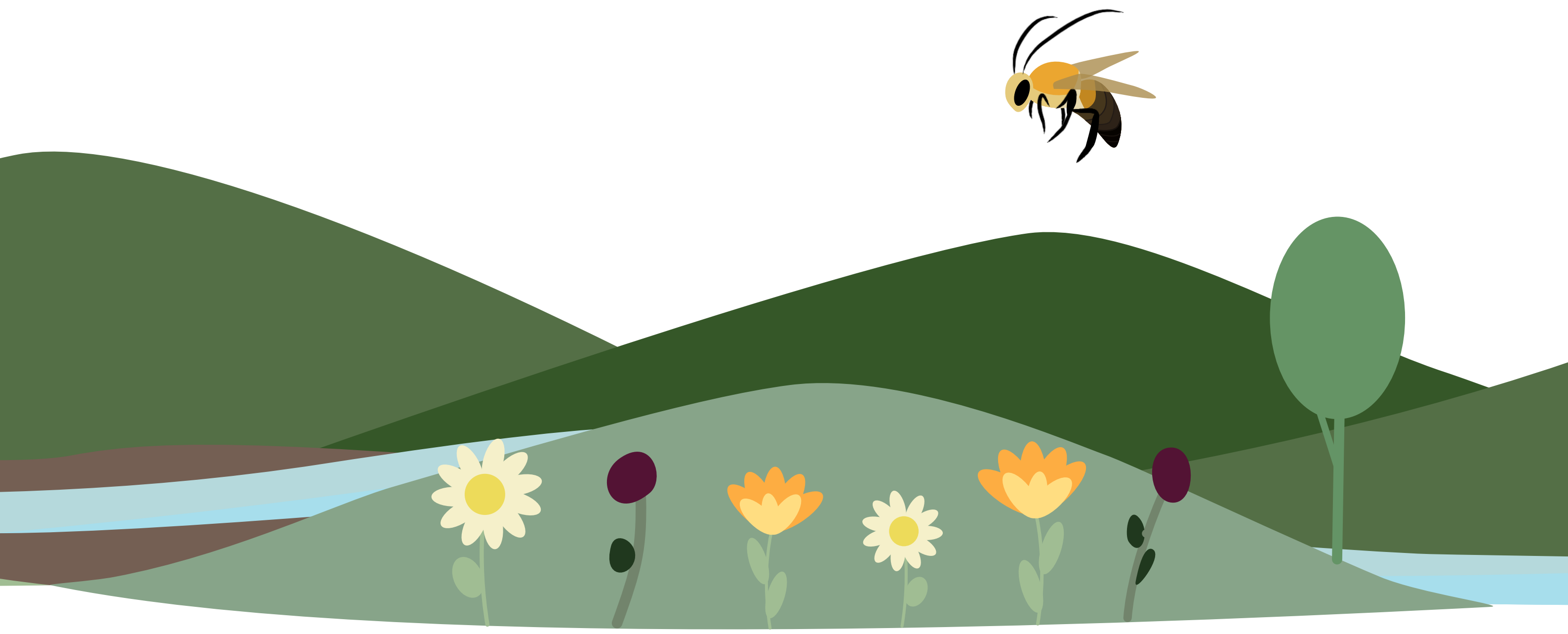
New Genomic Techniques (NGTs) are methods for targeted mutagenesis that can be used in both basic research and in the application of plant and animal breeding. Molecular ecology is a modern branch of research investigating molecular interactions between living organisms and their environment. Based on previous experience, it can be assumed that NGTs can be used in a variety of ways in molecular ecology: (1) Autoecological studies of ecologically relevant metabolic pathways (2) Population ecological studies of intra- and intergenetic interactions (3) Ecosystem monitoring using genetic markers (4) Conservation applications in the control of invasive species or the promotion of threatened populations.

This contribution provides a brief overview of ecological methods whose efficiency and knowledge gain can be increased through NGTs, in particular plants. In Europe, however, such techniques are only used in molecular ecology if they are not fully classified as regulated genetic engineering. Otherwise, the costs and effort of obtaining permits generally outweigh the benefits and, to date, have lacked social acceptance. The current classification of NGT as regulated genetic engineering leads to significant delays in the approval process, which negates the core benefit of gaining environmental knowledge. Current legal changes based on the equivalence principle will enable molecular ecology to conduct "minimally invasive" studies and experiments with so-called Category 1 plants in the future. Category 2 plants remain subject to the cost-intensive approval process. For questions of evaluation, a common – ideally legally defined – understanding of the term "harm" is needed – including within the research community. The Neobiota Regulation and German nature conservation law are an additional and sufficient tool for supporting molecular ecological experiments with NGT 1 plants. Comparison is of central importance for all scientific findings and their evaluation. NGTs are a comparatively useful tool with a relatively small environmental footprint.

Session 25

Pollinators



Local habitat quality rather than landscape context shapes pollinator populations across European landscapes

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Reversing pollinator declines is crucial for securing the pollination of wild plants and arable crops but our understanding of their drivers is lacking. Effective pollinator conservation requires reliable predictors for pollinator species richness and densities across pollinator groups and regions as evidence base for the management of agricultural landscapes. Here, we synthesise data from a standardised pollinator monitoring comprising butterflies, bumblebees, solitary bees and hoverflies, performed across the vegetation period in semi-natural habitats in 330 cultural landscapes in 16 independent regions across Europe. We aimed to identify the importance of local and landscape-scale drivers of pollinator populations across European regions and assess whether habitat loss impoverishes pollinator communities. Landscape habitat availability was no suitable indicator for pollinator richness and density, with responses varying across study regions and pollinator taxa. In contrast, local habitat quality benefitted pollinators across taxa and regions with flowering plant richness being more universally beneficial than flower cover for pollinator richness and densities across taxa. Increasing landscape management intensity had no consistent negative effect on pollinator richness or densities. In fact, butterfly and solitary bee richness and butterfly densities peaked in mixed landscapes comprising cropland and high semi-natural habitat availability. In addition, we found no evidence for impoverished and homogenised pollinator communities in landscapes with little habitat availability. Habitat-poor landscapes and small habitat patches should thus not be neglected in pollinator conservation. Our results indicate that conservation policies for safeguarding pollinators in European cultural landscapes should not solely focus on increasing habitat amount but instead vitalise existing habitats by increasing their quality, even in landscapes with little remaining habitat.

Landscape management can foster pollinator richness in fragmented high-value habitats

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Pollinator diversity is declining due to habitat loss, low habitat quality, limited habitat connectivity and intensification of agriculture in remaining high-value habitats within human-dominated landscapes, such as calcareous grasslands. Options to increase local area of protected habitats are often limited. Therefore, we asked how local habitat quality as well as agri-environmental schemes (AES) and configuration of the surrounding landscape can contribute to the preservation of pollinator diversity. In 2022, we sampled bees, butterflies, and hoverflies in 40 calcareous grasslands in Northern Bavaria, Germany and assessed the effects of calcareous grassland area, quality (represented by flower cover, flower richness and cover of potential nesting sites) and connectivity, agricultural configuration, and AES on species richness and abundance. We found 231 wild bee, 90 butterfly, 62 hoverfly and 275 flowering plant species on the studied calcareous grasslands. While calcareous grassland area was an important predictor for bee and butterfly species richness, with strongest effects sizes for endangered species, local flower resources and nesting sites and landscape characteristics such as small field size, high proportion of organic fields and connectivity with other grasslands significantly enhanced pollinator richness with responses differing among the three studied taxa. In contrast to expectations, AES flowering fields did not benefit pollinator communities in grasslands. Our study reveals the potential of combined management options focused on improving local habitat quality, especially of nesting sites, the configuration of agriculture and the creation of beneficial AES in the surrounding landscape to ensure the long-term survival of diverse and partially endangered pollinator groups in highly fragmented protected grassland.

Winners and Losers in a Warming World: Trait-Mediated Wild Bee Responses to Global Change

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Global change—driven by climate warming and human impacts such as land-use changes, urbanization and pesticides—profoundly alters pollinator communities, yet the mechanisms underpinning species' fates remain elusive. We quantified how interacting anthropogenic pressures and climate warming have reshaped wild bee communities over the last century across eight sites in Upper Austria (300 km², 266–616 m a.s.l.). Drawing on ~17,500 museum and contemporary records of 342 species (1910–2021, aggregated into six 15-year intervals), we linked presence–absence data to interval-averaged temperature, precipitation, human population density (proxy for total anthropogenic impact) and sampling effort. A single binomial GLMM—with species and site as random effects and interacting environmental drivers—revealed that community turnover drove an ~18 % loss in species richness. Specialist "Disappearing" bees declined under rising human impact and warming, while generalist "Appearing" bees expanded under the same drivers. "Intermittent" species benefited from wetter, warmer periods but were constrained by human density. "Omnipresent" generalists remained stable, buffering pollination but promoting functional homogenization. These functional-trait-mediated responses underscore that compounded anthropogenic and climatic pressures oppress specialists yet favour generalists. Conservation must therefore safeguard specialist habitats, maintain landscape connectivity and protect climate- and moisture-sensitive refugia to preserve wild bee functional diversity under accelerating global change.

Costs and benefits of drought priming depend on climate and pollinators in an insect-pollinated crop

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Insect pollinators are crucial for agricultural yields, particularly for crops like strawberries. However, rising temperatures and episodic droughts alter plant performance, floral cues and insect communities, thus posing challenges for crop–pollinator interactions. To explore how drought priming, temperature and pollinators affect strawberry yield, a combined field and climate chamber experiment was conducted with plants grown under best practice with or without drought priming. To understand the effects of wild pollinators in two different climatic settings, one set of plants per region (warm vs cool) was placed on agricultural fields. Two other plant sets were exposed to hoverflies, solitary bees, or social bees in climate chambers with simulated current (cool) or future (warm) climates. We expected drought priming to reduce fruit mass under optimal (i.e., cool or current) temperatures, but to maintain or increase it under stress (i.e., warm or future) temperatures due to memory effects. Unexpectedly, no drought-priming costs or benefits were observed in fruit mass in the field experiment, likely due to other abiotic stressors interfering with fruit development. In the climate chambers, however, insect pollination did offset the costs of drought-priming under current temperatures, compared to smaller fruits in pollinator-excluded plants. Under future temperatures, priming had no effect when pollinators were excluded, while fruits of insect-pollinated plants were smaller when drought-primed, suggesting lower pollinator activity due to exceeded climatic ranges. The study underlines the role of drought priming and insect pollinators in mitigating climatic effects on crops, though their effectiveness is limited for heat-sensitive pollinators, e.g., hoverflies. Thus, climate adaptation strategies should include conservation measures for heat- and drought-tolerant pollination, aiming at a functional diversity of pollinators to secure future agricultural yields.

Drought events reduce reproductive success in bumblebee colonies

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Climate change poses challenges to pollinator populations through rising temperatures, altered precipitation regimes and an increased frequency of extreme weather events. Drought events, in particular, are becoming more frequent and severe, with largely unknown effects on pollinator fitness and associated ecosystem services. In a two-year field experiment, we compared bumblebee colony development and reproductive success between a drought year and a year with average climatic conditions. Colonies were established from wild-caught queens, placed in high-quality semi-natural grasslands and assigned to either a sugar-water feeding treatment or no feeding to evaluate resource limitation effects. Colony weight and reproductive output were both strongly reduced in the drought year and colony lifespan was shorter. Sugar water supplementation enhanced colony performance only during drought, suggesting that nectar scarcity limits colony success during dry periods. Our findings suggest that increasingly frequent droughts could pose a major threat to bumblebee populations and the pollination services they provide.

Towards a more mechanistic understanding of anthropogenic drivers of plant-pollinator interaction networks in agroecosystems

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Anthropogenic pressures not only profoundly change plant and pollinator communities, but they likely also shape their interactions, and thus the structure and stability of plant-pollinator networks and pollination functions. Despite a wealth of case studies investigating the effects of single pressures, we lack a systematic analysis synthesising the direct and indirect effects of multiple pressures on plant-pollinator interaction networks and the underlying mechanistic pathways. We analysed 28 data sets comprising 487 plant-pollinator networks sampled in agricultural landscapes across Europe. Using structural equation modelling and trait analyses, we investigated the direct and indirect pathways mediating how local habitat degradation, landscape simplification and potential competition with managed honeybees affect pollinator communities and plant-pollinator networks. We explore the roles of these multiple pressure in driving the disassembly of wild bee communities and how these processes are mediated by the bees' traits. Moreover, we examine to what extent potential competition of wild bees with honeybees is buffered by local floral diversity and the proportion of semi-natural habitats in agricultural landscapes. To gain a better understanding of the functional consequences on plant pollination we investigate how high honeybee densities drive rewiring of plant-pollinator interactions, traitmatching between plants and their pollinators, and the pollinators' functional diversity. We find that pressures affected plant-pollinator network structure and stability mainly indirectly through changes in the the composition of pollinator communities, their traits and behaviour (i.e. foraging specialisation). Our findings contribute to better mechanistic understanding of how multiple anthropogenic pressures shape wild pollinator communities, plant-pollinator interactions and their functional consequences on pollination services in agroecosystems.

Synthesis of apple pollination research reveals positive contributions from wild bees relative to those of honeybees

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Apple (*Malus domestica*) is one of the most important entomophilous crops in the world. To safeguard future yields, it is essential to understand which pollinating insects contribute to its pollination across production regions. Here we present a set of meta-analyses of site-replicated, observational studies on insect-mediated pollination in apple cultivation. Using raw data from 30 studies, totaling 546 site replicates, we determine the contribution of honeybees (*Apis mellifera*) and wild bees to apple pollination. We find that the honeybee is the most abundant pollinator (72.9% on average) compared to wild bees across all studies. From our meta-analyses we detected strong evidence of pollen limitation for fruit set and seed set, but not for fruit weight. We also conclude that variation in honeybee visitation rate did not influence fruit set or seed set, yet increasing honeybee visitation rate negatively affected fruit weight. Fruit set was not influenced by wild bee visitation rate, whereas fruit weight and seed set increased with increasing visitation rate of wild bees. Bee species richness positively affected seed set, whereas it did not affect fruit set and fruit weight. In sum, a diverse community of bees contributes to apple pollination and yield. The positive effect of wild bee visitation rate and species richness on fruit weight and seed set aligns with previous research, which has demonstrated that wild bee pollination results in better-quality fruit production. Hence, our synthesis highlights the importance of conserving pollinator diversity to maintain pollination services and reduce pollen limitation. The absence of a clear effect of honeybee visitation rate on fruit and seed set, coupled with its negative impact on fruit weight, suggests a need for further optimisation of honeybee management to improve the cost-efficiency of pollination management.

Beyond Flower Visitors: Pollinator Diversity, Genetics, and Environmental Factors Enhance Cacao Pollination in northern Peruvian Amazon

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Cacao is a major commodity globally and productivity is limited by pollination, but the drivers of pollination success are largely unknown.

We investigated how plantation management, landscape composition, weather conditions and cacao genetic diversity influence pollinator diversity and pollination success in 22 cacao agroforestry plantations in the northern Peruvian Amazon.

Our results show that forest cover around the plantation positively influenced both pollinator richness and abundance. In landscapes with low forest cover, plantation management practices became more critical in preserving pollinators. These include maintaining or restoring canopy cover and favouring the presence of different canopy heights. Further, higher temperature and higher pollinator diversity were positively correlated with pollination success. The genetic makeup of cacao trees and their genetic distance to other cacao trees can also influence compatibility as increasing genetic distance had a strong positive effect on early fruit set.

Our study highlights key drivers of pollination success and the need to combine plantation and landscape management for pollinator conservation and high crop yields in cacao agroforestry systems.

Flower-derived environmental DNA reveals community diversity, species abundances and ecological interactions in bee pollinators

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Flower-derived eDNA holds great promise as a rapid and non-invasive tool for monitoring pollinators and their plant-associations. However, pollinators often only briefly interact with a plant and leave little eDNA, making them particularly challenging to detect. In addition, taxonomic biases in eDNA deposition and PCR amplification prevent quantitative analysis of pollinator diversity. These limitations have so far precluded the widespread use of eDNA in pollinator monitoring. Comparing flower-derived eDNA with conventional monitoring in flower strips, we here explore the utility of eDNA to detect community diversity, species abundances and ecological specificity of plant-associated arthropods. We show that read abundances are a bad predictor of true abundances at the community level. Instead, the occupancy of individual species in replicated flower eDNA samples provides reliable quantitative estimates of pollinator biodiversity and detects their ecological specificity very well. Also, we find that pollinator eDNA can be collected non-invasively, by washing off from flowers in the field. Our work highlights eDNA analysis as a powerful tool for the rapid future monitoring of plant-arthropod interactions and plant-pollinator networks.

Pollinators during and after mass flowering: How landscape-scale organic farming, semi-natural habitats and post-bloom weeds shape wild pollinators in oilseed rape

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Agri-environment measures such as organic farming are widely implemented to enhance biodiversity and ecosystem services, like pollination and pest control, in agricultural landscapes. However, their effectiveness for mass-flowering crops and interactions with other landscape features remain insufficiently understood. Furthermore, the extent to which pollinators utilize oilseed rape fields beyond their short blooming period has rarely been studied. Here, we aim to address these knowledge gaps.

We conducted fieldwork over two consecutive years in oilseed rape fields in agricultural landscapes surrounding Würzburg, Germany. We examined the interactive effects of landscape-scale organic farming and semi-natural habitats on three key groups of wild pollinators – bumblebees, solitary bees, and hoverflies – during the flowering period of oilseed rape. In addition, we surveyed pollinators after oilseed rape bloom and monitored pest damages of harvested oilseed rape plants.

Our results show that bumblebees benefitted from higher proportions of semi-natural habitats at the landscape scale. Solitary bees benefited from organic farming, but only in landscapes rich in semi-natural habitats. After the flowering period of oilseed rape, weeds provided valuable floral resources for pollinators, particularly attracting hoverflies and solitary bees. While pollinator abundance did not enhance seed weight of oilseed rape, seed weight and weight per seed were affected by pest damage, depending on the pest species' ecology.

Our findings underscore the importance of combining organic farming and the preservation of semi-natural habitats to support diverse pollinator communities in agricultural landscapes. Our study further highlights the ecological value of weeds as floral resources after the bloom of mass-flowering crops.

Perennial flower fields as nesting habitats for ground-nesting wild bees

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Wildflower fields are a widely adopted agri-environmental measure that can provide a continuous supply of floral resources for pollinators. However, their suitability as nesting habitats for ground-nesting bees, as well as the influence of local and landscape characteristics on the nesting behaviour of these bees remain unclear.

To address this knowledge gap, we studied 12 perennial wildflower fields in the vicinity of Göttingen sown on two different soil textures (silt vs. loam) along a gradient of landscape diversity. We recorded nests of ground-nesting wild bees along 10 x 50 m² transects in each flower field during three survey rounds from March to June 2024. To assess wild bee species richness, we installed mini emergence traps over each nest. Moreover, we estimated the availability of bare ground in each transect area.

In total, we found 17 species that were nesting on the studied flower fields. The highest number of nests was observed in May with an average of 10 nests per 500 m². We found significantly more nests and a higher species richness on flower fields established on silt soils compared to loam soils. Moreover, nest abundance and species richness increased with bare ground availability. However, landscape diversity did not influence nest abundance and species richness.

These findings highlight the value of perennial flower fields as nesting habitats for ground-nesting wild bees. Our results further underline the importance of local characteristics such as soil texture and bare ground availability for the effectiveness of perennial flower fields in promoting nesting of ground-nesting bees. These should be carefully considered when designing and implementing wildflower fields in agricultural landscapes.

Increased climate resilience of wild pollinator communities visiting crop flowers through agri-environmental interventions

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It is an established fact that wild and managed pollinators play a vital role in the pollination process, thereby ensuring the production of crops is maintained at a consistent level. It is hypothesised that diverse wild bee communities will act as a buffer against environmental changes, such as climate change and increased weather variability, through functional redundancy and complementarity. However, the available empirical evidence for this hypothesis is limited, and the effectiveness of management options, such as agri-environmental measures, in enhancing the buffering capacity of wild pollinator communities and their impact on crop yields remains underexplored. In this study, we examined how agri-environmental measures, such as grassland extensification, in agricultural landscapes around cherry orchards influence the thermal niche breadth and complementarity of bee communities, potentially boosting climatic resilience, crop yield, and its stability. Utilising the framework developed by Kühsel and Blüthgen (2015), an assessment was conducted of the thermal niche of bee communities as a proxy for ecosystem resilience. This study represents the first investigation to calculate the thermal species niches and aspects of thermal niche breadth and complementarity for both wild and managed pollinators in cherry orchards. The results indicated that wild bee diversity and abundance are significant factors in the expansion of the thermal niche. However, no clear relationship between pollinator metrics and early fruit set was observed, likely due to unexpected cold weather events in late spring. Nevertheless, the study emphasises the significance of preserving resilient ecosystems.

Insect houses buffer urbanization effects on cavity-nesting Hymenoptera

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Insect houses may support bee and wasp populations in urban areas, where nesting opportunities are typically scarcer than in rural landscapes. Despite their popularity, their effectiveness as a conservation tool is still debated.

As part of a citizen science project, standardized trap nests were installed at 240 schools across Germany and monitored over the course of one year to sample cavity-nesting bees and wasps. Additionally, we recorded whether insect houses had already been installed at each site prior to the study. The percentage of sealed surfaces around each site was calculated as a proxy for the degree of urbanization.

Parasitism rates in bee and insect-hunting wasp nests declined with increasing urbanization. For bees, this pattern was evident particularly when insect houses were absent; for insect-hunting wasp nests, it declined regardless of nesting aid availability. In contrast, spider-hunting wasp nests were more parasitized with increasing urbanization, especially at sites without insect houses. Parasitism by generalist natural enemies was slightly higher in the absence of insect houses, but declined in overall as urbanization increased. Specialist parasites showed higher parasitism only in less urbanized areas without nesting aids, but their rates remained stable across urban gradients when insect houses were present.

Overall, our findings suggest that insect houses effectively support local bee and wasp populations, likely by alleviating nesting site limitations, particularly in urban environments. In addition, insect houses contribute to maintaining populations of specialized natural enemies, thereby enhancing local biodiversity. The mitigation of urbanization effects also implies that floral resources were not limited for bees even in urban areas, whereas wasps may be constrained by both nesting and food availability.

In conclusion, insect houses support cavity-nesting bees and wasps, and are therefore valuable conservation tools.

No one-size-fits-all: trait-dependent effects of local plant diversity on pollinators and pollination services along an urban densification gradient

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Urban densification reduces landscape-scale pollinator habitat quantity, reshuffling plant–pollinator interactions and affecting the provisioning of pollination function. Improving local-scale habitat quality, e.g. by planting more flowers on cultivated urban greenspaces such as private gardens, has been proposed to compensate landscape-scale habitat loss, but effective pollination depends on the match between pollinator and flower traits. To test this expectation, we used four experimentally established phytometer species differing in floral traits to assess flower visitation by distinct functional groups of pollinators, and consequences on plant reproductive success along two independent gradients: local flowering-plant species richness in urban private gardens and landscape-scale urban densification. We found that pollinator abundance and richness declined with urban densification and increased with local plant species richness. Flower-rich gardens supported more small solitary and large social bees, but not hoverflies, beetles, or small social bees. Plant reproductive success declined with urban densification but was buffered by local flowering-plant richness, but only in phytometers associated with more specialised pollinators. Our results suggest that while increasing local-scale flowering plant richness can support plants mainly pollinated specialised visitors in areas with increased urban density, this mitigation approach is less effective for generalist plants, which are generally more abundant than specialists. This highlights that no single strategy can mitigate the loss of pollinators and pollination services in increasing urbanising environments. Habitat loss due to urban densification needs not only to be compensated with high-quality green spaces and also complemented by additional targeted measures.

The invasive Himalayan balsam (Impatiens glandulifera) severely threatens pollinator diversity in Southwest Germany

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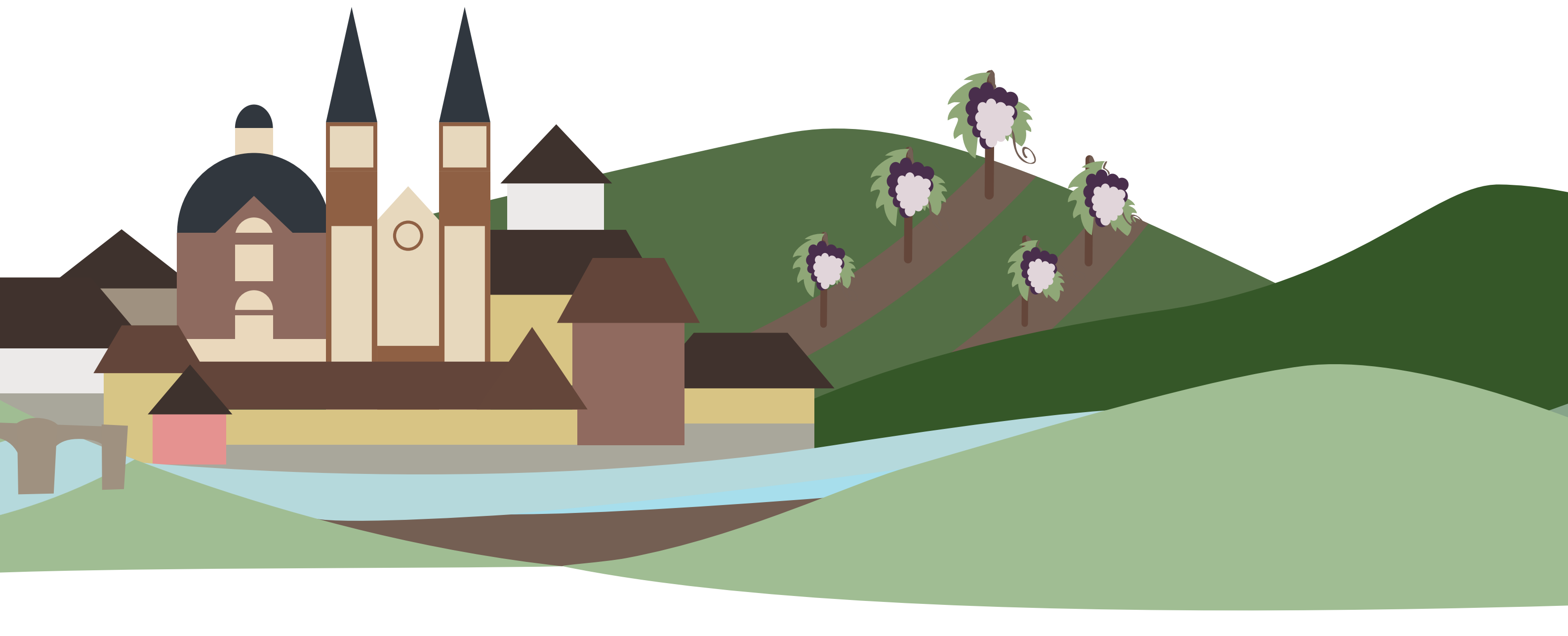
Invasive alien plants can threaten biodiversity by outcompeting native species and affecting higher trophic levels such as pollinators. Invasion effects can be trait-dependent: some pollinators benefit when their traits align with those of invasive plants, while others are disadvantaged when such matching is absent. We investigated changes in the taxonomic and functional composition of pollinator communities driven by the Himalayan balsam (*Impatiens glandulifera*), one of the most rapidly-spreading invaders in Europe. We recorded pollinator communities at 24 study sites in Southwest Germany, comparing invaded with non-invaded sites in a paired design, and sampled plant-pollinator interactions in three observation rounds during the flowering period of *I. glandulifera* in 2024. We observed a total of 12,009 interactions involving 281 pollinator species visiting 80 plant species. Invasion by *I. glandulifera* strongly reduced pollinator richness by 57% compared to uninvaded sites. This was particularly prevalent for wild bees and syrphid flies, which declined by 38% and 53%. When excluding honeybees (*Apis mellifera*) from the analysis, plant invasion reduced pollinator abundance by 24%. However, this pattern was reversed when honeybees were included because of their high numerical dominance in invaded sites. The trait-based analysis of wild bees revealed that large-bodied, social, generalist species were more prevalent in invaded sites, while uninvaded areas supported a greater abundance of small, solitary, specialist bees. In summary, our study suggests that *I. glandulifera* is driving a severe decline in taxonomic diversity of pollinator communities, and has diverging effects on their functional composition, mainly disadvantaging specialist bee species. With 48 percent of wild bees already considered threatened in Germany, the ongoing spread and lack of effective control of this invasive plant may further accelerate pollinator declines and contribute to local extinctions.

Session 26

Pollution



Flooding as a vector of pesticides from water to land: exposure of the riparian food-web

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Globally, surface waters are at risk of contamination with pesticides, with small agricultural streams being especially prone due to their size and position in the landscape. With climate change progressing, the frequency and intensity of flooding events will intensify. The relevance of flood-mediated pesticide transfer is therefore also expected to increase. We investigated the flood mediated transfer of pesticides from polluted streams into riparian food-webs at laboratory batch microcosm, aquatic-terrestrial mesocosm and the field scale. In these studies, we performed targeted analyses for 98 pesticides commonly applied in agricultural in Southern Germany using liquid chromatography coupled to mass spectrometry (HPLC-MS/MS). We found that in the field, riparian plants in regularly flooded riparian zones of small agricultural streams contain pesticide concentrations which are up to twice as high compared to plants in close-by rarely flooded areas. We also found that pesticides bioaccumulate in riparian plants after regular flooding events, and as a result may be taken up by herbivorous insects. Furthermore, we found that phytophagous aphids feeding on regularly flooded plants, i.e. stinging nettle, biomagnified up to five pesticides, potentially making aquatic contamination available for higher trophic levels in the terrestrial food-web. Spiders for example, as riparian top-predators, feed on, amongst other things, aphids. We found that spiders did not directly biomagnify pesticides from aphids in a mesocosm experiment. However, spiders in riparian zones are contaminated with up to seven pesticides, highlighting the variety of exposure routes of pesticides to higher trophic levels in the riparian zone. This aquatic-terrestrial contamination link highlights the role, aquatic contaminants may play in the pollution of terrestrial riparian ecosystems and their food webs.

Changes in the microbiome of Tetragnatha montana along a chemical stream pollution gradient

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Many freshwater streams are exposed to chemical pollutants that can affect both the aquatic and the surrounding terrestrial ecosystems. Some pollutants are transported by the aquatic-terrestrial food web and can accumulate in terrestrial predators, such as spiders. If pollutants have anti-microbial activity, they can alter the microbiome of exposed predators. This may lead to individual and population-level consequences in spiders due to the influence of endosymbiotic bacteria on spider traits related to sex, fitness and survival. In this study, we investigated the bacterial microbiome of *Tetragnatha montana* at differently polluted streams in southwestern Germany. We used DNA-metabarcoding to identify bacterial 16S rDNA obtained from spiders collected at stream sites along a quantified chemical pollution gradient. We then investigated changes in microbiome composition, diversity and the prevalence of spider endosymbionts. Preliminary results indicate that spider microbiomes are more diverse and that endosymbiont infections are more prevalent at polluted streams. Final results will further describe changes in microbial diversity and their possible consequences for spiders and spider populations at polluted streams. Altered microbiomes represent an unexplored route through which chemical pollution can affect the roles of spiders and other predators in riparian ecosystems.

Reduced fungicide sprayings: a biodiversity boost?

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Pesticides are considered one of the main causes for arthropod decline in agriculture which in turn may affect ecosystem services such as natural pest control and soil fertility. Although insecticides are usually most harmful to non-target organisms, also fungicides can have unintended side effects on arthropods. Grapevine typically receives ten fungicide sprayings in three months of growing season in the Palatinate region, Germany. Sprayings contain several plant protection products of varying toxicity towards non-target organisms in both organic and conventional viticulture. However, fungus-resistant grape varieties allow to study substantial reductions in fungicide applications under realistic conditions.

We compared the effects of reduced fungicide applications across 36 vineyards in a 2x2 factorial design, including fungus-resistant and susceptible grape varieties under organic and conventional management. Our sampling included arthropods from the grapevine canopy and the inter-row vegetation as well as soil dwelling arthropods and soil fungal communities. Additionally, we set up camera surveyed sentinel cards to identify predators of the European grapevine moth (*Lobesia botrana*).

First results indicate that canopy dwelling arthropods were strongly enhanced by reducing fungicide sprayings, particularly predatory arthropods including spiders. However, these effects were less pronounced in the inter-row vegetation and on the soil. Both organic management and fungus-resistant grape varieties influenced arthropod communities, but to different extents depending on the sampled microhabitat.

These preliminary results indicate declining effects of fungicides on non-target arthropods from the grapevine canopy (to which the fungicides are applied) towards the ground. The cultivation of fungus-resistant varieties represents a crucial step in the pursuit of sustainable viticulture.

Testing for wing impairment and asymmetry in honey bees after exposure to plant protection products

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Pollinators are exposed to many pollutants through air, water, food, or the flowers they visit. This environmental pollution can cause stress during development. In insects, this is often associated with morphological asymmetries as a stress response. Asymmetries can lead to reduced mating success and asymmetrical wings in insects might affect their flight capacity. This study investigates whether the exposure to field-realistic concentrations of plant protection products during development might affect wings of the imagines. Therefore, female honey bee larvae were reared in vitro until emergence. They were fed with diets spiked with various active substances, which are used in synthetic plant protection products, or a formulated biological plant protection product. Insecticides, fungicides, and herbicides with varying potential risks to bees and modes of action were used. The dataset was expanded by honey bee workers of a field study and another laboratory study. Fore and hind wings were investigated regarding crippling, vein deviation, and asymmetry. Rearing honey bees in vitro affected wings with increased proportion of crippled wings and increased fluctuation asymmetry of fore and hind wings compared to the wings of newly emerged bees taken from parental colonies. Honey bees that were treated with sub-lethal concentrations of chlorpyrifos or fenoxycarb showed more often crippled wings. In honey bees from the field study, which were exposed to a plant protection product based on Bacillus *thuringiensis* subsp. *aizawai* (strain ABTS-1857), differences in directional wing asymmetry were observed. The current study shows that wing morphology of honey bees can be affected by active substances used in synthetic plant protection products as well as formulated biological plant protection products.

The neonicotinoid Acetamiprid alters the chemical profile of the primitive eusocial bee Lasioglossum malachurum

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The widespread use of agrochemicals, particularly neonicotinoids, poses a significant threat to the health of (pollinating) insects. Various health traits are affected but the impact on the chemical communication of wild bees remains a poorly studied aspect. Here, we assessed how field-realistic exposure to the 'honeybee-safe' neonicotinoid Acetamiprid affects the behaviour, cuticular lipids and microbiome of *Lasioglossum malachurum,* a small ground-nesting sweat bee. *L. malachurum* is an important, abundant pollinator of several crop plants with primitive social behaviour which relies on cuticular lipids for communication. We collected bees in the field for a controlled pesticide treatment in the lab. Pesticide-treated individuals increased their sugar-water consumption rate compared to the control group. After 7 days of experiment, the treatment group showed a trend towards less developed ovaries and an increased amount of odour with significantly altered queen pheromones. While the microbiome was not affected by the treatment, a comparison with field individuals showed an erosion of their gut microbiome with a reduction in *Apilactobacillus* during laboratory keeping. Our findings indicate that neonicotinoids may disturb chemical communication in *L. malachurum* and thus might impair social behaviour. This raises concerns about the threats of currently approved pesticides to wild pollinators.

Effects of microplastic on Lasius niger ant colonies: a multi-omics perspective

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Ants provide important ecosystem functions, such as pest control, seed dispersal, or bioturbation of soils. However, their abundance and diversity are currently threatened by habitat destruction and anthropogenic pollution. Microplastic (MP) is emerging as an omnipresent pollutant in terrestrial ecosystems. Ants may take up pollutants including MP with their food, e. g. through trophic transfer when consuming prey, or by consuming contaminated liquid food sources such as extrafloral nectar or plant exudates. We tested the effects of MP on colony development and physiological parameters on the black garden ant *Lasius niger* using a multi-omics approach. We fed *L. niger* colonies with $_{\text{mealworm}}$s as a protein source and sugar water mixed with 2 % w/w MP of five different polymers (polystyrene (PS), low-density polyethylene (LDPE), polyethylene terephthalate (PET), polylactic acid (PLA), polypropylene (PP)). To test effects of the trophic transfer of MP we fed one additional group with pure sugar water and mealworms, which were previously fed with polystyrene (PS_{mealworm}). After 12 weeks the number of alive workers and the number of pupae did not significantly differ between treatments, but we observed a significantly higher mortality among workers of the LDPE and PS treatments. Additionally, the workers' gut microbial beta-diversity shifted after LDPE and PLA exposure. While we could not identify a gene expression pattern that is shared among multiple treatments in our transcriptome data, the abundance of key metabolic proteins such as Vitellogenin, Hexamerin, Transferrin, and Chymotrypsin-like proteins were significantly reduced in multiple treatments including the PS_{mealworm} treatment. Alterations of the microbiome and proteome could ultimately result in stronger adverse effects over a longer period of time or when combined with other stressors. Our results provide important insights into sublethal effects of MP on ants.

Plastic Bees: Exploring micro plastic pollution in bees

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Micro plastics, polymer particles in size ranges smaller than 5mm (especially size ranges of 100-1μm), were found to have negative effects on insects, including bees. Micro plastic particles can disrupt the gut, impair cognitive functions and increase mortality. However, studies on the micro plastics exposure of bees under field realistic conditions as well as tests on their effect on bee larvae development, especially with compound mixtures, were hardly performed. In our study, we address both the uptake of micro plastic from the environment and the effect of a micro plastic mix on bee larvae.

We sampled nectar from various flower as well as several bee species feeding on them. Both bees and plants were sampled together. Both were analyzed applying a newly developed method using Nile Red staining and fluorescent microscopy. The protocol followed Meyers et al. 2022, but was adapted for the terrestrial environment, further automated and minimal particle size further reduced. To additionally assess the effect of micro plastics on bee larvae, we fed larvae of two bee species (Bombus terrestris, Osmia bicornis) diets containing different concentrations of three different micro plastics and we observed the developmental processes as well as the emerged adult bees.

With the newly developed method, we were able to assess the contamination of bees and flowers together, providing novel insights into how these tiny particles are dispersed within the pollination system. Additionally, the analysis on the effects on bee larvae revealed further detrimental effects, which highlights how these particles could affect whole populations and generations of bees.

Effects of multiple stressors on the health of Bombus terrestris: microplastic, heat and ozone

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Insect pollinators provide a vital ecosystem function, that supports the majority of world´s plant species and the organisms that are associated to them. However, currently worldwide the abundance and diversity of insects are declining, due to various drivers such as habitat loss or anthropogenic pollution. Since a loss of pollination services would jeopardise the maintenance of wild plant diversity and wider ecosystem stability, it is crucial to investigate its causes. In their natural environment insects are exposed to a multitude of stressors simultaneously. We therefore chronically exposed *Bombus terrestris*, as a model organism for non-Apis pollinators, to multiple stressors. We exposed worker bumblebees to food containing microplastic (MP), which is a frequently found anthropogenic pollutant. Additionally, we exposed them to increased ozone concentrations like they occur during peaks in the afternoon of hot sunny days, and heat stress. The latter two stressors increase in intensity and frequency with global warming. We used these three stressors individually as single stressors and in combination. Throughout the ten-day experiment we recorded the mortality of bumblebees and afterwards measured the bodyfat content. Mortality was significantly higher in treatments including MP. Additionally, the mortality was higher with all three stressors combined, compared to MP individually and for the combination of MP and heat stress it trended towards a higher mortality. The bodyfat content was decreased for the combination of ozone and MP, compared to the control treatment, and MP individually. These results suggest that the negative effects of multiple stressors synergise, which can be observed at both lethal and sublethal level. Our study contributes to the understanding of the mechanisms of the drastic decline of entomofauna.

Invisible death in the city: How the quality of foodplants in urban areas affects larval growth and survival of a common moth

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As the human population continues to grow, pollution is becoming an increasingly critical factor contributing to biodiversity loss. In urban environments, emissions from traffic may play a significant role in insect population declines, potentially through direct exposure or indirectly via contamination of their host plants.

In this study, we investigated whether potentially reduced food plant quality in urban areas negatively impacts herbivorous insects. We conducted a feeding experiment using larvae of the coronet moth (Craniophora ligustri), which were fed with privet leaves (Ligustrum vulgare) collected from either semi-natural or urban habitats. Larval survival was significantly higher on privet from semi-natural sites (45.8%) compared to urban sites (28.8%). While final larval size did not differ significantly between groups, growth rates were significantly lower for individuals fed with urban-sourced leaves.

The mechanisms underlying the reduced performance of caterpillars on urban plants remain uncertain, but may include heavy metal accumulation, microplastic or particulate pollution, atmospheric nitrogen or sulfur oxides, or changes in plant physiology.

Metal Pollution Shapes Earthworm Communities: Evidence from Field Surveys and Mesocosm Experiments

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Urbanization profoundly alters soil ecosystems through habitat fragmentation, contamination, and changes in land-use intensity. However, the extent to which soil organisms can adapt to these stressors remains unclear. We present findings from two complementary studies investigating the responses of earthworms to metal pollution in urban soils. In a controlled mesocosm experiment, we tested whether populations of three endogeic earthworm species collected from rural and urban lawns differed in their behavioural avoidance of metal-contaminated soils. Despite prior exposure to urban conditions, all populations strongly avoided contaminated substrates, indicating limited local adaptation and a persistent avoidance response. In a second study, we assessed how soil contamination and habitat characteristics influence earthworm communities across 18 Parisian parks. We found that concentrations of metallic trace elements—particularly mercury (Hg), lead (Pb), zinc (Zn), copper (Cu), and cadmium (Cd)—frequently exceeded statutory limit values. Earthworm species richness and overall abundance declined with increasing metal concentrations, especially in soils with low organic matter content. Community composition was shaped by both soil pH and copper levels. For example, *Allolobophora chlorotica* was more frequently found in soils with elevated copper concentrations. Our findings demonstrate that the diversity and composition of earthworm communities in urban lawns are strongly influenced by legacy pollution and edaphic conditions. Together, these studies suggest that while behavioural plasticity may buffer short-term exposure to urban stressors, it does not necessarily lead to evolutionary adaptation. These results underscore the importance of integrated urban greenspace management strategies that consider soil health to support belowground biodiversity and ecosystem resilience.

Environmental sensory pollution affects stability of predator-prey interactions

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A source of anthropogenic stress for predator-prey interactions that has increased in intensity in the last decades is “sensory pollution”, who can disrupt the information transmission and perception that is crucial for species interactions, survival, and reproduction. To understand how sensory pollution affects predator-prey dynamics, we developed a predator-prey model that integrates sensory information flow with trophic interactions. Our results show that increasing sensory pollution can induce state transitions of the predator-prey system from stable equilibria to oscillations and back to equilibria. Strikingly, high levels of sensory pollution lead to stable equilibria followed by predator extinction, suggesting that low-density equilibria may serve as early-warning indicators of extinction risk. These effects are strongly modulated by predator sensory acuity, defined as the threshold of signal strength required for predator reaction. Predators with low acuity achieve higher detection rates in low-noise environments, whereas predators with high-acuity maintain foraging efficiency under high noise, thereby stabilizing population dynamics and reducing extinction risk. Furthermore, predators exhibiting plasticity in sensory acuity can dynamically balance prey detection and identification, enhancing system resilience by mitigating the adverse effects of elevated background noise. Our study provides new insights into how sensory pollution regulates ecosystem stability and highlights the role of behavioral plasticity in maintaining ecological resilience under anthropogenic disturbance.

Contrasting effects of artificial light at night (ALAN) on common roadside herbaceous plant species

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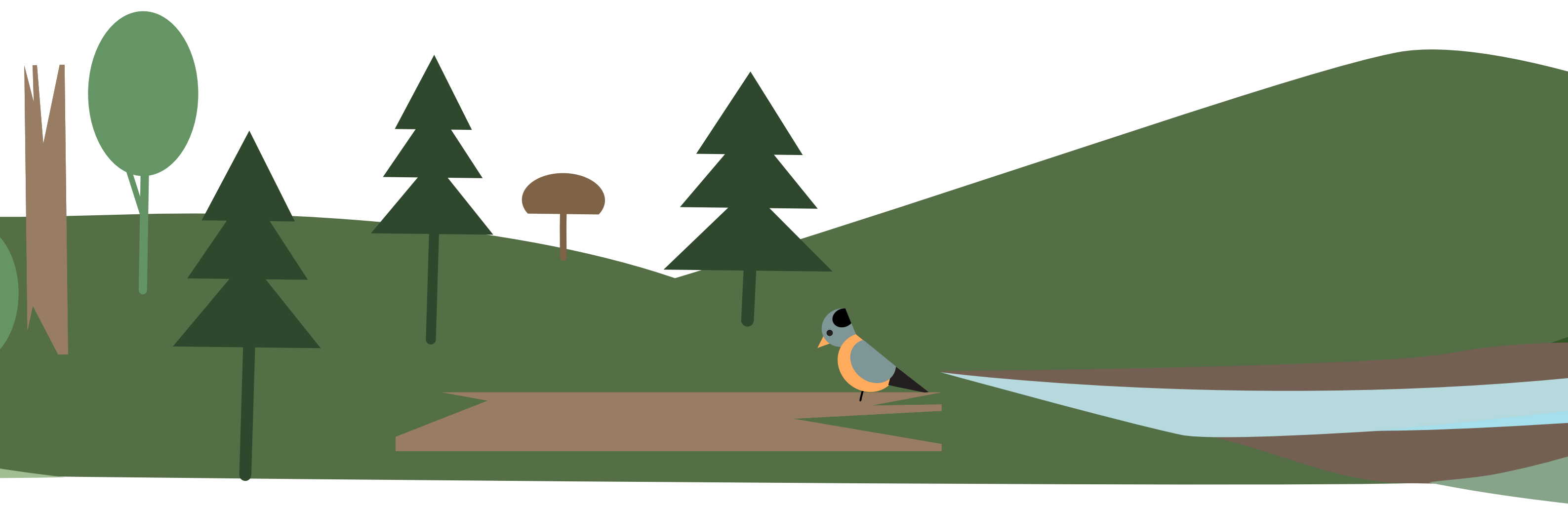
Artificial light at night (ALAN) is an increasing but often overlooked stressor in terrestrial ecosystems. Surprisingly, despite street lights lining many road verges, particularly in western Europe, very little is known about how these altered light conditions at night impact on the performance of plants. Here, we used a climate chamber experiment where we exposed twelve common roadside herbs from three functional groups to either ALAN or dark night Control treatment, to test how ALAN impacts their growth above- and belowground. Our results indicate that there are winners and losers in an illuminated world. Some species are negatively impacted by ALAN in their biomass, while others are positively impacted. A number of species seems unfazed by the light environment, growing equally well under ALAN and Control conditions. Current work is ongoing to test whether phenotypic plasticity in traits, i.e., specific leaf area, may facilitate plant growth under these different light environments. Road sides have been coined in various countries as potential biodiversity networks of conservation importance. Our results call for more detailed investigations from individual species to plant community dynamics under different ALAN conditions, to understand whether the distinct species-specific responses also lead to altered dominance and diversity patterns in roadside vegetation, and how this ultimately affects ecosystem functioning in these widespread and potentially important habitats.

Session 27

Reconciling forest protection, forest conservation and forest management in the climate crisis



Drought reactions in mixed and pure stands: Influence of tree species composition, competition and tree morphology

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Droughts in Europe are expected to become increasingly frequent and intense, which could further increase vulnerability and reduce productivity of forests. A central question in forestry is whether mixed forests enhance drought resilience. It is unclear if mixing drought-tolerant species like Douglas fir (*Pseudotsuga menziesii)* or silver fir (*Abies alba*) with European beech (*Fagus sylvatica*) improves water availability and growth. Combining the drought-sensitive, anisohydric beech with isohydric species may promote complementarity, reduce competition, while supporting timber production.

In the Spessart region (northern Bavaria), we established 94 forest plots in pure and mixed stands (Douglas fir/beech (38), silver fir/beech (31), beech stands (25)). The drought response of the trees was determined using the $\delta^{13}C$ stable isotope ratio from tree ring samples from 2015 to 2022. An increase in the $\delta^{13}C$ signal can indicate lower water availability and reduced stomatal conductance, and thus experienced drought stress. The surrounding forest around the investigated trees was recorded using mobile laser scanning to extract metrics on individual tree morphology, competitive environment and tree species composition.

This study examined whether neighborhood composition and competition in mixed or pure stands affect individual trees' stomatal conductance and drought response. We also investigated the influence of individual tree morphology on the stomatal conductance of the tree species Douglas fir, silver fir and beech in differing neighborhoods.

The results aim to provide a better understanding of inter- and intraspecific competition in mixed stands and show to what extent structural characteristics of individual trees influence their response to drought stress. Such findings are essential for adaptive forest management to promote the resilience and stability of forests under increasingly dry climatic conditions.

From curse to blessing: Sulfur-application enhances forests resilience?

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Until the late 1980s acid rain from industrial sulfur dioxide emissions have been a major cause of forest damages in Central Europe. Due to stricter air quality regulations sulfur inputs have declined, while biomass harvesting and leaching continues to deplete sulfur from forests soils. Since then, climate change-related stressors, including drought, heat, or storms, have increasingly affected Central European forests, which have also been exposed to severe attack by pests and pathogens. Despite its negative role as an air pollutant, sulfur (S) is an essential macronutrient and plays a key role in various plant metabolic and defense pathways, contributing substantially to stress tolerance and immune function. Recently, sulfur deficiency has been proposed as a potential cause of forest vitality loss on soils with poor sulfur availability. We also observed this in such forest ecosystems in the "SIRT" project. As part of the project, we are experimentally investigating whether sulfur deficiency influences stress physiology and defense capacity of European beeches (*Fagus sylvatica*) against biotic attack. In a controlled greenhouse experiment, we expose three-year-old beech saplings in a full-factorial design to two different sulfur levels (no S vs. S satiation), water availability (drought stress vs. well-watered), and biotic attack (fungal *Biscogniauxia nummularia* inoculation vs. control). During this year's growing season, we monitor physiological responses of gas exchange, water potential, impact of pathogen attack (necrosis), and the molecular status of the immune system. Our results will provide new insights into the role of sulfur nutrition in tree vulnerability to biotic attack as a linkage to currently observed declines in forest vitality, thereby offering a physiological basis for future studies exploring these patterns under natural forest conditions.

Can VOC emission profiles of drought stressed and windthrown Norway spruce trees (Picea abies) guide Ips typographus host selection?

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Norway spruce (*Picea abies* [L.] H. Karst) has experienced increasingly high rates of mortality in recent decades from spruce bark beetle (*Ips typographus L.*) attack. Outbreaks have been favoured by increasingly extreme climatic conditions, including warm and dry summers, which influence beetle phenology and propagation, along with negative effects on spruce physiology. Outbreaks are known to be initiated in drought-affected stands and following windstorms, though the underlying mechanisms of selecting weakened trees are still poorly understood. As Norway spruce is a widely planted and commercially important tree species in Germany, efforts to understand the interaction between spruce bark beetles and stressed Norway spruce is critical for reducing further losses.

Norway spruce trees naturally produce volatile organic compounds (VOCs). The VOC profiles of the trees are assumed to change when experiencing abiotic stress, such as under drought or following windstorms. It is hypothesised that bark beetles are able to detect changes in the VOC profiles. As part of the FICHTENRETTER project, a collaboration between the recently established Institute for Forest Protection at the Federal Research Centre for Cultivated Plants (JKI) and the Max-Planck Institute for Biochemistry, we aim to investigate these interactions. Firstly, a field study during the current growing season determines VOC profiles of Norway spruce under simulated drought and wind-thrown conditions, which will be presented here. Later, under laboratory conditions, the attractiveness of the these VOC profiles to spruce bark beetles will be tested, as a likely olfactory linkage during host selection. The overall outcome of the project is to better understand the underlying mechanisms that influence bark beetle behaviour and determine possible biocontrol opportunities for managing outbreaks.

Influence of forest management and abandonment on the structural complexity of forests

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Forest structure is a key factor in maintaining biodiversity and providing many ecosystem services. Forest management has a major influence on stand structure, and given the many challenges currently facing forests, there is a clear need for research into management strategies that can promote near-natural and diverse forest structures.

Studies on management-related structural differences have mainly focused on the comparison of intensively managed and unmanaged stands. The aim of this study is to compare several management concepts and to focus on two of the most common used silvicultural tree species in Germany, *Fagus sylvatica* and *Pinus sylvestris*. Along a gradient of decreasing management intensity, 98 plots were established in forests of northeastern Germany: intensively managed, naturalness promotion management, recently unmanaged and long-term unmanaged. The stand structural complexity index (SSCI;(Ehbrecht et al. 2017)) will be calculated from terrestrial laser scanning data. Extensive information on past silvicultural measures were researched for each plot and will be included in the analyses. Additionally, a modified SSCI of the understory will be calculated and analyzed. It is hypothesized that significant differences of the SSCI will be observed between the individual management classes and between the two main tree species. The intensively managed stands are expected to demonstrate less stand structural complexity than the more natural ones, as silvicultural interventions have been known to result in a more homogeneous stand structure.

Ehbrecht, Martin; Schall, Peter; Ammer, Christian; Seidel, Dominik (2017): Quantifying stand structural complexity and its relationship with forest management, tree species diversity and microclimate. In: Agricultural and Forest Meteorology 242, S. 1–9. DOI: 10.1016/j.agrformet.2017.04.012.

Ecological and economic trade-offs of bark treatments for European Spruce Bark Beetle regulation across scales

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Increasing disturbances, climate warming, and outbreaks of the European Spruce Bark Beetle (*Ips typographus*) led to unprecedented amounts of Norway spruce timber (*Picea abies*) damaged in recent years. To fulfill forest protection goals, damaged or weakened spruce trees are either salvage logged or made unsuitable for breeding by debarking. Manual debarking is not efficient enough for large amounts and the extraction of dead wood can compromise biodiversity. This highlights the need for innovative pest management strategies that can treat large quantities of wood while preserving forest functionality. We research mechanical bark treatments as alternatives to salvage logging for bark beetle regulation, while controlling for variations in management and climate across Germany. We quantified pest control efficiency, economic effort, wood properties and effects on species richness as well as community assembly of saproxylic beetles, fungi and bacteria over the first two years. The repeated handling of logs with the harvester for bark removal, indicates efficient reduction in bark beetles, which is important for the treatment of large amounts of calamity wood. Additionally, we confirm motor-manual bark gouging and debarking as effective methods for low quantities. With increase in bark removal intensity, saproxylic beetle as well as bacteria richness decreased while for fungi we observed an increase. Differences in moisture content between treated and control logs was found as main driver for changes in fungi and bacteria community assemblages, while other elements and the calorific value remained constant. After a triple harvester treatment (large volumes) or motor-manual bark gouging (small volumes), logs can be left for intermediate storage to buffer economic bottlenecks during landscape disturbances. *I. typographus* is effectively reduced while adverse effects on saproxylic biodiversity can be minimized.

Effects of high stump retention and partially cleared stands on bird and saproxylic beetle diversity after bark beetle outbreak

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Climate change-induced weather extremes, such as droughts and heatwaves, are weakening forest ecosystems worldwide, making them more vulnerable to natural disturbances like windthrow, wildfires, and insect outbreaks. In the Northern Hemisphere, spruce forests have been particularly affected by bark beetle infestations. This has resulted in substantial economic damage. A common post-disturbance management practice involves the felling and removal of infested trees to recover economic value and limit further beetle spread. Post-disturbance logging can pose significant threats to biodiversity and ecosystem services, implying integrative management strategies that balance ecological and economic demands. We investigate the effects of different post-disturbance management strategies, including (a) undisturbed spruce stands, (b) partially cleared stands (50% of deadwood retained), (c) retention of high stumps, and (d) complete clearing, on the diversity of bird and saproxylic beetle communities in bark beetle-affected spruce forests in Germany. Preliminary results indicate highest species numbers of birds in undisturbed control plots and partially cleared stands, and lower richness in areas with high stump retention and clear cut.

Impact of management components, abiotic factors and soil biological activity on carbon stocks in temperate forests

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The impact of forest management on the sequestration potential of forests is a heavily debated issue in climate policy. To contribute to this discussion, we analyzed the above- and belowground organic carbon (OC) stocks of forest ecosystems and disentangled the influence of abiotic, biotic and management factors. To cover regional variation, research was conducted in four ecoregions of north-western Germany that differ significantly in site conditions and natural forest community. Within each region, 50 plots were established along a gradient of forest management intensity, ranging from forest reserves where management ceased 30-50 years ago to conifer plantations.

Aboveground OC stocks were significantly higher in the base-rich regions, increased with clay content and soil pH and were strongly influenced by stand age, and timber harvest volume. Soil organic carbon (SOC) stocks were mainly controlled by abiotic site conditions. Beech forests on Cambisols in low mountain areas had SOC levels of ~100 t/ha. In lowland oak forests on Stagnosols, these levels were on average 80 t/ha higher, reaching at maximum 300-400 t/ha. SOC stocks in the organic layer increased with conifer proportion across all study regions. Thick organic layers under confers are rather vulnerable and can be rapidly decomposed after canopy opening disturbances such calamities, windthrow and fires. The mineral soil plays a critical role in long-term stable carbon storage. Higher proportion of broadleaved trees led to marginally lower SOC in the mineral soil. Significant liming effects could be found to a mineral soil depth of 5 - 30 cm in base poor low mountain forest, leading to average losses of 22 t/ha SOC. Structural equation modelling revealed that a higher proportion of deciduous trees raised biological activity (measured by microbial biomass and earthworm abundance) which again enhanced a transfer of OC from the labile surface pool (organic layer) to the more stable mineral soil pool.

Far from carbon copies: Forest reorganization impacts carbon balance differently across temperate forest landscapes

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Forests mitigate anthropogenic climate change as they take up and store vast amounts of carbon. However, environmental change – especially warmer and drier climate conditions and increasing disturbances – influences the ability of forests to remain carbon sinks as they reorganize via shifts in composition and structure. Future carbon dynamics will likely differ among forests: landscapes with low disturbance activity could see increases in carbon uptake due to climatic changes improving growing conditions, while landscapes with currently high disturbance activity could be at risk of turning into carbon sources if carbon recovery intervals exceed disturbance return intervals. The landscape-scale impacts of climate change on forest reorganization and carbon dynamics unfold across decades to centuries. To study these effects, we here applied the process-based forest simulation model iLand to three forest National Parks (Shiretoko, JP; Berchtesgaden, DE; Grand Teton, US) under current and future climate. We asked, “How do carbon dynamics of reorganizing forests differ from those of resilient forests?”, and “Which particular shifts in composition and structure are most relevant for future carbon dynamics?”. We found that the consequences of forest reorganization varied between landscapes, with reorganization increasing carbon stores in Shiretoko, while largely turning forests into carbon source in Grand Teton, especially under dry climate scenarios. This divergence was due to climate and disturbance change promoting forest growth in Shiretoko – where structural indicators like basal area increased – while hampering it in Grand Teton – where those indicators decreased. We conclude that resilience *sensu strictu* – i.e., the conservation of forest composition and structure – does not necessarily equate stability in forest functioning under climate change. Our analysis suggests that for the same level of functioning in a changing climate, reorganization might be necessary.

Modelling drought-induced forest dieback and reforestation scenarios in the Harz Mountains under climate change

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German forests, especially spruce-dominated regions, are increasingly affected by drought events driven by climate change. In the Harz mountains, which were severely impacted by the 2018-2020 multi-year drought, over 70% of spruce stands have died. This extensive dieback reduces landscape multi-functionality by losing habitat for biodiversity, altering water & carbon cycles, and diminishing nutrient retention. However, simulating such massive dieback events and subsequent reforestation remains a challenge, as existing forest models often fail to adequately capture these dynamics.

We apply the individual-based, spatially explicit forest model FORMIND to simulate forest dynamics and drought-induced tree mortality across the whole Harz region from 2012 to 2023. Preliminary results indicate a marked decline of forest productivity during the 2018 peak drought year. Yet, discrepancies between simulated and observed mortality remain, both in spruce-dominated forest stands as well as in mixed or broadleaf stands.

These results underscore the need to incorporate missing processes and drivers, including improved modelling of biotic damaging agents like bark beetle infestations and more mechanistic representations of drought-related mortality. To enhance tree mortality estimation, we are testing refined mortality routines and additional proxy measures of tree fitness, such as tree growth efficiency and productivity-related mortality thresholds.

In a next step, we will analyse and compare various reforestation scenarios, including spruce

Temporal patterns of soil meso- and macrofauna in the last decade under the influence of forest management

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Biodiversity loss poses a major threat to ecosystem functioning, yet belowground trends, particularly in forest soils, remain understudied. We analyzed a 12-year dataset (2008–2020) of soil meso- and macrofauna from forests with varying management intensities in the German Biodiversity Exploratories. In contrast to documented aboveground declines, neither species richness nor γ-diversity of soil fauna declined over time. Mesofauna density and diversity fluctuated significantly across years and regions, closely linked to soil moisture in preceding winter months and during sampling. Macrofauna densities showed inconsistent temporal trends, depending on region and forest management. Community stability was strongly associated with species asynchrony and effective diversity, supporting the insurance hypothesis. Forest management influenced both soil fauna composition and their sensitivity to precipitation, thereby modulating stability. These findings reveal notable resilience of soil animal communities and highlight the importance of biodiversity for maintaining temporal stability under environmental variability.

Session 28

Resilient forests under climate change: integrating perspectives of ecologists, modelers, and stakeholders

Early leaf senescence in response to drought – From quantification towards projection

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In recent years, unprecedented responses of deciduous tree species to intensifying drought stress have been observed in the temperate forests of central Europe, such as the widespread occurrence of premature leaf coloration and litterfall – collectively referred to as early leaf senescence. This phenomenon has been reported both as a protective physiological reaction aimed at reducing evapotranspiration to avoid xylem cavitation and hydraulic failure, but also as a direct consequence from such failure. In European beech in particular, early leaf senescence has been observed to indicate drought damage, eventually leading to crown dieback and even tree mortality. Still, the extent of forest areas affected in recent years remains largely unknown, and the underlying drivers as well as the long-term consequences for forest vitality and productivity are poorly understood.

To close this gap, we here assess the temporal and spatial patterns of early leaf senescence from 2018 to 2023 across the deciduous forests in Germany by combining ground-based observations from ICP Forests and phenological records from the German Weather Service with high-resolution satellite time series from Sentinel-2. We model the mapped occurrence of early leaf senescence using key environmental drivers , focusing on meteorological and soil drought, while also considering remotely sensed stand characteristics and physiological differences between tree species. To explore potential lasting impacts on forest vitality and carbon uptake, we evaluate satellite-derived indicators of canopy health and leaf area in subsequent years. Additionally, we present an approach for mechanistically incorporating early leaf senescence into an existing process-based ecosystem model (LandscapeDNDC) in order to simulate impacts on carbon dynamics. Our findings advance the understanding of drought stress responses in temperate deciduous forests and offer a framework for better predicting forest resilience and carbon cycling under future climate conditions.

Are fine roots an early indicator of drought stress in mature beech?

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European beech (*Fagus sylvatica L.*) is known to be sensitive to drought. Clearly visible responses to drought include leaf shedding and browning. Severe drought leads to branch drop and crown dieback, resulting in increased crown transparency in mature beech. Fine roots respond to drought earlier and more strongly than aboveground organs, making them a potential early indicator of drought stress. However, we lack a fundamental understanding of how changes in fine root vitality might be reflected in aboveground morphological responses, i.e. crown structure, of adult beech trees.

In our study, multitemporal terrestrial laser scanning (TLS) and soil core data are used to quantify crown and fine root traits under different soil water conditions (dry – intermediate – wet) in the Beneath project. We measured crown vitality, based on the structure of the finest branches, and fine root mortality, i.e. the ratio of fine root biomass to necromass (FRB to FRN ratio). To quantify the effect of fine root mortality on crown structure, linear models were fitted using a stepwise approach with different radii of the sample plots and different inclusion of trees. A distance of 5-8-10-12 m from the centre of the root sampling plot was tested, as well as including only dominant trees or the entire tree community in the model. We expected that a decrease in the FRB to FRN ratio is an early indicator of reduced beech tree vitality following drought stress, and that this reduced vitality reflects delayed in the tree crown structure.

First results showed a significantly lower FRB to FRN ratio at the dry study site in July 2022, and significantly lower fine branch lengths for the dry and wet study sites in February 2024 compared to December 2021. Linear models revealed an increase in fine branch formation of dominant beech trees with increasing FRB to FRN ratio.

Douglas-fir raises xylem safety in response to a drier climate but also increases supported leaf area

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Phenotypic plasticity in traits related to plant water relations and hydraulics is fundamental for the adjustment of trees to rapid climate change. It is not fully understood, how conifers can acclimatize their hydraulic system and foliage to a reduction in water availability. For the economically important species Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), we assessed the acclimation potential to a drier climate for mature trees of a common seed source by exploring the phenotypic plasticity of 15 hydraulic and water status-related traits across a steep precipitation gradient in the North German lowlands. Branch embolism resistance (P_{12}, P_{50}), turgor loss point (ΨTLP), hydraulic safety margin (HSM), Huber value [Hv], foliage area and needle lifespan, and leaf mass $\delta^{18}O$ and $\delta^{13}C$ were measured.

Across the 10 study sites, precipitation explained a large proportion of the variance in P_{12}, P_{50}, ΨTLP, leaf $\delta^{18}O$ and $\delta^{13}C$ and Hv, while its influence on foliar traits was small. P_{12} and P_{50} increased in resistance by ~0.2 MPa and ΨTLP by ~0.1 MPa with a precipitation reduction by 310 mm yr-1, indicating significant increases in embolism resistance and HSM with increasing climatic aridity; the extent of adjustment was small, however. Contrary to expectation, needle lifespan and foliage area increased with a reduction in precipitation, while Hv counter-intuitively decreased, suggesting greater foliage drought exposure at drier sites.

We found fairly high plasticity in hydraulic and foliar traits and enhanced embolism resistance in drier climates, which might distinguish Douglas-fir from other conifers. However, the Hv reduction with decreasing precipitation suggests drought vulnerability in drier lowland regions.

Timing matters: divergent soil desiccation patterns, not isohydricity, drive stem water and growth dynamics in European beech and Douglas fir

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Trees exposed to soil drought close their stomata to reduce transpiration, but inevitably face water loss and turgor decline in the stem cambium, which reduces stem radial growth. Isohydric species regulate their stomata more stringently than anisohydric species to reduce leaf water potential fluctuations, but it is unclear whether isohydric behavior is linked to smaller reversible stem shrinkage during drought (reflected in a smaller 'minimum tree water deficit', TWD) and a lower drought sensitivity of radial growth.

Operating sap flow sensors and precision dendrometer synchronously, we measured stem water content (SWC), stem rehydration, sap flow (as a proxy of transpiration) and radial growth in nearby mature trees of anisohydric European beech and isohydric Douglas fir during progressive soil desiccation. We determined the critical soil moisture levels (expressed as Relative Extractable Water, REW) and the elapsed time associated with 30-90% downregulation of these physiological traits.

Sap flow and growth started to decline in both species at REW ~0.6, well before the decline of stem rehydration. Due to its higher transpiration, Douglas fir approached a 50% drop in SWC, sap flow, stem rehydration and growth faster, with proceeding soil desiccation than beech, demonstrating a higher drought-sensitivity. In mixed stand, it took 200-500 kPa hours longer for both species to reach these critical declines. This delay suggests positive neighborhood effect in beech-Douglas fir mixture by enhancing drought resistance of both species.

Our findings demonstrate contrasting patterns of sap flow and growth reduction with proceeding soil desiccation and drought effects on radial growth before decline in stem rehydration capacity in isohydric and anisohydric tree species.

The new normal: increasing probability of late frost and drought. Effects on juvenile trees.

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Drought and late frost events are major disturbances within forest ecosystems. Under a climate change regime, their likelihood, frequency and severity are expected to change, which makes it important to investigate their impact on trees. In a potted experiment, we simulated late frost and drought regimes by putting the trees in a cooling truck to simulate a frost night after bud burst and by controlling the watering during drought season. Overall, the experimental design had five late frost levels and eight drought levels with double control groups, which led to 70 groups and 2250 pots in total. 33 forestry-relevant species were tested within the experiment. Goal of this experiment was to analyze the influence of both disturbances on leaf phenology and other survival parameters in the post disturbance year. This experiment showed differences in responding to drought and late frost between multiple tree species.

Simulating drought-driven tree mortality of European Beech and Norway Spruce: the roles of predisposing, inciting, and contributing factors

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Drought increasingly shapes forest dynamics, impacting tree survival and species composition. We evaluated a novel predisposing-inciting (PI) drought mortality framework within the forest gap model ForClim v4.1, focusing on European beech (*Fagus sylvatica L.*) and Norway spruce (*Picea abies L.*). Additionally, we integrated a bark beetle module to better capture biotic interactions exacerbating spruce mortality. We tested three hypotheses across diverse German ICP-Level II sites: (1) the PI framework's is effective over broad climatic and ecological gradients, (2) soil available water capacity (AWC) significantly influences drought-induced mortality, and (3) low local soil heterogeneity increases drought vulnerability.

Simulations showed that ForClim reliably reproduced drought-induced mortality patterns but revealed discrepancies due to sparse empirical data and bark beetle sensitivity. Soil water availability proved pivotal: sites with low AWC experienced elevated tree mortality, while high AWC buffered drought impacts, aligning simulations closely with observations. Moreover, local soil heterogeneity mitigated mortality risks by offering microsite variability, which are particularly crucial under drought stress.

Our results underscore (1) the strength of process-based modeling in elucidating drought vulnerability mechanisms and (2) the need for enhanced regional calibration and finer-scale empirical data for improved predictive accuracy. This research advances our understanding of forest resilience to drought, ultimately guiding management under changing climate conditions.

Tree mortality trends in the Swiss National Forest Inventory

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Tree mortality has increased in Europe and globally as a result of climate change and associated intensified disturbance regimes. Assessing whether these increasing mortality trends affect all species equally, and under which conditions, is crucial to foresee how forests will develop under future conditions. This study aims to explore two key aspects of tree mortality in Switzerland: (1) whether species-specific tree mortality has increased over the past decades, and (2) the potential role of climate in shaping these tree mortality patterns. To address these questions, we used data from the Swiss National Forest Inventory, which provides a comprehensive and representative sample of the entire forested area of Switzerland. We developed for each predefined species group two Generalised Additive Models: one to assess the temporal trends in tree mortality and another to examine the impact of climate. The trend model focused on identifying any changes in mortality over time, independent of climate influences, while the climate model aimed to evaluate the relationship between tree mortality and climate factors, excluding the temporal component already inherent in the climate data. Our findings suggest that in Switzerland, tree mortality has been increasing over the years for most species groups, with more pronounced patterns at lower elevations. Additionally, we observed higher mortality rates in sites experiencing drier conditions, especially for conifers. While a causal relationship between climate change and increasing mortality trends cannot be established, our results suggest that factors such as rising temperatures and more frequent droughts could be contributing to these observed patterns. If current climate trends persist, future tree mortality could rise further, with conifers being more vulnerable than broadleaved species.

Current trends of forest regeneration in a changing world

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Forest regeneration is crucial for sustaining future forest generations, especially in the face of global climate change, enhanced tree mortality, and increased disturbances. Despite its importance, the current status and recent changes in forest regeneration remain under-evaluated. In this study, we assess key indicators of forest regeneration, including total density, species richness, and climate-adapted species composition, using data on small trees from the German National Forest Inventory. In addition, we analyse trends in forest regeneration by examining repeated inventory data. Our results reveal significant gaps and trends in forest regeneration, providing valuable insights for forest management and stakeholders.

Microclimatic buffering through deadwood retention and understory vegetation after bark beetle disturbance

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Bark beetle outbreaks and summer drought have led to large-scale forest dieback across conifer-dominated Central European low mountain ranges. Canopy loss leads to significant microclimatic changes in affected forest stands, particularly increased surface temperatures that may hinder tree regeneration. While previous studies have focused on the buffering capacity of intact canopies versus open sites, less is known about the role of deadwood retention and understory vegetation in moderating post-disturbance microclimates. In this study, we investigate (1) how coarse and fine woody debris (CWD and FWD) influence microclimate and (2) the extent to which understory vegetation contributes to temperature buffering. We hypothesize that dense understory vegetation in later successional stages will synergistically enhance microclimatic buffering by shading the forest floor and reducing temperature extremes. The study sites with varying levels of deadwood retention (clear-cut, high stumps, snags) were located across three low mountain ranges in Thuringia, Germany. We surveyed vegetation in 2024 within 0.5 m radius plots (N = 42), and microclimate loggers (N = 90) measured temperature and humidity at 15-minute intervals. The results show that FWD exerts a more substantial effect than CWD in moderating soil and soil surface temperatures and enhancing soil moisture. Our findings support the management concept that, in the absence of an intact canopy, deadwood and understory vegetation function as critical structural components that can partially compensate for overstory loss. We propose an expanded framework for forest microclimate management, where deadwood retention and vegetation dynamics play a key role in post-disturbance recovery and climate adaptation strategies.

Drought impacts on forest ecosystems: a case study in the forest around Darmstadt

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Climate change strongly impacts forest ecosystems, exacerbating drought stress, tree mortality, and shifts in species composition particularly in Central Europe. In a large forest area (>1960 ha) owned by the city of Darmstadt ('Darmstädter Stadtwald'), recent drought led to a huge increase in tree mortality since 2018, currently resulting in 7 % dead trees and 14 % severely damaged tree crowns. Strong edaphic gradients and management contributed to a huge local variation across sites in crown damage (0 – 100 %), canopy openness (0.8–74 %) and resulting microclimate (T_{max}: 22 – 43°C at soil surface).

We established 70 long-term research plots in the 'Darmstädter Stadtwald' to study a broad set of ecosystem components and the diversity of plant and animal taxa together with students in a MSc course and in several Bachelor and Master theses. In the analyses presented here, we particularly focus on communities of soil-dwelling organisms (oribatid mites, earthworms, terrestrial isopods) that play a crucial role in maintaining ecosystem functions through organic matter decomposition and nutrient cycling. Oribatid mites and earthworms were significantly more abundant in moister regions, while isopods showed no clear abundance differences. Soil moisture and tree community composition were the primary drivers of decomposer density, diversity and community composition. Microclimatic changes and corresponding canopy openness in response to tree mortality and altered species composition significantly influenced decomposer communities. Drought-prone sites were favored by drought-tolerant taxa, suggesting ongoing shifts in belowground biodiversity.

Enhancing insect diversity through structural enrichment in managed forests: Insights from a transnational experiment in Italy and Germany

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Managed forests often lack structural complexity and continuity of deadwood habitats, leading to reduced biodiversity, particularly for saproxylic organisms. Although protected areas such as those in the Natura2000 network conserve critical habitats, they are frequently embedded in intensively used landscapes and suffer from poor connectivity. The LIFE SPAN project addresses this issue by establishing a network of Saproxylic Habitat Sites (SHS) within managed forests in Italy and Germany that are connected to Natura2000 areas. These SHS include experimental interventions aimed at enhancing structural diversity, such as the creation of artificial tree microhabitats, e.g., uprooted trees, tree cavities and basal slits or pollarded trees, small forest openings and forest gaps combined with conventional forest-thinning activities. We monitored insect assemblages using flight interception traps, as well as birds and bats, across 18 SHS in Germany and 25 SHS in Italy over 4 and 3 years, respectively. Using linear mixed models, we assessed the temporal effects of each intervention on abundance and species richness of our target orders. Our preliminary analyses reveal that forest gaps, for example, significantly promoted beetle diversity and abundance over time in both countries. In contrast, habitat trees and thinning activities did not show measurable effects compared to control sites. These findings underscore the importance of targeted structural interventions in production forests to foster habitat quality and landscape-level connectivity for forest-dwelling beetles.

Exploring climate change effects on Swiss Alpine forests: management, disturbances, and ecosystem services

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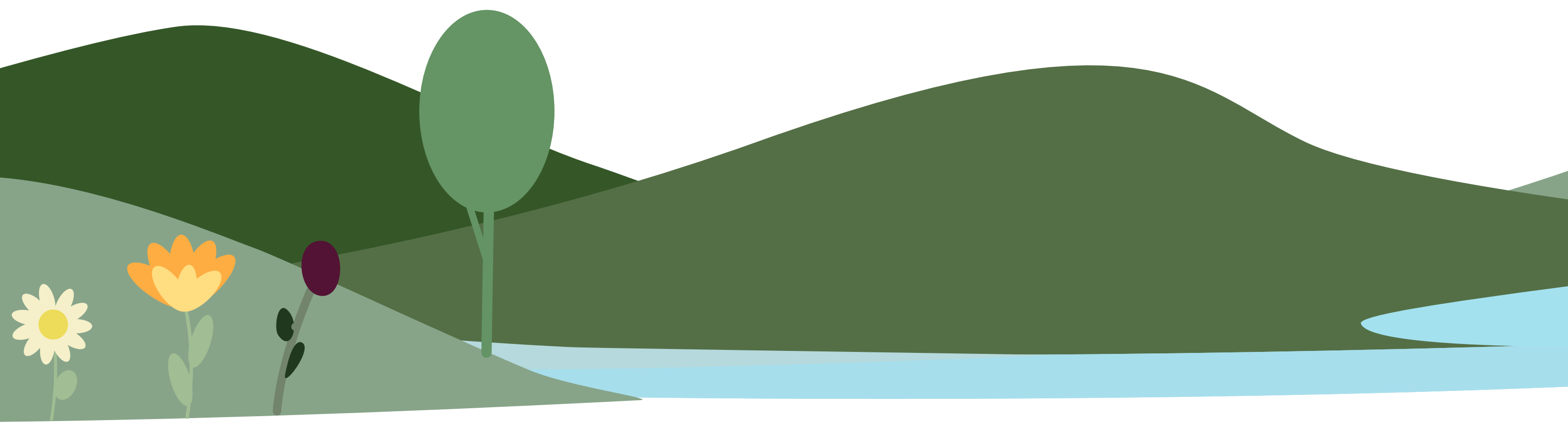
Sustainable forest management is likely to be critical for maintaining the functionality of ecosystem services (ES) under climate change. Our work focuses on a Living Lab (LL) situated in the canton of Grisons (Swiss Alps), covering an area of over 1200 km². This LL represents the Alpine environment, featuring a wide elevational range (700 to 2500 m asl) and multiple tree species, including Norway spruce (Picea abies (L.) Karst), larch (Larix decidua Mill.), and Swiss stone pine (Pinus cembra L.), with some broadleaved species at lower elevations. Forests in this region provide a variety of ES, particularly protection from natural hazards such as rockfall and avalanches. We use the spatially explicit, process-based dynamic model LandClim, which incorporates natural disturbances (e.g., wind, bark beetle outbreaks), to assess how different scenarios of climate change (e.g., RCP 4.5 vs. RCP 8.5) and different forest management strategies affect the future provision of timber and the protective function of forests. Simulations are initialized at the stand scale based on detailed forest inventory data. We explore a range of management strategies, developed in close collaboration with local stakeholders, to identify sustainable balances between competing ES under climate change. Natural disturbances and their changing regimes are also explicitly considered in the simulations. Overall, this study aims to contribute to more resilient forest management strategies, enhancing the sustainability of ES provision and supporting adaptation to climate change.

Session 29

Plant population biology and seed ecology



No evidence for small-scale local adaptation to productivity in Bromus erectus & Arrhenatherum elatius within a heterogeneous grassland suggests tolerance to environmental heterogeneity

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Local adaptation is a common phenomenon in plant species inhabiting a broad range of environmental conditions. It has been chiefly investigated across large climatic or altitudinal gradients, and resulted in practical applications like recommending regional seed material ('Regio Saatgut') for restoration and conservation measures. However, less is known whether local adaptation is remodeled by environmental heterogeneity at much smaller spatial scales.

Here, we tested for small-scale local adaption within a heterogeneous 10 ha protected calcareous grassland that spans from nutrient-poor to productive patches. From 63 vegetation plots (2m x 2m) across the grassland, spanning a large productivity gradient of mean Ellenberg indicator values (EIV) for nutrients from 2.8 – 7.3, we collected seeds of >100 mother plants for both of the dominant grasses: *Bromus erectus* (dominating toward poorer patches) and *Arrhenatherum elatius* (dominating toward productive patches). We raised their offspring in a common garden and measured 11 functional traits potentially related to productivity (e.g. seed mass, germination, SLA, LDMC, stomata size & density, biomass, root traits).

All traits varied substantially among plants. However, in neither species and none of the traits was this variation correlated to productivity (EIV nutrients) of the plants' original vegetation plot. Hence, we found no evidence for local adaptation to the small-scale heterogeneity within the grassland, suggesting that geneflow via seed or pollen dispersal exceeded the contrasting selection pressures between patches.

This is remarkable because the seed material originated from mother plants that were obviously able to germinate, grow, survive, and reproduce within their patch without local adaptation. This suggests that the genotypes inhabiting the grassland can attain substantial fitness in productive and very poor patches alike, suggesting a broad tolerance to environmental heterogeneity.

The evolution of annual plant diversity with between-year environmental fluctuations

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Between-year fluctuations in the environment can drive diversity in annual plants when a seedbank is present, that is when a proportion of seeds stays dormant for multiple years before germination. The underlying mechanism is well known as the temporal storage effect, and has been studied intensively for decades. In previous models on this topic, however, niche partitioning could occur only during one life stage (e.g., during adult growth and reproduction), while it is well known that also the germination niche of seeds could diverge within and between species. To this end, we use mathematical modeling and individual-based simulations and study how the co-evolution of the germination and post-germination niche affects diversification. We find that such co-evolution facilitates plant diversity when seed germination is adaptive, that is when seeds could germinate preferentially in those years that also favor their subsequent growth and reproduction. In turn, maladaptive germination plasticity opposes diversity, when seeds are not able not direct their germination to beneficial years. We further find that the evolution of plant diversity can be constrained in sexually reproducing species when recombination breaks apart genetic associations and phenotypic covariance among germination and post-germination traits. This constraint in sexually reproducing species, however, can be overcome either by strong genetic linkage between both traits, or by temporal assortative mating when individuals germinate and thrive in alternate years. Overall, our results shed new light on a basic coexistence mechanisms and better illustrates how diversity in annual plants evolves in fluctuating environments.

Growing plants from aged seed: effects on seedlings and adult plant traits

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Stored seeds are crucial repositories of plant genetic diversity. However, long-term storage inevitably leads to seed deterioration and loss of viability. Chemical processes within the seeds during storage can influence germination and adult plant traits (direct storage effects). Furthermore, seed mortality during storage is likely non-random, potentially causing the loss of certain genotypes (invisible fraction).

The extent to which these phenomena are relevant across species, particularly for wild plant species with high genetic variation, remains unclear. To address this, we simulated long-term storage by exposing seeds of 14 grassland species to artificial ageing conditions (50% RH, 45°C) and compared plants grown from the aged seeds with plants from fresh seeds in a common garden experiment.

Artificially aged seeds germinated later, the developing seedlings had lower survival rates and reduced growth. Adult plants that grew from aged seeds flowered later, produced fewer flowers, and had less biomass by the end of one vegetation period than those from fresh seeds. The effect of the ageing treatment varied between study species, but the trend was overall significant across species.

Our results show that seed storage affects seedling performance, plant growth and flowering phenology. These direct effects should be considered when using stored seeds for species conservation, evolutionary research or ecosystem restorations.

Seed production for restoration: the timing of seed harvest affects traits of the progeny plants

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Restoration of terrestrial ecosystems typically requires large quantities of native seeds to establish native vegetation. To provide seed in sufficient quantities, seed production companies grow native wild plants as crops on large agricultural fields to produce seed, and such farm-propagated seed is then available for ecosystem restoration. We have shown that if this production process is repeated over several generations, the wild plants can evolve towards a domestication syndrome, parallel to the early domestication of crops. This includes larger size, retention of mature seeds and synchronisation of flowering. However, it is not clear which steps in seed production contribute most to the evolution towards domestication. One of the production steps is timing of harvest. Most large-scale seed production fields are harvested once, at the peak of seed ripening. In a production population that harbours heritable variability in reproductive phenology, such as the onset of flowering or the timing of seed ripening, a single seed harvest may select for genotypes that have ripe seeds at the time of harvest, while early or late ripening genotypes are lost. To test whether this is indeed the case, we obtained seeds from 12 species that had been manually harvested up to 15 times per seed ripening season from the same production populations. We grew the progeny plants in a common garden and found that the time of seed collection affected seed weight, germination time and flowering time. Specifically, later seed collection resulted in later flowering progeny plants in 40% of the study species. Our results show that the timing of seed harvesting affects plant traits. If seed producers wish to minimise the evolution towards domestication syndrome during seed production for restoration, a good step would be to harvest the production population several times per season.

Effects of experimental warming and climatic origin on alpine plant germination and its plasticity

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Mountain ecosystems are disproportionately exposed to global warming which may put alpine plant species at particular risk. Alternatively, plants may find suitable microclimates at most elevations due to high small-scale microclimatic heterogeneity. Furthermore, phenotypic plasticity can help plants to overcome negative effects of global warming. Germination is strongly sensitive to climate and may present a major bottleneck to species. Yet, little is known on alpine plant germination under warming and if this is co-determined by the macro- and/ or microclimate of the seeds' origin.

Here, we investigated intraspecific variation in germination fraction and timing of six co-occurring alpine plant species sampled from different micro- and macroclimatic (i.e. elevational) origins under three temperature treatments (low, moderate, extreme warming).

Our results show that species were plastic in germination fraction and timing to temperature, with all species being able to germinate even under extreme warming. Interestingly, the germination fraction of herbs was significantly affected by temperature but not of the shrub or the grass. Warming mostly hastened germination depending on species but not on the macro- and microclimatic origin of the seeds. Instead, seeds originating from the upper range margins, i.e. colder macroclimate, generally germinated less irrespective of the temperature treatments. Furthermore, microclimatic origin affected germination fraction and timing as well as plasticity in germination fraction.

Our results suggest that global warming will impact alpine plant regeneration from seeds through maternal effects and concurrent effects during germination. Furthermore, the importance of the climatic origin for regeneration from seed confirms the need to think beyond global climate trends towards organismal exposure.

Forest structure and connectivity jointly shape functional diversity and composition of seed rain in recovering tropical forests

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The natural recovery of tropical forests crucially depends on seed dispersal by animal frugivores. However, it is little understood how the interplay of local forest structure and landscape-level connectivity to other forest patches shape seed dispersal towards recovering forest. Here we combined empirical data from a seed rain study across 24 recovery plots in the Ecuadorian Chocó with detailed observations of plant-frugivore interactions on the same plots. Both for the collected seed species and the interacting plants and animals, we measured functional traits related to plant and animal size, plant successional stage and animal mobility. Using structural equation models, we quantified the direct effects of forest structure and connectivity as well as their indirect effects mediated by plant-frugivore interactions on the functional diversity and composition of seeds. We found that functional seed diversity (i.e., the trait diversity of seeds) was primarily driven by indirect effects of the local plant-frugivore interactions, whereas functional seed composition (i.e., the mean trait values of seeds) was mediated both by the local interactions and by a direct effect of forest connectivity. Our findings suggest that functional seed diversity is primarily related to local factors, whereas the type of seeds, and in particular the presence of large-seeded, late-successional plant species, was also driven by the landscape-level connectivity of the recovering forests. Hence, both local conditions and landscape-level factors are important in shaping natural forest recovery through seed dispersal.

Legacy effects of farming practices and climate conditions on the seed microbiome and its consequences on the next generation of plants under water stress

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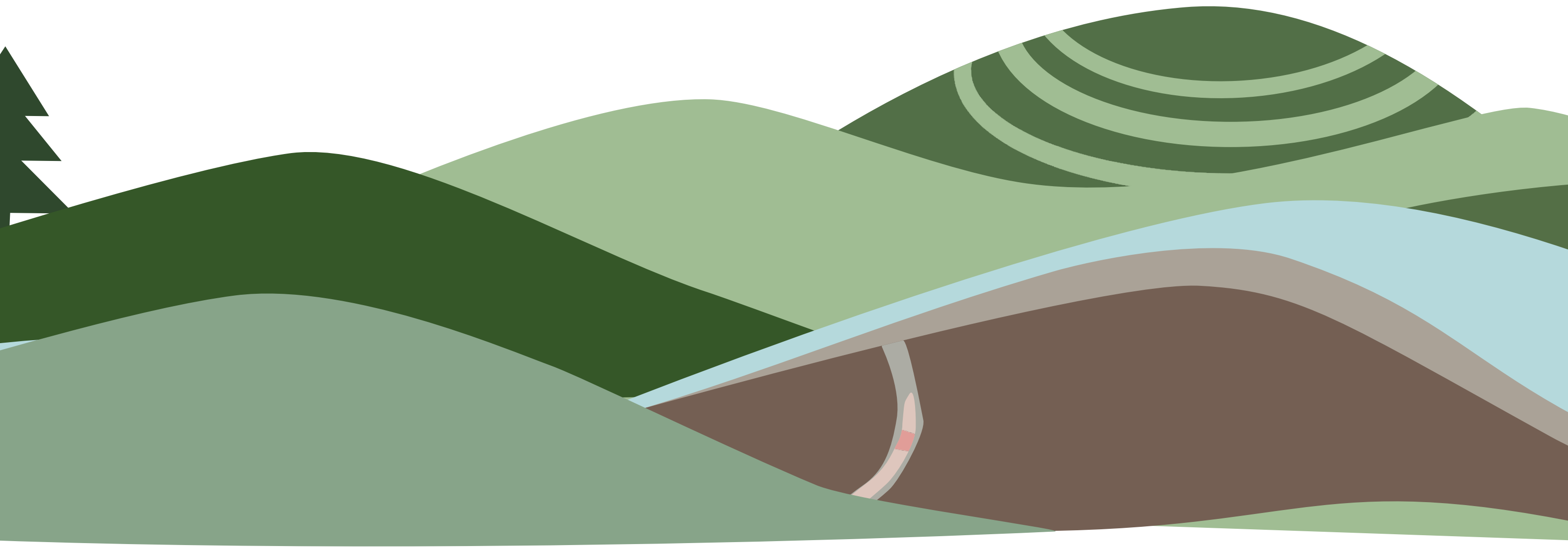
Seed-associated microbiomes play a critical role in plant health and serve as the primary source in shaping microbial communities in the next plant generation. In this study, we investigated how the farming (conventional vs. organic) and climate (ambient vs. future) history of seed-associated microbiomes impact the growth of the next generation of plant and their rhizosphere microbes under water stress. We collected the seeds in three different years (2018, 2021, and 2024) from the Global Change Experimental Facility (GCEF) in Bad Lauchstädt. The seeds carried a distinct epiphytic and endophytic microbial communities reflecting the multi-year land use and climate conditions. A greenhouse experiment was conducted using these seeds to assess plant performance and microbiome dynamics under drought conditions. Pre-sowing analysis of seed epiphytic and endophytic microbiomes, followed by rhizosphere microbiome profiling post-harvest, was performed using 16S rRNA gene sequencing. Results revealed that year-wise pattern of seed-associated microbes was clearly reflected in above-ground biomass. The seeds from the field history of distinct farming and climate history promoted better growth under water stress than seeds with no such environmental history (controls). Furthermore, we found that seed-borne microbiota strongly influenced the diversity and the structure of the rhizosphere microbial community on the next generation of plants, suggesting a dominant vertical transmission effect and persistence of maternal microbiome signatures. Our findings highlight the role of seed microbiome history in modulating plant performance and microbial succession under stress. These insights provide a foundation for utilizing seed microbiota in developing climate-resilient agricultural strategies through targeted microbiome manipulation.

Session 30

Soil ecology



BioDive4Soil – A systematic assessment of soil biodiversity

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The decline in biodiversity in conjunction with global change poses a threat to human well-being. Soils are home to c. 60 % of species on Earth but our knowledge of soil biodiversity across different land-use types and its drivers is limited. Here, we present and give an overview of the recently initiated German BioDive4Soil project – a large-scale systematic assessment of soil biodiversity.

In BioDive4Soil, we, a team of 11 partners together with the German Environment Agency, aim to assess soil biodiversity in up to 300 sites spread across Germany covering all major land-use types and soil districts. We will establish baseline knowledge of soil communities indicative of healthy soils by sampling in pristine, near-natural ecosystems via morphological, functional, and molecular determination of soil microorganisms and fauna. In addition, we will sample across a gradient of increasing land-use intensity to identify changes in soil community composition as well as identify potential underlying important drivers, such as land-use management, soil type and pH, and pollution. We will run eDNA analyses as well as DNA barcoding of multiple species across different soil taxa to improve the currently still sparse information on genomic data of soil organisms.

Taken together, BioDive4Soil aims to close existing knowledge gaps in order to better understand soil biodiversity change and thus possible avenues of sustainable action for the protection and restoration of soils and soil biodiversity. We also present and make a case for the importance of long-term systematic national soil monitoring.

BioDive4Soil is funded by the Federal Ministry for Environment under the Action Plan Nature-Based Solutions for Climate and Biodiversity.

Investigating identification techniques and sample sizes effect on soil nematode community assessment

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Nematodes are abundant and diverse in soil, and they can influence microbial community composition, plant performance, and nutrient cycling, serving as vital bioindicators for soil ecology and health. While metabarcoding techniques have become highly standardized in the identification of microbial (i.e., bacterial and fungal) communities, similar techniques are still under development for soil animals. As metabarcoding techniques become increasingly popular for characterizing soil animals, establishing protocols that are adapted to larger-bodied organisms is necessary. To optimize nematode metabarcoding workflows, we assessed how different identification techniques and soil sample sizes influence community composition estimates.

We compared three identification techniques: traditional morphological identification, and two molecular methods based on either nematode-extracted DNA ("nematode soup") or total soil DNA. Each technique was tested across varying soil sizes. DNA was amplified using nematode-specific 18S rRNA primers (Nemf/18Sr2b) and sequenced on an Illumina MiSeq platform. Sequencing data obtained from different protocols were filtered, trimmed, merged using the DADA2 pipeline, followed by taxonomy assignment using the PR2 reference database.

Our results demonstrated that both sample size and identification technique significantly influenced estimates of alpha and beta diversity. Nematode soup technique yielded the highest taxonomic richness but also greater variability across replicates. Larger soil input volumes generally increased richness while reducing variability, regardless of technique. This study serves as a guide for the selection of appropriate protocols in soil nematode metabarcoding studies.

The Impact of Plant Species Diversity on Nematode Communities: A Meta-Analysis

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Nematodes are the most abundant metazoans on Earth, occupying all trophic levels and serving as key components of the soil food web. Their ecological versatility makes them valuable bioindicators for assessing food web complexity, ecosystem health, and stress responses. Nematode community indices provide critical insights into environmental conditions, soil functioning, pollution levels, and microbial dominance (bacterial vs. fungal-driven systems). Consequently, nematodes have been widely utilized in biodiversity experiments to investigate the effects of plant species richness on soil ecosystem processes. Numerous studies from Germany, Sweden, Ireland, the Netherlands, and the United States have contributed to this field; however, a comprehensive meta-analysis has been lacking. Here, we present the first meta-analysis synthesizing data from all available nematode studies conducted within biodiversity experiments. Specifically, we address (1) the general effect of plant diversity on nematode community structure and function, and (2) how experimental duration modulates these relationships.

Deep soil profiles under young mycorrhizal forest stands: soil fauna and microbial gradients

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Mycorrhizal symbiosis is widespread across terrestrial ecosystems, with most forests dominated by either ectomycorrhizal (ECM) or arbuscular mycorrhizal (AM) fungal associations, making the mycelium of mycorrhizal fungi a significant functional component of soil and a food source for soil fauna. This effect is expected to be more pronounced in the subsoils (below 20-30 cm) due to the general shortage of organic resources.

This study was conducted within the MyDiv tree diversity experiment, Bad Lauchstädt, Germany. The plots composed of exclusively ecto- ($n = 4$) or arbuscular mycorrhizal ($n = 4$) tree species were selected. Soil cores ($d = 5$ cm) were collected to a depth of 1 meter. The soil profile was analyzed according to genetic horizons.

Nematodes were extracted using a modified Baermann funnel method, counted, identified to the genus level, and feeding types were assigned. Due to the small amount of soil, the relative abundance of other animal taxa and fungal biomass was assessed indirectly using the qPCR approach. Soil parameters: water content, bulk density, organic C total N content were measured. Environmental DNA was extracted from sieved fresh-frozen soil. The relative abundance of fungi was assessed using a set of primers fITS7:fITS7o/ITS4 (ITS2 region). The relative abundance of soil microarthropods was assessed using a set taxa-specific primer pairs.

The biomass and density of nematodes significantly decreased with depth, being the most pronounced for bacterivores in ECM systems (LSMeans test, t-ratio ≤ -5.293; $p < 0.0001$). The nematode community of only topsoil (Ap1; 0-10 cm) differed (MANOVA, $F = 2.525$; $p = 0.0332$) between ECM and AM dominated ecosystems. The abundance of all studied resources correlated strongly and positively between each other and decreased along with organic carbon content with depth increase (Spearman correlation; $R2 \geq 0.7$, $p < 0.05$).

The study is supported by Paul Ungerer Foundation Programme 2025 and the Senckenberg Strategy Fund.

High species diversity and biochar can mitigate drought effect in arid environments

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Introduction:

Climate change, such as drought, is a threat that affects ecosystem function worldwide. The current study, investigated the effects of species diversity and biochar amendment on the performance and productivity of five native species of Oman under control and drought conditions.

Methods:

A fully controlled greenhouse experiment was conducted in which five native species of three different diversities (one, two, and four species) were grown under four different treatments: biochar+drought, biochar, drought, and control. Productivity was measured through total biomass and root-to-shoot ratio), while performance was assessed in the form of plant functional traits (plant height, specific leaf area (SLA), specific root length (SRL). Nutrient availability in the soil was measured using soil organic carbon (SOC) and soil total nitrogen (STN). Soil microbial content was determined through soil microbial biomass “Cmic” and soil microbial basal respiration. Biodiversity effects were analyzed using complementarity effect (CE), selection effect (SE), and net biodiversity effect (NBE).

Results and discussion:

The study showed that high diversity and biochar produced productive species with 66.6% higher total biomass and 3% lower RSR, better species performance 25% taller plants, 50% higher SLA, and 25% higher SRL), more fertile soil with 40% higher SOC and 33.3% higher STN, and better microbial content with 15% higher Cmic and 33.3% higher basal respiration under drought conditions in comparison to monoculture. These findings elucidate the complex interactions between climate change and biodiversity, which are essential for predicting the effects of functional composition changes on ecosystem processes and, subsequently, the rehabilitation of arid ecosystems in Oman.

Severe drought impacts tree traits and associated soil microbial communities of clonal oaks

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Biotic and abiotic factors, including plant age, soil pH, organic matter, and especially water availability, significantly influence soil microbial populations and plant traits. While many ecosystems tolerate occasional droughts, climate change is increasing their frequency and severity, negatively affecting plant productivity and survival. Long-lived, drought-sensitive species like Quercus robur are particularly vulnerable. Drought alters soil microbial communities by reducing and reshaping their diversity, biomass, and activity, potentially disrupting ecosystem functions.

This study investigated the effects of natural drought on soil properties, plant traits, and microbial communities of the oak clone DF159 in Central Germany. The two study sites, Bad Lauchstädt and Kreinitz, differ in water retention. Data were collected before and after the severe 2018 drought, with oak traits monitored from 2011 to 2023. Trees were planted annually between 2010 and 2019, and microbial communities were sampled biennially from 2015 to 2021 in five age groups.

Plant traits such as apical growth, branch elongation, and number of shoot flushes correlated positively with precipitation and humidity. Despite site differences in leaf number and shoot flushes, the 2018 drought negatively affected all plant traits. Soil bacterial richness and diversity declined at both sites, independent of tree age. Fungal richness increased only in Bad Lauchstädt, likely due to its higher water-holding capacity. Bacterial communities were more strongly impacted by drought, while fungal communities were more responsive to plant age.

These findings suggest strong functional links between vegetation, microbes, and soil during drought. Bacteria were more drought-sensitive, whereas fungi showed greater resistance, possibly aiding plant survival. Prolonged drought may cause lasting shifts in microbial communities, with major implications for soil function and plant-microbe interactions.

Shifts of soil fungi in beech and Douglas-fir forests during severe summer drought and recovery

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Central Europe has experienced long periods of drought during the growth season over the last decade. It has been suggested that mixed forests may be more stable than pure forests under conditions of climate change. Soil fungal communities differ between monocultures of native beech (*Fagus sylvaticl*) and introduced Douglas-fir (*Pseudotsuga menziesii*) forests as well as in the mixture of these tree species (Likulunga et al., 2021). Furthermore, the soil fungal communities in pure and mixed stands are affected by abiotic habitat conditions such as soil properties and climate (Likulunga et al., 2021). Main constituents of soil fungal communities in forests soils are mycorrhizal and saprotrophic fungi. They are crucial drivers of biogeochemical cycles, making nutrients available for ecosystem nutrition. How long-term summer droughts influence the composition of fungal communities in dry-sandy and humid-loamy forests of beech and Douglas-fir is not known. We hypothesised that (1) summer drought results in a decline of active fungal communities and recovery during wet conditions in late fall; (2) these shifts are more pronounced in pure than in mixed forests and (3) drought results in greater similarity of soil fungal communities than humid weather. To address these hypotheses, we studied DNA- and RNA-based metagenomics to distinguish total and active soil fungi during summer drought and recovery in late fall. The experiment was conducted in two regions in Lower Saxony, differing in climate and soil properties. In each region, fungi were studied in beech, Douglas-fir and mixed plots. The results from these experiments will be presented.

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Likulunga, L.E., Rivera Pérez, C.A., Schneider, D., Daniel, R., Polle, A., 2021. Tree species composition and soil properties in pure and mixed beech-conifer stands drive soil fungal communities. Forest Ecology and Management 502, 119709. https://doi.org/10.1016/j.foreco.2021.119709

Remote sensing and GIS-based approaches to assess the effect of biochar-based fertilizer in matured cocoa farms

***Otis Senalor*[1,2,3,4]**

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Cocoa farming accounts for nearly a third of Ghana's export earnings. Amid climate change and soil degradation, biochar-based fertilizers (BCF) offer a promising solution to improve soil health, boost yields, and reduce greenhouse gas emissions. Made via pyrolysis of biomass like cocoa pod husks, BCF enhances fertility and serves as a carbon sink. While its benefits on young plantations are known, the effects on mature cocoa farms remain understudied. This study assessed the impact of organic (poultry manure) and inorganic (NPK) BCF on soil nutrients, crop health, and yield in mature cocoa plantations in Boaso, Bechem (Ahafo Region, Ghana). Using a randomized complete block design (3 blocks, 10 treatments, n=600 trees), we measured soil nutrients (N, P, K, Mg, Ca, S), pod count and weight, flowering intensity, and NDVI (via drone imagery) as a proxy for tree health. Lab and remote sensing data were analyzed using factorial ANOVA and Generalized Linear Models in R. BCF significantly improved soil fertility, canopy health, and yield, with the strongest results from treatments combining biochar and poultry manure. These findings highlight BCF as a climate-smart strategy for sustainable cocoa farming and provide data-driven insights for farmers and policymakers.

Belowground animals and microorganisms responses to root exclusion and litter removal in tropical ecosystems

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Belowground life fundamentally depends on carbon inputs from plant roots and leaf litter; however, the relative importance and mechanisms of these pathways remain poorly understood in tropical ecosystems. We investigated how soil animals and microorganisms respond to root trenching (exclusion of living roots) and litter removal in rainforest and plantation systems (rubber and oil palm) in Sumatra. For soil animals, root exclusion reduced their abundance significantly, with a stronger impact in soil layers (42% reduction in rainforest, 30% in plantations) compared to litter layers. Conversely, litter removal primarily affected animal abundances in the litter layer, reducing total abundance by 60% in rainforest and rubber plantations, but had little impact in oil palm plantations. Animal responses to these manipulations were influenced by body size and vertical distribution in soil profiles.

Microorganisms showed different patterns; notably, living roots had a stronger linkage to microbial biomass and basal respiration in litter (32% and 38% decreases, respectively) than in soil, indicating tropical trees preferentially allocate resources toward litter nutrient mining. Although microbial biomass and respiration in soil remained unchanged by trenching, there was a marked decline in total and mycorrhizal fungal proportions, especially when litter was present. Litter removal had negligible effects on microbial biomass and community structure in soil, highlighting a clear compartmentalization in carbon processing between litter and soil layers.

Overall, these findings demonstrate that plant roots significantly shape belowground life through distinct pathways for soil fauna and microorganisms across different land-use types. Our results enhance understanding of carbon flow dynamics in tropical soil food webs, providing essential insights for ecosystem modeling and sustainable soil management.

Microhabitat matters: contrasting protist responses to tropical land-use change in litter, rhizosphere, and bulk soil

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Litter and rhizosphere are critical microhabitats that supply resources to soil food webs. However, how land-use change alters biodiversity and restructures community composition within these microhabitats remains largely unexplored. Here, we assessed how protists—key regulators of microbial diversity and nutrient cycling—vary in composition and ecological roles across litter, rhizosphere, and bulk soil along a land-use gradient intensification from rainforest, shrubland, rubber, and oil palm plantations in Sumatra, Indonesia. High-throughput sequencing revealed that rhizosphere protists responded strongly to land-use intensification, with a 36.5% increase in α-diversity and altered community composition from rainforest to oil palm plantation. Bulk soil protists showed similar but weaker responses, while litter communities exhibited compositional shifts without significant α-diversity changes. Protist communities were shaped by abiotic factors (e.g., pH, water content, carbon, and nitrogen) and biotic factors (e.g., bacterial, fungal, and nematode diversity). Notably, the effects of biotic factors were predominant in the rhizosphere, while the effects of abiotic factors were more pronounced in the litter, and both shaped communities in the bulk soil. Additionally, protist functional groups responded differently to land-use change. Generalists remained relatively stable along the intensification gradient, particularly in the litter layer, whereas specialists in the rhizosphere and bulk soil exhibited reduced niche breadth and richness. These patterns highlight the rhizosphere as the most dynamic microhabitat for protist community restructuring, likely driven by root-associated biotic interactions. Our study clarifies microhabitat-specific responses and the underlying abiotic and biotic drivers, advancing our understanding of protist-mediated processes in intensifying tropical land-use systems.

Shifts in Plant Root Diversity Are a Major Driver Mediating Fungal Species Turnover Among Rhizosphere, Soil, and Litter in Tropical Land-Use Systems

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Tropical belowground fungal communities—including those in litter, rhizosphere, and bulk soil—play crucial roles as decomposers and symbionts, mediating energy flow from aboveground vegetation into the soil. However, how the entire belowground fungal community responds to changes in the two main energy input channels—plant roots and litter—remains poorly understood in tropical land-use systems. Specifically, we investigated how reduced plant diversity associated with land-use conversion (from rainforest to scrubland and monoculture plantations of rubber and oil palm) affects fungal community composition across microhabitats (litter, rhizosphere, bulk soil) and whether it further leads to a reduction in belowground fungal community heterogeneity as indicated by decreased species turnover. Our findings show that reduced tree diversity in monocultures leads to increased saprotrophic fungi and decreased mycorrhizal fungi across all soil microhabitats. Beta diversity partition analyses revealed that species turnover dominates community dissimilarity among rhizosphere, soil and litter, with lower taxonomic turnover between rhizosphere and soil fungal communities than between litter and soil communities. Furthermore, reduced plant roots diversity had a stronger negative impact on fungal community heterogenization than reduced litter diversity—particularly in oil palm plantations. Overall, our results demonstrate that the changes in plant root diversity under different land-use intensification, mediating energy flow in tropical ecosystems, play a more central role than litter in structuring belowground fungal communities.

Depth-dependent responses of soil microbes to land use and managment intensity of grasslands and forests

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Land use and management intensity significantly drives changes in biodiversity. However, its long-term effect on soil microbial communities across ecosystems and soil depth remains unresolved. This study took advantage of the framework of the German Biodiversity Exploratories to examine how gradients of land use and management intensity shape the microbial communities in temperate forests and grasslands in two contrasting regions of Germany. The use of standardized indices for forest silvicultural management index (SMI) and for grassland management, land use intensification index (LUI), and their components (e.g., grazing, mowing, fertilization) is employed to explore microbial diversity and composition based on relative abundance at the phylum and genus levels. This finding illuminates which specific management practices are responsible for shaping the distinct soil bacterial (16S V4 region) and fungal (ITS2) communities in the two ecosystems. Community profiles are assessed using high-throughput Illumina amplicon sequencing from both topsoil and deeper soil layers, and analyzed in relation to management gradients. We expect a more direct negative impact of targeting the ITS2 region for fungi and the 16S rRNA gene (V4 region) for bacteria. Our results reveal that land-use intensity has a stronger impact on topsoil than deeper soil microbial communities, likely due to higher resource availability and greater exposure. Overall, fungal alpha diversity appears relatively stable, while bacterial communities are more sensitive to increasing land use and management intensity, as indicated by marked shifts in their beta diversity and dominant phyla. These results highlight differential depth-dependent responses of soil fungi and bacteria to land use and management practices and underscore the importance of developing management strategies for maintaining the biodiversity under increasing anthropogenic pressures, especially in topsoils that provide most of the service crucial for plant growth.

Soil disturbance by animals increases under multi-nutrient fertilization in global grasslands

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The consequences of nutrient enrichment and loss of grazing mammals are affecting grassland systems worldwide. While much attention has been paid to changes in plant communities, soil disturbance caused by animals has rarely been considered. Using data from a globally distributed experimental network with factorial nitrogen (N), phosphorus (P) and potassium (K) fertilization and exclusion of herbivores, I found that the cover of animal-induced soil disturbance is strongly promoted by N fertilization in combination with P and K, whereas this was not the case under fenced conditions. Most of the "troublemakers" come from the order Rodentia. Preliminary results suggest that the extent of disturbance is negatively related to mean annual air temperature and vascular plant and graminoid biomass, with the direction of the latter two depending on fertilization and/or fencing treatment. Contrary to my expectations, I found no clear relationship between the extent of soil disturbance caused by animals and the nutrient content of plant biomass. Regardless of the mechanism, soil disturbance had a positive effect on plant community diversity, but only under non-nitrogen fertilized conditions. This suggests that although the level of disturbance is much higher under N addition, this cannot override the known negative relationship between nitrogen based fertilization and diversity.

Depth-dependent dynamics of microarthropods in forest floors: interactions with temperature and phosphorus levels

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Forest floors buffer harsh environmental conditions and insulate soil, thereby mitigating the effect of climate extremes on soil fauna. Conversely, the soil fauna is key for shaping the structure of FFs. Considering the recently documented decline in FFs across Europe, changes in the composition and activity of soil animal detritivores and their consequences for changes in the structure of FFs need closer attention. Unfortunately, the structure of decomposer animal communities across different layers of FFs and their variation with soil nutrient status and climatic factors has not been comprehensively investigated. We investigated the distribution patterns of two major decomposer microarthropod groups (Collembola and Oribatida) across the different layers of the FF (Ol, Of/Oh and Ah) of 12 forest sites representing temperature and phosphorus gradients. A total of 58 Collembola and 144 Oribatida species were recorded. Phosphorus as main factor neither significantly affected the abundance of Collembola nor that of Oribatida. The same was true for the effect of temperature on the abundance of Collembola, whereas the abundance of Oribatida varied significantly with temperature. Further, Oribatida richness significantly increased with increasing temperature but decreased with increasing phosphorus level. The effect of layer was highly significant for both Collembola and Oribatida. Specifically, the abundance, richness and biomass of both microarthropod groups was at a maximum in the Of/Oh layer followed by Ah and Ol layer. Collembola and Oribatida community structured varied with temperature and phosphorus levels but in both this depended on layer. The differential responses of Collembola and Oribatida to temperature and phosphorus gradients underscore functional and ecological differences between these groups, with Oribatida displaying a stronger sensitivity to climatic and nutrient changes.

Mesh material of tea bag affects stabilisation of organic matter in soils according to Tea Bag-Index – How to take different outcome into account?

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The Tea Bag Index (TBI) is widely known as a cost-effective measure to monitor soil ecological processes and is globally implemented due to globally available tea bags. The TBI is a measure for decomposition and stabilisation of organic matter through soil microbial activity as important ecosystem services. Since the establishment of the TBI in soil ecology more than 10 years ago, companies modified the mesh material of tea bags from polypropylene to biodegradable material to make the bags environmentally friendly. The aim of this study was to assess the influence of mesh material on the decomposition rate and stabilisation factor of the organic matter. Therefore, a laboratory experiment (n=5) was implemented based on tea bags of both mesh materials in 6 different soils of different characteristics regarding texture and C:N saturated to field capacity. The tea bags of both mesh materials were placed together in soil containers and remained in soil over 70 days, while kept in a constant environment. Through all soils the stabilisation factor was affected by the mesh material, showing a lower stabilisation factor for organic matter in biodegradable mesh material. The effect this has on the TBI explanatory power and for comparison with historical data from literature will be discussed and recommendations be given.

Microplastic fragments in soil alleviate the negative effects of heavy metals on plants

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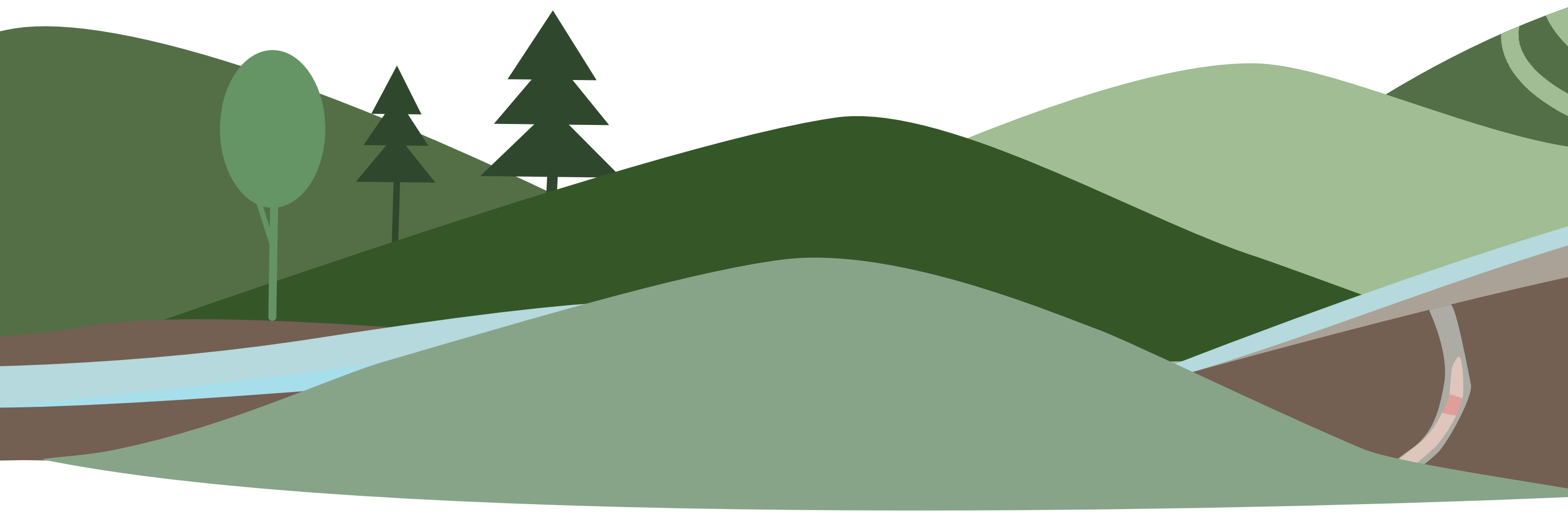
Microplastic (MP) are a recognized novel stressor, but their impacts on soil and plants is poorly understood. Agricultural activities, such as the use of mulching foils, are an important source of MP into the soil. MP alter soil chemical, physical, and biological properties, with potential consequences for the bioavailability of contaminants. Heavy metals, such as cadmium (Cd), are contaminants associated with mining and fertilizer applications, and can be harmful to plants even at low concentrations. Recent studies suggest that MP may either enhance or mitigate the negative effects on Cd on plants. However, little is known about this interaction and the underlying mechanisms. In a greenhouse experiment we tested the response of two related plant species with distinct Cd tolerance levels to different concentrations of Cd and MP. We hypothesized that MP modify Cd bioavailability in soil, with stronger effects on the non-hyperaccumulator species compared to the metal-hyperaccumulator, and this may occur via direct MP-Cd interactions or indirectly via effects of MP on soil pH and water content. Plant biomass was negatively affected by MP and Cd alone, but when the two stressors were combined, MP alleviated the negative effects of Cd on plant performance. These effects were significant only for the non-hyperaccumulator species. MP increased Cd bioavailability in soil, and this effect was not mediate by soil pH or water content. However, plants accumulated less Cd when MP was present, suggesting that MP particles may hinder Cd absorption by plants. We highlight the complex interplay between MP and Cd, and how multiple factors can affect this interaction in a highly context-dependent way. Understanding how MP interact with other environmental stressors, potentially modifying their effects on plant and soil systems, is critical in the face of intensifying land use and global environmental change.

Session 31

Species interactions and interaction networks



Evolution of coexistence ability in experimental Daphnia mesocosms

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Understanding species coexistence is central to community ecology, given its role in biodiversity maintenance. Theory indicates that coexistence is determined by niche and fitness differences. Both can evolve due to selection and potentially alter coexistence dynamics. However, it remains unclear how adaptations to competitors develop over time and how abiotic environmental properties influence dynamics, shaping evolutionary trajectories of competition and coexistence. We conducted a multi-year, semi-natural outdoor mesocosm experiment with planktonic communities to study different selection pressures as drivers for evolution of coexistence. Mesocosms used realistic annual hydroperiods, which allows us to determine whether rapid evolution observed within a growing season persists when genetic drift and sexual reproduction are considered and allows for eco-evolutionary feedback dynamics between phytoplankton and zooplankton. To generate distinct evolutionary histories, focal zooplankton species Daphnia magna and Daphnia pulex were included either in monoculture or in competition into mesocosms as initially diverse populations (22 unique clones). Three years after the initial implementation we tested how evolution acted on niche and fitness differences of focal species. Both were measured in laboratory experiments, using recent methodology measuring intrinsic, invasion, and no-niche (when niches are equivalent between the two species) growth rates. We hypothesized that Daphnia from competition treatments would evolve either increased niche differentiation and/or reduced fitness differences in competition treatments, facilitating coexistence by reducing direct competition or stabilizing effects. Our results showed evidence for reduction of fitness differences among Daphnia populations with histories of coexistence, but no directional shifts in niche differences. The findings indicate that Daphnia evolve mechanisms that impact coexistence in different, repeatable directions when the competitors are present or absent. A next critical step will be to determine which life history traits drive the reduced fitness inequalities observed in populations exposed to competition.

From friend to foe and back - Coevolutionary transitions in the mutualism-antagonism continuum

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Interspecific interactions evolve along a continuum ranging from mutualism to antagonism. Evolutionary theory so far focused mostly on parts of this continuum, notably on mechanisms that enable and stabilise mutualism. These mechanisms often involve partner discrimination ensuring that interaction intensity is higher with more cooperative partners. However, the gradual trajectory of coevolutionary transitions between mutualism and antagonism remains unclear. Here, we model how discrimination ability in one partner coevolves with mutualistic service provided by the other and analyse the resulting evolutionary trajectories in the mutualism-antagonism continuum. We show that strong ecological change, such as a radical host shift or colonisation of a new environment, can trigger transitions in both directions including back-and-forth transitions between antagonism and mutualism. Moreover, we find an evolutionary tipping point: a stable mutualism may break down to antagonism if the cost of either mutualistic service or discrimination ability gradually increases above a threshold beyond which this transition cannot be reversed by reducing costs again. Our study provides a new perspective on the evolution of biotic interactions and hence on the dynamic structure of ecological networks.

Evolution of prey traits under multiple stressors explains changes in trophic interaction with predator

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Global environmental change imposes multiple, often interacting stressors on populations and communities. Environmental changes can drive evolutionary shifts, with cascading effects on trophic interactions. Additionally, when stressors act in combination, evolutionary responses may be enhanced or dampened compared to when stressors act in isolation (interactive effects). In a long-term selection experiment, we selected a protist prey species in four environments (a factorial combination of low/high levels of salinity and temperature). We then tested in a common garden experiment if prey evolution affected the functional response of a protist predator (i.e. the per-capita consumption rate as a function of prey density). We also quantified prey trait evolution to link trait changes to shifts in the predator's functional response parameters. We found that prey selection in high-temperature environments increased the attack rate of the predator (how efficiently it encounters and captures prey per unit time), but this increase was smaller when the prey had been selected in the multi-stressor environment. These results matched an increase in prey swimming speed in high-temperature selection lines, with some evidence of selection in the multi-stressor environment dampening this increase. Evolutionary increases in prey swimming speed thus seem to increase the ability of the predator to find and attack prey. These findings suggest that prey evolution in response to abiotic stressors can alter predator-prey interactions, likely through trait-mediated mechanisms influencing predator foraging efficiency. Overall, our study highlights the importance of accounting for evolutionary responses to multiple stressors when predicting changes in trophic dynamics under complex environmental change.

Eco-evolutionary dynamics in competitive systems: coevolution mitigates the potential for evolutionary rescue

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Understanding how species respond to changing environments is important for maintaining biodiversity and well-functioning ecosystems. Environmental change can affect species' population densities and their traits. Previous work has shown rapid evolutionary trait changes of species to changing environments, which could have both beneficial (e.g. evolutionary rescue) or detrimental (e.g. evolutionary suicide) outcomes for species survival. In a multi-species setting, whether evolution is beneficial or detrimental for species persistence is even more challenging to predict, but an important step to consider. Using a theoretical model, we simulate the density and trait dynamics of one or two competing species, which experience a decline in the quality of their abiotic environment that ultimately leads to their extinction. The exact extinction time points, however, depend on the speed of evolution. We consider two evolving traits, capturing a species' tolerance to the abiotic conditions and its competitive strength, respectively. In the single-species system, we consistently find that evolution is beneficial, meaning that it delays species extinction, potentially resulting in evolutionary rescue. By contrast, in the two-species system, we find both beneficial and detrimental effects. In particular, we find that a species' extinction is advanced when its competitor's is delayed, potentially resulting in evolutionary murder. Both in the single-species and in the two-species system, we find that the effect sizes are strongly modulated via trait coevolution, as well as by the shape of ecological and evolutionary trade-off functions. Our study consequently sets the stage for exploring eco-evolutionary dynamics in more complex biotic settings, extending our understanding of species responses to the abiotic and biotic changes.

Specialist species increase the resilience of tree-liana interaction networks by reducing destabilising feedback

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Tree-liana interactions play a key role in structuring tropical forests, which in turn provide a range of important ecosystem services, such as carbon storage, food for primates and for human communities, but also medicine, fiber and poles for construction. The interaction between trees and lianas itself is considered antagonistic, given that lianas depend on tree support to have access to the light-rich canopy and that they have a direct negative effect on trees via reduced tree growth and fecundity, as well as increased tree mortality. Tree-liana interaction networks are thus comparable to food webs, but classical tools from ecological network theory have rarely been applied to these systems. We aim at deriving predictions for the structure-stability relation in tree-liana interaction networks, using tools from random matrix theory. More precisely, we build artificial community matrices, where the matrix elements are filled with random numbers, which represent biotic interactions (e.g. tree-tree, tree-liana, liana-liana). Community structure is then imposed and modified by varying the connectance, degree of specialisation, nestedness, modularity, and module connectivity. Our results indicate that tree-liana community resilience is maximised in systems with a relatively high degree of specialism, which is in line with the predominance of highly specialised tree-liana interactions observed in nature. We explain these results via a reduction of self-reinforcing and hence destabilizing feedback arising from pairwise interactions among lianas. We argue that our model might serve as a hypotheses generating tool for further empirical and theoretical research.

Latitudinal patterns in the structure and stability of competition networks

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The structure of ecological networks has been shown to be linked to community dynamics, for example through specific patterns in interaction strengths that enhance

stability. While such stabilising patterns have been described in many example systems, it remains unknown whether they are also linked to environmental conditions, which could potentially imply regional differences in community stability. Here, we use networks parametrised using records of overgrowth competition between bryozoan assemblages to study regional differences in stabilising patterns of interaction strengths. Polar assemblages have previously been shown to be unstable, but their level of instability was linked to asymmetric pairwise interactions. We tested whether this relationship between asymmetry and stability varied along a latitudinal gradient by comparing polar networks to other data sets collected in temperate and tropical locations. Using a set of network indices, we found that pairwise interactions in polar networks were more asymmetric than in tropical locations. This resulted in stronger amplifying 2-link loops, and thus in a latitudinal gradient in instability, with tropical networks being more unstable. Across all datasets, we found that the strongest 2-link loop closely predicted stability, highlighting the general relationship between asymmetry and stability in competition networks. While we could confirm latitudinal differences in instability, some sampling locations also showed a large variation in asymmetry and stability, which is potentially linked to assemblage age and disturbance regimes. Further work is needed to understand this potential role of disturbances, as well the ecological implications of this instability gradient.

The role of fitness landscapes for eco-evolutionary dynamics of biodiversity and interaction networks

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Two fundamental properties of life are the diversity of organisms and the interactions between them. Biodiversity dynamics and biotic interactions are tightly connected since the latter can promote, maintain or reduce diversity within and between species through both ecological and evolutionary processes. To this date, several authors have argued that it is mutualism that fosters diversification, while others claim that it is instead antagonism. These contrasting results call for a systematic investigation of the conditions that enable high diversification rates in nature. We address this challenge by introducing a simulation model that allows for the eco-evolutionary emergence of complex interaction networks. Our model is conceptually similar to previous approaches but based on fitness landscapes of biotic interactions instead of simple trait matching. Using these fitness landscapes as a key element allows us to not only consider the concerted effect of multiple interaction types on diversification rates but also track how interactions transition from mutualism to antagonism, or vice versa. Our results support the view that mutualism acts as a driving force for diversification. Moreover, we find that transitions from antagonism to mutualism occur relatively early during network assembly, while the opposite direction only happens after trait diversification. Our work is embedded into the DFG-funded Package Proposal FLINT (Fitness Landscapes of biotic INTeractions and their role for eco-evolutionary biodiversity dynamics: towards theory-based synthesis across interaction types, see https://ecology.uni-hohenheim.de/en/flint).

Isotope labeling elucidate trophic interactions in pine canopies

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The isotopic composition of insects can be indicative for their feeding behavior. However, it is not yet fully understood how variations in isotopic signals from plant sources are reflected in food webs under different environmental conditions. Here we performed a 15N-labelling experiment in a natural dry Pine forests in Switzerland, where a long-term irrigation experiment has been conducted for two decades. We sampled foliar material and insects of control and irrigated pine trees and associated mistletoes that were either treated with 15N-labelled water one year before sampling or not. We separated the insects into known feeding guilds (primary and secondary consumers, omnivores), and analyzed the 15N-label and the carbon isotopic composition (δ13C) at natural abundances in plant and insect material. We found clear evidence that the 15N-label can be recovered in all feeding guilds sampled from pine and mistletoes, with a slightly higher 15N-content in omnivores and primary consumers than in secondary consumers, while almost no lable was found on trees not treated with 15N. The observation that 15N was rarely retrieved in trees further away from the 15N-labeled trees, suggests a strongly limited mobility of insects in the studied forest. We also found trends that environmental-induced (control vs irrigated) and species-specific (pine vs. mistletoe) d13C variations influence the isotopic composition of the consumers. However, the influence of plant water availability on the N-transfer from plant to insect and carbon isotopic composition was limited in our study. In summary, our study provides evidence that the isotopic composition in insect food webs can be indicative for insect ecosystem mobility, feeding source, and stress signals such as the plant water use efficiency.

Revealing "hidden" species interactions for enhanced Ecosystem Management Strategies

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Ecological network models are essential for developing and quantifying ecosystem-based management strategies across both terrestrial and marine systems. "Hidden" interactions - those that exist in the field but are not represented in ecological network models - alter the interpretation of structural and functional characteristics of ecosystems being studied. Link prediction algorithms can help to identify such unobserved interactions by estimating potential interactions which are not present in the existing network model. However, due to general unfamiliarity and insufficient ecological interpretations, the use of link prediction algorithms in ecology remains limited.

In this presentation, we propose an enhanced framework to improve the ecological usability of link prediction approaches. We introduce a bi-dimensional perspective that evaluates link prediction algorithm results at both the interaction and species level. This integrated perspective helps to identify under-connected species in ecological network models due to unobserved "hidden" interactions without the need of active sampling. At the same time, it supports the targeted and resource-efficient planning of measurement campaigns by prioritizing predicted interactions for validation and thereby contributing to the refinement of ecological network models. Amid ongoing environmental changes, the development of more comprehensive network models improves the ability to quantify management strategies and provides more accurate assessments of their effectiveness.

Diet of carabid beetles in riparian habitats

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Riparian habitats link aquatic and terrestrial ecosystems through the exchange of energy and nutrients. Aquatic subsidies can be an important source of energy for terrestrial consumers. Carabid beetles contain many riparian specialists and are often used as indicators of riparian conditions. However, detailed knowledge of the prey species consumed by carabid beetles and their dependence on aquatic prey is very limited. To fill this gap, we sampled carabid beetles in near-natural riparian habitats using pitfall traps and hand collection at five streams in south-western Germany. Sampling was carried out in May and September 2023 in three stream sections each (upstream, midstream, downstream). We performed molecular gut content analyses of 579 individuals from 28 species. We used high salt DNA extraction for the digestive tract of species with a body size > 8 mm, and the whole body of species < 8 mm. We used the fwhF2 and FwhR2n primers to detect consumed prey. Illumina MiSeq metabarcoding was done by GeGat GmbH (Tübingen, Germany). Bioinformatic analysis revealed that 354 (61.1%) of the processed samples contained DNA from taxa other than the predator. In total, DNA from 219 different prey items was detected in the gut contents of the carabids, representing 92 families and 27 orders. The number of prey items per carabid species varied between 1-13 (average 2.2). Importantly, the diet of the carabid beetles varied between stream sections and depended on carabid species traits such as body size and mobility. Our results provide a detailed insight into the prey species consumed by carabid beetles in riparian habitats and indicate that several riparian carabids use aquatic subsidies.

Natural recovery of multiple species interactions to agriculture in a tropical rainforest

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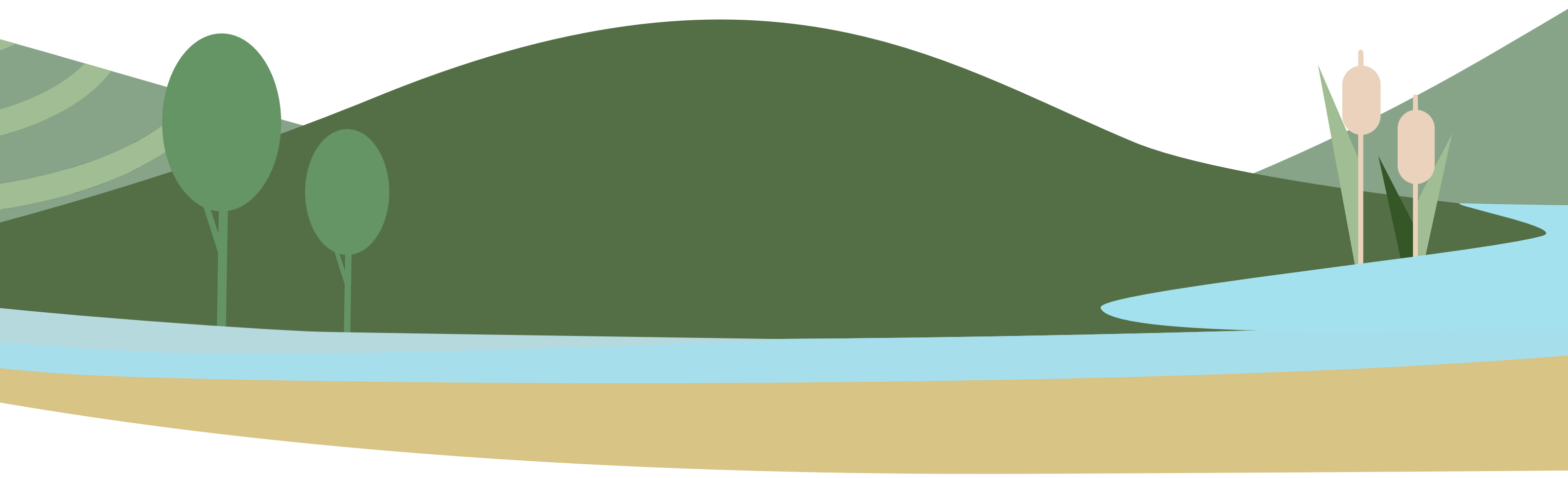
In the context of rapid deforestation of rainforests driven by agricultural expansion, studying the secondary succession of these ecosystems has become a central focus in restoration ecology. While research on species communities offers valuable insights into the natural recovery process, species recruitment often depends on interaction with other species. Therefore, the study of species interactions is key to understanding natural recovery, an area that has been largely understudied. In particular, comparisons among different types of ecological interactions are still lacking. To address this gap, we investigated the changes in species interactions of different taxa representing different types of ecological networks: primary seed dispersion (bats and birds), secondary seed dispersion (dung beetles), decomposition (ants, termites and saproxylic beetles) and pollination (bees) networks along a chronosequence of secondary rainforest in the Ecuadorian Chocó. We compared how network specialisation, interaction diversity and interaction evenness among the different networks respond to the time of recovery. We found that while there are no changes in specialisation and diversity of interactions in most ecological networks, the evenness of those interactions decreases with forest recovery. These results suggest a high species and trait turnover resulting in the dominance of some species in the latest stages of recovery.

Session 32

Traits and functional diversity



A trait-based approach to investigate changes in plankton phenology with global warming

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Global warming leads to extended periods of summer stratification. While algae growthtypically occurs during stratified periods where the warmer and shallower epilimnion layer provides enough light for growth, lake stratification also increases the risk of sinking out of the upper water column. Planktonic primary producers have developed diverse strategies to counteract sinking such as specific morphologies, flagella, or the ability to regulate cell buoyancy. A cyanobacteria with buoyancy regulation is Planktothrix rubescence, for which a strong increase has been observed in several deep stratifying lakes across Europe. One suggested reason is that they strongly profit from lengthened periods of summer stratification, with their ability to move below the thermocline giving them a unique advantage over passive sinking algae to overcome nutrient limitation in the epilimnion. So far models on phytoplankton competition and seasonal plankton succession (such as the PEG model) largely ignore vertical gradients in resource availability and specifically do not consider vertical movement strategies. This limits our ability to assess how changes in stratification regimes will impact algal growth and community composition. In this study, we theoretically investigated resource competition between two phytoplankton species along a 1D water column, contrasting passively sinking algae with taxa that can regulate buoyancy to ascend or descend along the water column according to optimal resource availability. We investigated how competition between sinking and buoyancy regulating taxa is influenced by physiological traits related to resource use efficiency of light andnutrients as well as by environmental conditions such as background turbidity and eddy diffusion. Our results show that coexistence between buoyancy-regulating and sinking algae is critically influenced by differences related to light and nutrient use efficiencies. This also applies to the occurrence of a deep chlorophyll maximum (DCM), its location along the water column as well as which species is forming the DCM.

Relationships between spectral and biological diversity depend on season and temperate open habitat type

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Remote sensing is increasingly used in biodiversity monitoring, with spectral diversity—variation in spectral reflectance among pixels—serving as a key proxy for both taxonomic and functional diversity. While spatial patterns of spectral diversity have been widely studied, its temporal dynamics and ecological drivers remain less understood. In this study, we investigated these dynamics across three contrasting temperate open habitats in Germany: nutrient-poor grasslands, wet heathlands, and nutrient-rich floodplain meadows. Using 128 permanent 1 m² plots, we quantified taxonomic diversity (Shannon, Simpson, inverse Simpson, and Pielou's evenness), functional diversity (functional dispersion, richness, evenness, divergence, and Rao's Q), and four spectral diversity indices (average angle dissimilarity, coefficient of variation of whole spectra, coefficient of variation of optical traits, and Rao's Q) across 166 wavelengths. Spectral data were collected on five to six dates during the growing season using a field spectrometer, enabling us to capture seasonal variation in both spectral and biological diversity. We applied linear mixed-effects models (LMMs) and structural equation models (SEMs) to assess how spectral diversity reflects biodiversity changes over time and across habitat types. Results showed that spectral diversity–biodiversity relationships were dynamic and context-dependent. Spectral diversity corresponded to both taxonomic and functional diversity, but strength and direction of associations varied by habitat type and time. SEMs revealed that vegetation structure (e.g., non-photosynthetic vegetation [NPV], canopy height) influenced both biological diversity and spectral diversity, with differing effects across habitat types. For instance, NPV was positively associated with spectral diversity in grasslands and floodplains, while canopy height enhanced functional diversity, particularly during mid-season. In wet heathlands, canopy height was negatively related to both spectral and functional diversity. These findings highlight the importance of ecosystem-specific calibration of remote sensing approaches, integrating temporal and ecological context to improve biodiversity monitoring and guide conservation strategies.

Comparative chemical analysis of major social pheromone glands in Asian and European honeybees

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Research on honeybee pheromones and pheromone communication mainly focused on the European honeybee populations *Apis mellifera carnica* and l*igustica* neglecting ecologically and functionally important variation among populations and species. Therefore, we recently started a comparative chemical analysis of the mandibular gland, Nasonov gland, and Dufour's gland in workers and queens of four honeybee species: the open-nesting species *Apis florea* (dwarf honeybee), *Apis dorsata* (giant honeybee), and the cavity-nesting species *Apis cerana* (Asian honeybee), and *A. mellifera*. The species differ in many aspects that might affect pheromone communication, for example colony size, nesting behavior, foraging range, collective defense, and spatial density of colonies. The analysis with gas chromatography/mass spectrometry revealed that all three glands exhibit species- and caste-specific pheromonal compositions. Large chemical variation is present in the queen mandibular glands which are the source of the sex pheromone of virgin queens and the major social pheromone of the mated queen. Moreover, we found substantial variation in the pheromonal blends between northern and southern populations of *A. cerana* in India. This might be caused by adaptions to specific environmental conditions since this species, similar to *A. mellifera*, extended its distribution range from tropical to temperate climate zones. For a long time, honeybees have been regarded as a very homogenous group of species, but it turns out that it is a group of species with an interesting evolutionary history that led to various adaptations. The results help to better understand and reconstruct the evolution of the pheromone composition in the genus Apis.

LEPY: A Python Pipeline for Automated Trait Analysis of Lepidoptera Images Tested Along an Elevational Gradient

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We present LEPY, a Python-based pipeline for the automated extraction and analysis of morphological traits, including structural and colour properties, from mounted specimens of Lepidoptera (butterflies and moths). The pipeline uses a U-Net neural network for image segmentation and a scale bar for accurate morphological measurements. LEPY is designed to be user-friendly and reproducible, ensuring efficient and consistent analysis of large image datasets. It also supports the integration of ultraviolet (UV) photographs for improved colour analysis, an innovative feature rarely available in existing trait analysis tools.

LEPY computes structural traits such as body length, forewing length, and specimen area. It also extracts colour characteristics, including hue, saturation, intensity from the red, green, and blue (RGB) channels and brightness, contrast, chromaticity, and luminance from both RGB and UV channels. These data are used to calculate colour diversity using the Shannon index and exported in a structured, machine-readable format. Visual summaries of each image pair are also generated.

We tested LEPY on specimens of Sphingidae and Saturniidae moths, known for their contrasting traits, sampled along an elevational gradient in the Peruvian Andes. In both families, forewing length increased with elevation. However, Sphingidae had smaller wing areas despite their longer forewings. Colour brightness decreased with elevation in both families, and Sphingidae appeared generally darker. Contrast varied among species but showed no consistent trend with elevation.

LEPY provides a robust and fully automated approach to morphological trait analysis in Lepidoptera, supporting ecological and evolutionary research. Its scalability and ability to generate standardised, high-resolution trait datasets make it a valuable tool for monitoring biodiversity, conducting macroecological research, and developing global trait databases.

Hugging trees: From leaf functional diversity through crown interactions to canopy structure

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Forest biodiversity-ecosystem-functioning (BEF) experiments, deliver more and more evidence for a simple paradigm: Tree biodiversity boosts ecosystem functioning in forests. The literature suggests that high tree diversities can alter the canopy structure. In turn, this causes positive feedback effects on ecosystem functioning. But how exactly can tree diversity change the structural composition of a forest? Building on previous work, we argue that trees and their crowns compete for space on a local level, hereby creating the overall canopy structure of a forest. Trees that differ in their functional traits will also differ in their space exploration strategy. In such scenarios a more heterogeneous canopy forms and positive ecosystem functioning effects follow. Accordingly, we formulate the following hypotheses: H1: Crown interaction of tree-pairs reacts positively to differences in leaf traits. H2: The interaction of tree-pairs is influenced by the presence and functional composition of neighboring trees. H3: Canopy complexity metrics of tree-pairs and their neighborhoods increase in scenarios of higher functional diversity. Here, interaction is defined as “nearness” of crown elements. To test these hypotheses, we use data from the BEF-China experiment. We present a zoomed-in perspective on tree-pairs and their tree-neighborhoods. To quantify structural crown interaction, high-resolution terrestrial LiDAR scanning (TLS LiDAR) is used. For the functional perspective, we utilize a set of leaf traits associated with light acquisition and space usage. Crown interaction of tree-pairs will be tested on the response to their own and neighboring trees’ functional diversities, hereby testing H1 and H2 respectively. For H3 the slopes of these models will be used as predictors for canopy structure parameters such as stand structural complexity. This is a work-in-progress study.

Recovery of tree taxonomic and functional diversity of Afrotropical rainforest following selective logging

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Anthropogenic disturbances, such as selective logging for timber exploitation, are considered crucial drivers of biodiversity loss in tropical forest ecosystems. While the impacts of selective logging on tree diversity are well studied, the recovery trajectories following management interventions remain unclear, particularly for African forests. Here, we aimed to assess tree taxonomic and functional diversity recovery in an Afrotropical rainforest following selective logging. We hypothesized that tree taxonomic and functional diversity take several decades to recover and reach levels comparable to unlogged primary forest. To test our hypothesis, we employed a space-for-time approach. We used forest inventory data collected across a permanent plot network, encompassing 40.3 ha along a time-since-logging gradient (30, 50, and 70 years since logging, plus an unlogged reference site) in the Budongo Forest Reserve, Uganda. We then investigated changes of tree taxonomic and functional diversity along the time-since-logging gradient. Surprisingly, our results showed higher taxonomic and functional alpha-, beta- as well as gamma-diversity in formerly managed compared to unmanaged compartments, indicating a decline of tree taxonomic and functional diversity with increasing time since logging. Our results further revealed an increasing homogenization of tree community composition from recently logged to unlogged forest compartments. Our findings support the intermediate disturbance hypothesis and suggest that moderate disturbances are vital in maintaining tree taxonomic and functional diversity in Afrotropical forest ecosystems. In our presentation, we will further highlight the links between taxonomic and functional diversity, how they are impacted by former forest management, and what this implies for future forest dynamics and possible successional trajectories.

Spatial scale dependence of tree functional diversity effects on herbivory

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Tree diversity is an important driver of ecosystem functioning and stability, with generally higher resistance to herbivory in more diverse forests. Recent research suggests that tree functional diversity is a more relevant predictor of forest resilience than tree species richness as the presence of a high number of functionally different species provides ecological insurance to cope with a variety of disturbances. However, research is lacking on the spatial scale dependence of tree functional diversity effects on forest resilience. Comparisons of multiple spatial scales are rare and the distance decay of tree functional diversity effects is largely unknown. Here we identify the dominant scale of tree neighbourhood diversity effects using data from the IDENT tree diversity experiment in Freiburg, Germany, which was specifically designed to test for effects of tree functional diversity. The tree species pool includes twelve species: three native deciduous and coniferous tree species each as well as one non-native congener per native species. We applied a novel method to calculate tree functional diversity effects on bark beetle infestation, leaf herbivory and herbivore load weighted by both the distance to the target tree and the area used/influenced by individual trees. Our preliminary results suggest that site level tree functional diversity matters much less than neighbourhood tree functional diversity. Thus, increasing local tree functional diversity with even mixtures of deciduous and coniferous species might help forest managers maximize forest resilience to disturbances. Moreover, our findings highlight the usefulness of our novel approach to tree functional diversity with flexible neighbourhood scales, which allows to reach a better understanding of the spatial scale dependence of tree functional diversity effects on the diversity and functioning of associated biota.

Functional and taxonomic shifts in nematode diversity following enhancement of structural β-complexity in forests

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Production forests are typically managed to optimize timber production, resulting in even-aged stands with few canopy gaps and little deadwood until the final harvest. This biotic homogenization can reduce biodiversity, with far-reaching consequences for ecosystem functioning and human well-being. To explore strategies that promote biodiversity while maintaining timber production, the BETA-FOR Research Unit investigates the effects of experimentally enhanced structural β-complexity, such as variation in canopy gaps and deadwood, on forest biodiversity. In eight forests across Germany, canopy gaps and various types of deadwood were introduced on 156 plots (each 50 × 50 m). Soils harbor a wide range of organisms, including nematodes, the most abundant metazoans on Earth. Nematodes contribute to numerous ecosystem functions and are widely used as bioindicators. We examine how increased structural β-complexity affects nematode diversity across local-site (alpha), forest-level (gamma), and between-site (beta) scales, considering both taxonomic and functional aspects and using Hill-Chao diversity indices. Results indicate that the functional diversity of nematodes is more broadly affected than taxonomic diversity. For both taxonomic and functional diversity, beta diversity of common and frequent taxa increases in sites where structural β-complexity was enhanced. Notably, alpha and gamma diversity of functional traits decrease simultaneously among nematodes.This counterintuitive pattern suggests that, although forest patches become more functionally and taxonomically distinct from one another, they also lose widely shared functional types. This indicates a shift toward more specialized nematode communities in structurally enhanced stands.

Tree Diversity and Mycorrhizal type Drive Shifts in Nematode Trait Composition in Forest Soils

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Tree-mycorrhizal associations shape belowground processes by influencing nutrient cycling, organic matter decomposition, and root exudation. However, their effects on soil biota, particularly nematode functional traits, remain poorly understood. In this study, we examined how tree species richness and tree mycorrhizal type (arbuscular mycorrhizal (AM), ectomycorrhizal (EcM), or mixed (AMEcM)) influence nematode trait composition and functional diversity in forest plots. We sampled nematode communities from 80 experimental plots with varying levels of tree species richness and contrasting mycorrhizal associations. Nematode traits related to body size, life-history strategy, and feeding morphology were quantified to assess shifts in community-level trait structure. We hypothesize that AM-dominated plots promote traits associated with fast resource acquisition due to higher nutrient turnover, whereas EM-dominated plots support traits linked to resource conservation. Moreover, mixed AM-EM plots may increase trait diversity through niche complementarity. We also predict that increasing tree species richness enhances nematode trait diversity by increasing soil resource heterogeneity. Our study offers novel insights into the role of tree-mycorrhizal diversity in shaping soil food webs and ecosystem functioning through trait-based responses in nematodes.

Enhancing Structural Diversity in Production Forests: Expanding the spider community through niche diversification in Germany

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1. Spiders provide important ecosystem functions and play a major role in maintaining the functioning and health of ecosystems in Europe and around the world. However, two centuries of intensive land use and timber production have led to a homogenization of temperate forests, causing a narrow spider community in our forests. Forest management strategies that enhance structural heterogeneity have shown potential for increasing spider diversity, but empirical evidence on a landscape level is lacking.

2. This study investigates the impact of Enhancing Structural Beta Complexity (ESBC) measures in former production forests on spider diversity on a landscape level. Eleven former broadleaf production forest sites were used, with each site having one control and one ESBC district, where different amounts of canopy cover and types of deadwood structures were artificially created. The spider assemblages were recorded monthly from May to July on 8 sites in 2022 and for 3 sites in 2023 using pitfall traps and a novel, comprehensive framework of different diversity measures (taxonomic, functional, and phylogenetic diversity) along three diversity orders (Hill numbers), which focus on the impacts that drive rare, common and dominant species of the community, was applied.

3. The results show that the strategy of ESBC led to higher spider diversity on a landscape scale, driven by an increase in taxonomic and phylogenetic diversity. Both common and rare species benefited mostly from the integrated heterogeneous forest structure, while dominant forest species preferred the intact control patches.

4. Our findings suggest that incorporating high structural complexity and creating a microclimatic mosaic through the opening of canopy in forest management strategies can effectively promote spider diversity, ecosystem functioning, and spider conservation on a landscape scale.

Functional and phylogenetic beta diversity response of nocturnal moth assemblages to land-use intensity in grasslands and forests

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Land-use intensification is filtering for species, able to cope with anthropogenic landscapes. This should result in functional more homogenous communities, but a recent meta-analysis could not confirm a consistent homogenization response to human pressure and raises open questions. In Central Europe, the two major steps of land-use intensification were the conversion of forests to agriculture, and the intensification of land use within both habitats. Using light trap data from nocturnal moths, we tested the hypothesis of trait filtering and increasing community homogenization, measured by beta diversity, as response to increasing land-use intensity. The study was conducted in three regions of Germany, each representing well selected and replicated land-use gradients in forests and grasslands. With increasing land use, we predicted (P1) decreasing functional and phylogenetic beta diversity, (P2) decreasing body size, (P3) increasing wing load and (P4) darker species in communities. We calculated sample coverage standardized functional (FBD) and phylogenetic (PBD) beta diversity along Hill numbers. We found decreasing FBD and PBD with increasing land use within both habitats, but only for common and dominant species, while rare species in forests showed the opposite pattern. In contrast, grasslands, with higher human pressure, showed overall higher FDB and PBD for rare species compared to forests, while FDB for common and dominant species showed the opposite pattern. Focusing on functional traits, community weighted means showed a decrease in average body size and an increase in wing load and colour darkness with increasing land-use intensity. These findings corroborate the increasing evidence of a more complex pattern of land use on beta diversity in species communities, varying in response over relative abundance and focused facets of biodiversity. It also shows how phylogeny can act as a surrogate for functional diversity because closely related species often share similar traits due to their common evolutionary history.

Carrion decomposition is controlled by canopy cover, topography and competition between decomposers rather than by tree species richness in a subtropical biodiversity experiment

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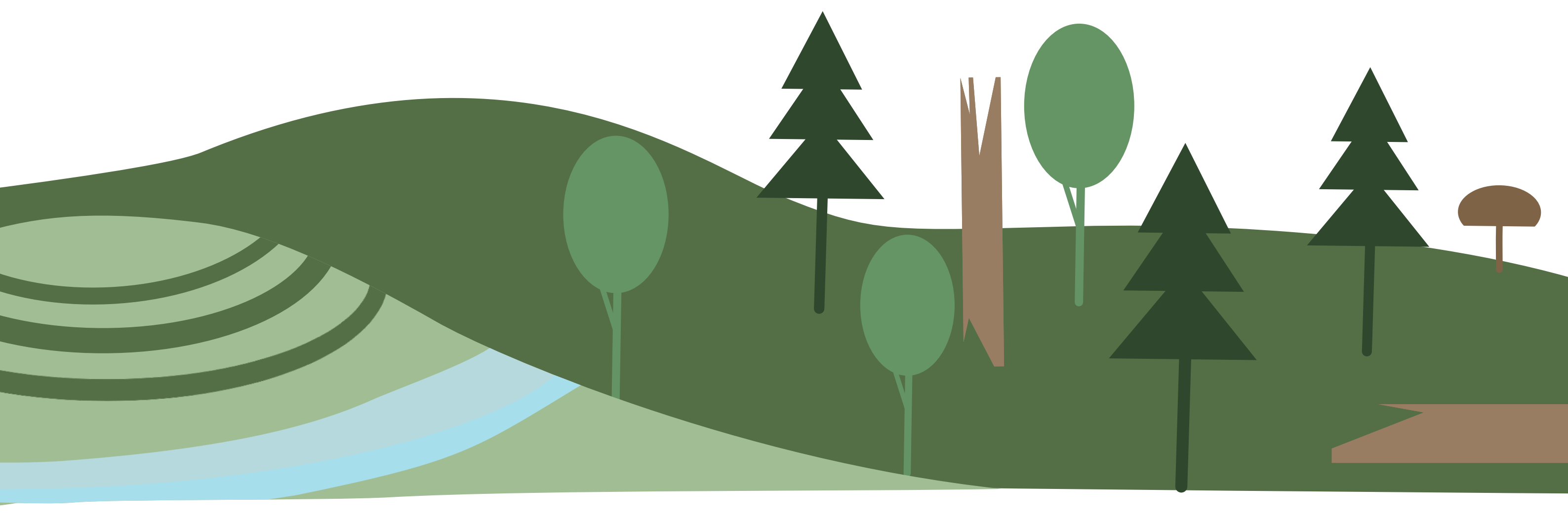
In forest ecosystems, tree diversity often positively influences the diversity of higher trophic levels and their ecosystem functions. Tree diversity may thus also promote communities of insect decomposers, and accelerate the decomposition of animal carrion. However, tree diversity effects on animal decomposition and decomposers have rarely been tested, and may be controlled by other (non-)trophic factors. Here, we investigated the interplay of forest canopy cover, slope steepness, and tree species richness in relation to animal carrion decomposition and the diversity of insect decomposers. For this, we (1) placed 1719 mice and monitored their decomposition for up to seven days, and (2) captured carrion decomposer with mouse-baited traps across 96 plots in a subtropical forest biodiversity experiment (BEF-China) in southeast China in 2023 and 2024. We found that the composition, abundance and species richness of different decomposer groups (flies, ants, other insects) was related to canopy cover and slope steepness, but not tree species richness. Carrion decomposition was accelerated under closed forest canopy and on steeper slopes, but was independent of tree species richness. Ants defended carrion against other insects, especially flies, and thereby reduced decomposition rates when flies and ants were present. This study highlights (1) the strong influence of environmental factors (forest structure and topography) and interspecific competition on carrion decomposition. In addition, because (2) both decomposing flies and predatory ants are largely unaffected by tree diversity, carrion decomposition also does not appear to be influenced by bottom-up effects of tree diversity, contradicting the commonly observed pattern of ‘diversity begets diversity’ and its links to ecosystem functioning.

Session 33

Tree traits, stress, and biodiversity



Architectural Traits Predisposing Trees to Damage: Usage of LiDAR Time Series

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European forests are subjected to increasing environmental pressures and disturbances. In particular, Norway spruce forests, already stressed by drought and storms, are more prone to attacks by bark beetles. Architectural traits serve as indicators of previous growth conditions and also determine future tree growth and behavior at the moment a disturbance occurs. Indeed, traits that can be beneficial in a steady state (without disturbance) may prove detrimental when a strong disturbance happens. Furthermore, the increased use of LiDAR reduces the difficulty of assessing tree architecture, promoting the adoption of these traits as indicators and tools for forest managers to prevent the spread of damage.

Using time series of laser (mobile and airborne LiDAR) scans repeated at one-year intervals in Germany and Sweden, we investigated the architectural traits of trees that predispose them to damages. Trees were scanned prior to the disturbance (storm or infection by bark beetles). The 3D point clouds were segmented into individual trees, and architectural traits were measured. The damage was evaluated from post-disturbance laser scans in cases of storms and from visual assessments in cases of bark beetle attacks. We modelled the intensity of the damage as a function of tree and crown traits.

In both cases, the height of the crown maximal radial extension prior-to the disturbance seems to play an important role. Post-storm leaning of the stem increased with increasing height of the crown maximal extension, and likewise top-heavy trees were more susceptible to attacks by bark-beetles.

We discuss the mechanisms behind these predisposing traits, particularly the trade-offs between the competitive benefits of increased crown projection area, and the mechanical instability it can create, as well as the effect of top heaviness, which decreases self-shading but increases the probability of attacks by bark beetles.

Within-individual leaf trait variation mediates the diversity-productivity relationship in a temperate forest biodiversity experiment

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In forest ecosystems, many ecosystem functions such as tree growth are affected by tree species richness. This biodiversity-productivity relationship is mediated by leaf traits, which, in turn, respond to tree species richness. Leaves, as the primary organs of light capture, are an important factor for tree growth. However, it is largely unexplored how a tree's ability to phenotypically adjust its leaf traits to the within-individual light gradient influences tree growth. Furthermore, it is not known how such impacts of within-tree leaf trait variation on individual tree growth sums up to productivity at the community scale. We tested, how tree species richness, a tree's mean leaf traits, within-tree leaf trait variation and the light interception efficiency within a tree crown influence tree growth. We measured these variables in the temperate forest plantation of the Kreinitz biodiversity experiment. We found that the relationship between tree species richness and tree growth is mediated via the leaf trait variation of the individual trees, which in turns was modified by light availability. In particular, trees in monocultures show a higher within-individual leaf trait variation, which partly compensates for the lack in among-species leaf trait variation, and thus, affects the biodiversity-productivity relationship. It seems that tree richness operates both through increased acquisitive trait values and within-individual leaf trait variation, two processes that cancelled out each other and resulted in the absence of a significant effect of tree richness on productivity in our study. In conclusion, to understand the biodiversity-productivity relationship, it is important to study the underlying processes and to know which ones reinforce or oppose each other. In particular, our study highlights the importance of including within-individual leaf trait variation in ecological research as one important moderator in the biodiversity-productivity relationship.

Trees, Traits and Traces: Tracking Herbivory and Predation under Tree Species Extinction

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Biodiversity loss can alter trophic interactions, and analyzing how different interaction types respond to species extinction is a central challenge in current ecological research. Additionally in planted and managed forests, with only a selection of specific trees species, the functional structure of the plant community may strongly shape interactions, as for example herbivore and predator activity.

We examined how food web interactions, herbivory and predation, respond to experimentally manipulated extinction scenarios of tree communities in a subtropical forest in China (BEF China), including three random and two trait-based scenarios. Herbivory was assessed as percent leaf damage, predation as the proportion of attacked artificial caterpillars per plot. We analyzed the influence of tree species extinction scenarios, plant functional traits, and environmental covariates on herbivory and predation.

Herbivory increased with higher tree species richness and was higher in deciduous tree species as well in tree species with higher leaf carbon concentration. Moreover, the extinction scenario, based on the selective loss of rare species, and one of the random extinction scenarios showed a particularly strong positive relationship between tree species richness and herbivory.

Predation rates showed a positive association with herbivory across all plots. This relationship became significantly stronger in one random scenario and in the rarity scenario.

Overall these findings highlight the need to account for interaction type, food web complexity and in particular the tree community structure when assessing biodiversity-function relationships. Depending on the functional and phylogenetic composition of the tree community, biodiversity can lead to either amplified or buffered ecological responses of interactions, providing valuable information on which species compositions may help sustain food webs and therefore ecosystems in the face of ongoing tree species decline.

The phyllosphere microbiome as an indicator of herbivory, leaf mining, as well as pathogen damage across tree species

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Fungal endophytes in the phyllosphere can have beneficial or detrimental effects on their host plants. Reducing herbivory, while herbivory itself can alter the diversity and composition of the leaf microbiome. Similarly, endophytes might reduce fungal pathogen damage. For most tree species, it is unknown whether such relationships between endophytes and herbivory or pathogen damage exist, and if yes, if they can be generalized across different tree species. To investigate the relationship between phyllosphere fungal diversity and the ecosystem functions herbivory, leaf mining and pathogen damage, we used next-generation amplicon sequencing and distinguished between the whole phyllosphere, endophytic and epiphytic fungal communities. We used a tree biodiversity experiment in which all trees grow under similar conditions to account for host identity, species richness and community composition. Our results reveal that across six tree species, the overall relationship of fungal diversity in the whole phyllosphere with pathogen damage was positive while the one with herbivory was nonsignificant and the one with mining damage was negative. In contrast endophytic fungal diversity positively covaried with herbivory while the relationships with pathogen and mining damage were insignificant. Detailed analysis of which fungal taxa drove these relationships demonstrated the importance of particular alternative sequence variants, and a strong host specificity. We clearly demonstrate significant relationships of foliar fungal diversity with herbivory, leaf mining, and pathogen damage, while the causality remains unresolved. We suggest that the leaf microbiome affects herbivores or pathogens either via changes in leaf chemistry or palatability, or phyllosphere microbiota are dispersed by herbivores.

Do flowering strips enhance tree vitality? Impacts on arthropod communities and tree performance in pine nurseries

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Flowering strips are increasingly recognized as a valuable tool in conservation biological control, as they provide floral resources and structural habitat that support populations of natural enemies and contribute to the suppression of herbivorous pests. Although their benefits have been widely studied in annual cropping systems, there is a lack of research on their role in woody plant nurseries, particularly regarding how they influence arthropod community composition and how these changes affect tree vitality and physiological performance. In this study, conducted in ornamental pine nursery, we compared arthropod communities and tree physiological traits between plots with flowering strips established in the interrows and control plots without flowering vegetation. Arthropods were sampled both from pine tree canopies and from the interrow vegetation to assess their distribution and abundance. Tree vitality was evaluated using chlorophyll fluorescence parameters, including SPAD (relative chlorophyll content), LEF (light energy used in photochemical reactions of photosystem II), NPQt (non-photochemical quenching as a stress indicator), and by quantifying herbivory on needles. We found that the presence of flowering strips significantly increased the abundance of spiders and reduced the abundance of herbivores on pine trees. These shifts in arthropod communities coincided with improved physiological parameters in pine trees, such as higher SPAD and lower NPQt values, indicating enhanced tree vitality and reduced physiological stress. These findings suggest that integrating flowering strips into pine nursery management can strengthen biological control services, reduce pest pressure, and promote the growth and health of young trees. This research was supported by the Specific University Research Fund MENDELU (Reg. No. IGA25-FFWT-IP-011).

An endophytic fungus alters the chemistry of black poplar leaves, repels herbivorous insects and shapes arthropod community assembly

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It is well known that endophytic fungi can provide herbaceous plants with defense substances against herbivores, but there is little information on whether endophytic fungi of trees also confer such benefits. Here, we investigated the influence of the endophytic fungus *Cladosporium sp*. on the chemical defense mechanisms of black poplar (*Populus nigra*) and the consequences on the feeding preference and fitness of herbivorous insects as well as on the assembly of the arthropod community in young trees. The colonization by endophytes strengthened both the constitutive and induced defense mechanisms of black poplar. Generalist *Lymantria dispar* caterpillars preferred uninfected poplar leaves to endophyte-infected leaves and developed better there, which is most likely due to the higher concentrations of salicinoids in endophyte-infected leaves and the alkaloid stachydrine produced by the endophyte. Under field conditions, the endophytic fungus also influences the composition of the arthropod community in young trees. For example, the number of aphids was higher on trees with the endophytic fungus, but the number of ants tending the aphids was lower, probably because the honeydew produced by the aphids also contains the alkaloid stachydrine, which may make it less attractive to ants. Our results show that endophytic fungi can play an important role in both defending against herbivorous insects and structuring arthropod communities in trees.

Exploring diversity effects on Fraxinus excelsior: Early experimental evidence on growth and disease susceptibility under pathogen stress

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The ongoing decline of European ash (*Fraxinus excelsior L.*) due to infection with *Hymenoscyphus fraxineus*, known as ash dieback, is a major threat to the functioning of temperate European forest ecosystems. While compensatory plantings with alternative tree species are often proposed to maintain structural and functional continuity (e.g. Steinhart et al., 2024), the role of ash itself within such communities is often ignored. This gap limits our understanding of how species richness and identity mediate performance under biotic stress and thus affect biodiversity–ecosystem functioning (BEF) relationships. This information could be vital for re-establishing ash in European forests.

Within the FraDiv project, we established a multisite field experiment across 12 formerly ash-rich forest stands in Schleswig-Holstein, using a factorial design with ash and four native tree species planted in monocultures and all 2-, 4- and 5-species mixtures. This approach allows us to explore how diversity modulates ash performance under disease pressure and variable environmental conditions.

Four years after planting, 81 % of ash trees survived with 55% of them showing symptoms of infection with *H. fraxineus*. Survival and performance was significantly affected by site conditions and disease status. Relationships between ash performance and environmental conditions were not always linear. Ash performance increased with moderate light but declined under very open canopies.

While tree species richness had no consistent effect on ash performance, species identity and specific identity-richness interactions significantly influenced growth and survival, partly in interaction with ash dieback infection. For instance, an inhibitory effect of *Carpinus betulus* on ash growth is only prevalent in healthy ash.

The importance of species identity and functional complementarity under biotic disturbance, supporting the insurance hypothesis in BEF relationships under real-world stressors, will be discussed.

Plasticity in thermotolerance in Central European timber species over time and in response to abiotic stress – comparison of standard and in situ techniques

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With rising global temperatures and more frequent, intense, and lasting heatwaves, assessing heat tolerance in trees becomes more important than ever. Thermotolerance thresholds calculated for leaves provide insights into potential declines in tree health at high temperatures, and have been commonly measured in tropical species. Research is increasingly available for Central European trees, but measurements are taken from excised leaves heated in a water bath, separating leaf tissue from the rest of the plant and preventing realistic VPD conditions. In addition, thermotolerance thresholds are often calculated at one point in time, with plasticity of thermotolerance remaining largely unexplored.

In this study, we determine temperatures at which photochemical efficiency of PSII (Fv/Fm) is impaired through the heating of attached leaves in situ and measurement of their dark fluorescence. Thermotolerance parameters are extracted from the temperature response curves for leaves of five Central European timber species over time, with measurements also taken from plants experiencing water stress, a simulated heatwave, or both, to allow for quantification of thermotolerance changes over time and due to abiotic environmental stresses. Water-bath leaf thermotolerance curves will provide a comparison to standard methods.

We hypothesize that heatwave stress will result in increased thermotolerance, with a return to non-stressed values after a recovery period, and that leaf thermotolerance measured from attached leaves heated in situ will indicate lower temperature thresholds than with the water bath technique due to the additional stress of more realistic, higher VPD on the leaf. Our results will improve the growing understanding of thermal sensitivity in Central European timber species as determined by leaf age and leaf history, as well indications whether the water bath technique is suited for predicting leaf response to more realistic high temperature conditions.

Seasonal plasticity in foliar drought and heat resistance in mature European beech and European ash

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The ability of a tree species to withstand drought and heat stress depends on the adaptive plasticity in its water-use strategies under dynamic climate conditions. We measured 12 foliar drought and heat resistance traits for mature European beech (*Fagus sylvatica L.)* and mature European ash (*Fraxinus excelsior L.*) at eight time points during the growing seasons of 2023 and 2024. For this, we sampled four sun-exposed branches, each from beech and ash in an unmanaged mixed stand of Hainich National Park, Germany.

Overall, ash had more negative midday water potentials (Ψ_{MD}), osmotic potentials at full turgor (ΨFT) and a by 0.3-1.0 MPa lower turgor loss point (Ψ_{TLP}) than beech. Furthermore, ash leaves had lower relative water contents at turgor loss (RWC^{TLP}) and were more elastic (higher bulk modulus of elasticity ε) than beech leaves. In 2024, ash displayed higher plasticity in most traits than the rather static beech, lowering its Ψ_{FT} and Ψ_{TLP} by 1.3 MPa. Minimum leaf conductance (gmin) was twice as high in beech leaves than ash at the beginning of the growing season. Against the expectation, ash gmin rose sharply by 150% towards the end of summer, overtaking beech. Ash displayed lower mean leaf water potentials at 12, 50 and 88 % loss of conductance (Ψ_{12}, Ψ_{50} and Ψ_{88}) than beech, with a difference in mean P_{50} of 0–1.2 MPa between the species. Seasonal osmotic adjustment was found to result in largely positive hydraulic safety margins for ΨTLP and P12. Both species increased the thermal resistance of PSII (T_{50} value of F_v/F_m) by ≈7 °C over the summer of 2024. Beech leaves were consistently more resistant to thermal damage with a T50 of ≈5 °C higher than in ash leaves.

Our results highlight higher adaptive seasonal plasticity to drought and heat of ash than beech suggesting seasonal plasticity is species-specific. The multi-trait approach provides further insights into the seasonal dynamics of foliar hydraulic and thermal traits in temperate broadleaf tree species.

Drought Stress Memory in Trees Promotes Long-Term Resilience

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Understanding tree drought resilience is key for predicting the fate of global forests under more frequent and intense droughts. However, the mechanisms underlying the acclimatisation of forests to drought remain unclear, largely due to a lack of long-term, continuous monitored data. Here, we investigate leaf physiology and gene expression of the keystone species European beech (*Fagus sylvatica*) using a two-year controlled pot experiment and a twenty-five-year natural field study. Trees with prior drought exposure exhibited delayed dehydration with prolonged photosynthetic activity, less leaf-damage and tree mortality, alongside reduced gene expression variance and fold change during subsequent droughts. Transcriptome profiles of pre-treated trees more closely resembled a natural forest response, suggesting that current drought response of trees is primed by past stress events. These findings provide evidence for a drought memory that enhances tree resilience and persists over decades, underscoring the importance of long-term adaptation for forest survival in a changing climate.

How tree size and neighborhood characteristics influence the vitality of European beech after severe drought

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The extreme drought of 2018/19 caused widespread early leaf discoloration and canopy dieback in European beech (*Fagus sylvatica L.*) across Central Europe. We found a high heterogeneity within forest sites, with declining and vital beech trees in close proximity. Therefore, we investigated abiotic and biotic factors influencing this variation in 520 beech trees in 20 beech-dominated forest stands in Bavaria, Germany. Using airborne laser scanning (ALS), we generated detailed terrain models for topographic and hydrographic analysis and extracted tree metrics such as height and crown projection area. In addition, individual distance-dependent tree competition and canopy gap size around the beech trees were quantified. To complement the dataset, we conducted high resolution soil sampling to estimate plant-available water capacity (AWC) at the tree-level.

Across all sites, trees in areas with generally higher water availability, based on soil data and topography, showed significantly greater mean defoliation. Larger trees and those with higher long-term growth (mean basal area increment) were also more vulnerable. At small scales, trees with slightly higher AWC performed better during the drought. Within sites, canopy gaps improved tree vitality, with stronger effects in pure beech stands. The influence of neighborhood composition on the drought response of European beech was mixed: beech trees growing with Scots pine performed slightly better during drought than those mixed with oak or growing in pure beech stands. Our results highlight the complex, scale-dependent interactions among water availability, competition, tree size, and species composition on the response of beech to severe drought. Our results emphasize the need for integrated, site-specific forest management strategies to enhance forest resilience to climate change.

Understanding Urban Tree Functioning and Ecosystem Services Under Climate Change Through the Coupling of Mechanistic Models

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Urban trees play a critical role in enhancing city livability by providing multiple ecosystem services (ES), such as microclimate regulation, stormwater mitigation, and air quality improvement. However, their performance is strongly influenced by species-specific characteristics and urban-specific stressors, such as water availability and heat waves, which will be increasingly variable under future climate conditions. To help quantifying the interplay between urban tree functioning, abiotic stressors, and ES supply, we couple a dynamic, individual-based mechanistic model of tree growth and related ES with an urban ecohydrological model focussed on simulating simulating tree evapotranspiration and plant water deficit phases. Our coupling aims to capture tree-specific responses to local environmental conditions. More precisely, we model growth processes—including energy allocation and phenology—at daily to hourly resolution. This linkage is done through an integration of a detailed urban microclimate and hydrological component, accounting for evapotranspiration, shading-driven heat mitigation, and runoff and infiltration reduction due to sealing, soil properties and interception. This coupling allows us to specifically evaluate how climate-related stress (such as water stress) constrains evapotranspiration, growth, and supply of key ES across species and locations. The coupled model is tested across different tree species commonly planted in temperate urban areas, accounting for spatial configurations and climate scenarios for site in Milan and Berlin. Results show how the interaction between tree traits, planting design, and water regimes can lead to divergent growth trajectories and ES delivery patterns. This coupled model helps both understanding and anticipating the functioning of urban forests, offering guidance for species selection and planning under climate uncertainty.

Session 34

Urban ecology

European cities manage their green space for people and biodiversity: a chance for urban (or ecosystem) restoration?

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Urban ecosystems have the potential to support biodiversity, yet many are in an ecologically degraded state due to intensive management or neglect. When designed and managed according to ecological principles, urban green spaces can enhance biodiversity while also improving the well-being of city dwellers. However, many cities lack initiatives to invest in both ecological design and management, limiting the potential of urban ecosystems to contribute to biodiversity conservation.

To better understand the motivations and goals of city administrations regarding green space planning and management, we conducted a questionnaire survey across Europe, gathering responses from 573 cities across all major climatic regions. We examined their basic motivations for green space management (people, biodiversity or both), key planning and management goals, and perceptions of the current state and changes in condition of their urban nature. We assessed whether cities provided staff training in biodiversity-friendly management, involved their population in planning and management, and implemented measures to improve public acceptance of biodiversity-friendly management.

Most respondents included biodiversity in their basic motivation. However, their top four management goals were people-focused; promoting biodiversity ranked fifth but also scored high. Cities that explicitly included biodiversity in their motivation invested more into public acceptance measures and reported higher ecological quality of their urban nature.

Our findings show that cities approach their green spaces differently, depending on, among others, population size and geographic location. These insights can help the development of

Lawns and order: Overcoming barriers to biodiverse urban greenspaces through stakeholder perspectives across multiple levels

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Urban ecosystems are often overlooked in large-scale biodiversity strategies, such as the EU Nature Restoration Law, which primarily natural and semi-natural habitats. Urban green spaces - ranging from parks and cemeteries to informal green areas - are still largely seen as areas for humans. Yet, these spaces can offer important habitat for wildlife and plant species. However, various hurdles - such as safety regulations, heritage protection, rigid bureaucratic structures, and aesthetic expectations - limit the biodiversity potential of urban greenspaces. This study identifies and categorizes such challenges, as well as suitable management strategies to address these, by combining three different methodological approaches on different scales: (1) a Europe-wide quantitative survey of urban administrations (n = 573), (2) qualitative interviews with experts from nature conservation and city administrations (n = 26), and (3) a stakeholder workshop in the Ruhr metropolitan area with representatives from administration, NGOs, research, and conservation stations (n = 17). Across all three approaches, the perceived need for visual orderliness emerged as a key barrier to urban biodiversity. Promising measures to overcome these hurdles included targeted public communication, “cues to care” such as mown edges, the use of grazing animals in urban areas, and training programs for municipal greenkeeping staff.

Contribution of public and private green space in spatial distribution based on green volume and green area perspectives

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Green space contributes to humans in various ways. However, it is unequally distributed in both public and private areas in cities due to the different management of land ownership. Numerous studies have found the contribution of green spaces to humans, but there is still a lack of attention to the mutual contribution of green spaces in different ownerships in spatial distribution. Previous studies on green space distribution have focused on the green area, i.e., the 2D representation of green. However, green areas do not consider the three-dimensional nature of green spaces that determines the provision of ecosystem services. To bridge this gap, we integrated very high-resolution remote sensing-based data (0.5m x 0.5m) of green area and green volume at grid cells of 100m x 100m, to examine the contribution of private green to public green in grid cells deprived of public green, and vice versa. In the city of Munich (Germany), private green spaces dominate in grid cells with little green, while public green spaces dominate in grid cells with larger green. We found that the contribution of private green to public green was in a large number of grid cells that contained little green (green area: 65.5%, green volume: 60.6%), while the contribution of public green to private green was in fewer grid cells that contained little green (green area: 34.5%, green volume: 39.4%). Proportionally equal contribution of public and private green was usually found in grid cells with large green surface area, or with low or medium green volume. From a practical perspective, our study helps urban planners and designers better understand public and private green space in cities, providing detailed information for improving public and private green spaces and enhancing green justice.

Through the lenses of urban green spaces: How human and environmental factors shape plant diversity in cities

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Compact city development and urban green spaces (UGS) have gained political momentum as key strategies for sustainable cities. However, limited space creates tension between urban densification and green spaces, placing increasing pressure on plant diversity. The heterogeneity of UGS, shaped by diverse uses and management practices, plays a key role in driving urban plant diversity. This diversity includes native and non-native species, which likely respond differently to human-related and environmental drivers. Understanding and quantifying these mechanisms across types of UGS is important for guiding urban planning strategies that balance ecological sustainability and urban needs.

To study the role of the types of UGS and the underlying drivers of urban plant diversity, we recorded plant species in five representative UGS (allotment, private garden, real estate, park, ruderal) across three culturally distinct Swiss cities (Geneva, Zurich, Lugano). We applied community ecology concepts and used General Additive Models to examine how cultural context, types of UGS, ecological, and management factors shape plant diversity, focusing on differences between native and non-native species.

Our findings show that privately owned green spaces, especially gardens and allotments, harbour ~50%, and real estate, parks, and ruderal spaces ~40%, of the city's plant species. Human management was the strongest predictor of non-native richness, while climate more strongly influenced native diversity. Notably, the disturbance had opposing effects, increasing exotic species richness while simultaneously reducing native species richness, suggesting divergent ecological responses to the management of UGS. Our results highlight that UGS heterogeneity and associated management support plant diversity. Importantly, management intensity, a modifiable factor, offers a key lever for biodiversity enhancement through planning.

Effects of global change factors on native grassland communities for infiltration swales

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Global change encompasses climate changes, pollution, urbanization, habitat fragmentation, and species losses. Such factors are increasingly interacting, as e.g. in urban green infrastructure (UGI). Given the limited urban green space, it is important to assess synergies and trade-offs of UGI as affected by such global change factors, to make sure that they provide ecosystem services in the long term. Infiltration swales are a specific type of UGI that provide localized stormwater management while having great potential to provide habitats for native plants. According to the conditions often found in such swales, we tested the effects of microplastic pollution, flooding, and drought on two grassland communities in a full-factorial greenhouse experiment. Contrary to our expectations, drought had a positive effect on biomass production, especially if alternated with flooding every other week, just as pollution with microplastics had a positive effect. However, this effect was generally lower in more competitive communities. The observed effect sizes were relatively small, but under conditions involving changes in water availability and typical urban microplastic pollution, the tested communities were just as viable, if not more so, than under control conditions. This is an important message to those responsible for the planning of UGI, as it demonstrates that native plant communities are a viable alternative to current turf vegetation in infiltration swales.

How “happy” are Germany’s pigeons?

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Animals need to procure sufficient ecological resources like food and nest sites to survive and reproduce, while balancing the risk of predation in the process. Across Germany, urban feral pigeons (Columba livia) are provided food and nest sites in supervised dovecots to attract breeding activity, and their eggs destroyed to limit population growth as part of the Augsburg model. Some interventions go further, taking pigeons off the streets and permanently housing them in aviaries.

Incidentally, pigeons subject to these forms of management may be experiencing stable, abundant food supplies, while risk from natural predators reduced or eliminated. This is generally assumed to confer animals greater reproductive fitness. But are these individuals “better off”, in terms of wellbeing? What happens when security (resource and safety) comes at a cost to physical freedom?

This talk introduces our ongoing study assessing the effects of resource provisioning and captivity on the wellbeing of urban feral pigeons imposed by nonlethal pest control. Preliminary findings will be shared, comparing integrated stress profiles (using physiological and behavioural indicators) representative of three population types (captive feral pigeons, free-living managed dovecot pigeons, and unmanaged “wild” city pigeons) experiencing varying degrees of freedom/security, sampled from the state of Brandenburg. These findings are relevant to conservation strategies involving captive breeding and translocations.

The role of regulators, decision makers and land managers in the conservation and management of invertebrate biodiversity in cities

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Invertebrate biodiversity is essential for functional ecosystems, but invertebrate management is a delicate balance between conserving beneficial species and preventing outbreaks of pests that have negative impacts on human and environmental health. In highly modified environments such as cities, very few biodiversity conservation initiatives consider invertebrates, and many urban ecosystem management practices, such as weed and pest management, cause direct negative impacts on invertebrate biodiversity. To create healthy, functional urban ecosystems, it is essential to plan cities and implement management actions that improve invertebrate biodiversity and support the ecosystem services they provide. Depending on the specific usage of an urban area different stakeholders hold responsibility for its management and have diverging priorities regarding invertebrates and their ecosystem services. Hence, effective urban invertebrate conservation and management requires support and action from regulators (governments, lawyers and policy makers), decision makers (planners, developers and architects), land managers (practitioners, community organisations) and the public (residents, community groups and visitors) alike. We provide a general framework and guidance on how different stakeholders can incorporate invertebrate conservation into their decisions and actions by mapping the invertebrate conservation priorities for different urban land-use types and reviewing the range of actions that can be undertaken. We include strategies to support invertebrates through policy, improving urban habitats, and increasing knowledge and community engagement based on research conducted in cities around the world. To support best practice, we present examples of well designed and implemented interventions that have positive invertebrate biodiversity outcomes and highlight ways to facilitate implementation including future research, interdisciplinary collaboration, and government support.

Beyond Greenness: Unveiling the Key Urban Features Driving Bird Diversity in Munich

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Urban areas can be biodiverse, yet how specific urban features affect species diversity remains poorly understood. While greenness metrics like NDVI are important, they may not fully capture the complexity of urban habitats. This study examined how vegetation structure and built infrastructure influence bird communities in Munich, Germany. Using passive acoustic monitoring at about 500 sites, we collected bird vocalisation data and used BirdNET to derive species richness, vocal activity rate, and Shannon diversity metrics. Random-forest models identified key predictors of bird diversity while linear models quantified their effects. Community composition was analyzed through non-metric multidimensional scaling. Our results showed shrub cover was the strongest positive predictor across all biodiversity metrics, highlighting this often-overlooked vegetation layer's importance for urban birds. Grass cover and NDVI also increased bird diversity, while road infrastructure and building density had consistent negative impacts. Tree-related variables, though not among the strongest predictors of overall diversity, were important in shaping community composition. Sites further from the city centre generally supported higher bird diversity. Notably, models incorporating multiple urban features explained over 10% more variance than those based solely on NDVI, demonstrating the value of detailed habitat assessment. These findings underscore the need for nuanced approaches to urban biodiversity conservation beyond simplistic greenness metrics. Our results suggest promoting structurally diverse vegetation, particularly shrubs and grass, could significantly enhance urban bird diversity while mitigating the effects of impervious surfaces and roads. By integrating these ecological insights into urban planning, cities can better support biodiversity while creating healthier environments for wildlife and people.

Why they occur here but not there – a case study of Great spotted woodpeckers in the city of Munich

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Many animal species can occur in the urban environment. The factors determining whether a species can live in a particular place in the city but not in another are, however, often not known. Such knowledge is needed to be able to design urban green infrastructure that is suitable for a particular species. The Great Spotted Woodpecker, Dendrocopus major, regularly occurs in cities. It breeds in self-made cavities in trees, thus the presence of trees is a necessary but not sufficient condition for woodpeckers to live in a particular place. Here we used a number of approaches to elucidate factors that influence the occurrence of woodpeckers in the build-up area of the city. We studied the occurrence of D. major on 103 squares in Munich, Germany, using seven rounds of observations both in summer and in winter. Squares were characterized by a number of variables including square size, position in the city, tree occurrences, and a number of other variables. We also observed the presence of nests and undertook behavioural observations to study tree use. Woodpeckers were observed on about 2/3 of the squares. A random forest model showed that a number of variables, in particular the number of trees on the square, tree diversity, and the sum of DBH of trees on the square as well as the amount of green in the surroundings positively affected woodpecker occurrence on squares, while closeness to the city center and the number of humans on squares negatively affected occurrences. Woodpecker cavities were found only in trees with a DBH>20 cm and there was a distinct preference for larger trees of softwood tree species. Behavioural observations showed that woodpeckers use a wide variety of trees e.g. for foraging, whereby trees between 40-60cm DBH and particular tree species were preferred. Our study shows that humans can design public places for the presence of the Great Spotted Woodpecker by providing a locally high abundance of trees of different species with total DBH close to 25m. Trees in the surroundings and the presence of softwood trees with >40cm will make it more likely that woodpecker use a space when local tree abundance is lower.

Impact of urban gradient on bee and hoverflie communities

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Human activities are leading to a rapid collapse of biodiversity. Through the increase of impervious surfaces and induced urban heat island effects, urbanization greatly contribute to this collapse, especially in pollinators which are sensitive at different levels to both habitat loss and thermal stresses. Bees and hoverflies are the two most efficient taxa among pollinators . Using a multi-taxon-approach and studying multiple anthropogenic stressors, we want to address how pollinators communities are impacted by urbanization ? We hypothesized a decrease in the abundance and species richness of wild bees and hoverflies caused by the habitat loss and thermal stress in cities. Regarding honey bees, thanks to the presence of managed colonies within the city, we only expect a negative effect of the thermal stresses in the most urbanized sites. To test this hypothesis, we followed pollinator communities on eighteen sites in the city of Rennes (Frances). Sites has been chosen for their location along two urbanization gradients, one of impervious surfaces and one on urban temperatures. On each site, flower strip has been sown a year before sampling to control for their floral composition and density. The amount of habitats was estimated within a 250m buffer centered on the flower strip. Urban temperature has been estimated using the climatologic monitoring network RUN deployed in the city of Rennes . Here, we will present the first results of our study. This work will provide strong bases for futures analyses on the effect habitat loss and thermal stresses on life history traits and how cities filter communities from regional pool to communities within flower strips.

Urban densification and biodiversity - Identifying thresholds and evaluating urban greening measures

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Urban densification is widely promoted as a strategy to limit urban sprawl and preserve surrounding agricultural and semi-natural habitats, thereby supporting biodiversity conservation at the landscape scale. However, the notion that urban densification primarily occurs through vertical expansion while sparing existing green spaces is misleading. In practice, low-density residential structures are often replaced by multi-story buildings that occupy a greater footprint, leading to a net loss of urban green areas. This ongoing erosion of intra-urban green space raises a critical yet underexplored question: Is there a threshold of urban densification beyond which biodiversity declines precipitously? Furthermore, can any urban greening measures effectively counterbalance the loss of habitat and ecosystem complexity? To address these questions, we analyzed biodiversity patterns across 43 private gardens and 42 allotment gardens in Zurich, Switzerland. These sites were selected along a gradient of urbanization within 50 m and 500 m radii and varied in local garden management intensity. We surveyed seven taxonomic groups of terrestrial arthropods using standardized sampling techniques (pitfall traps and coloured pan traps). Our results indicate that urban densification significantly affects both species richness and community composition, with threshold responses varying across taxonomic groups. Yet, certain management practices—such as reduced intensity and increased plant diversity—and the implementation of green roofs are insufficient to fully offset the biodiversity losses associated with habitat reduction. These findings highlight the urgent need to define ecological thresholds in urban densification and to critically assess the efficacy of commonly proposed urban greening measures.

Optimizing architecture for humans and plants: simulating a building envelope and analyzing the consequences for humans and nature

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Urbanization often leads to habitat loss for plants and animals, causing a decline in urban biodiversity. Despite this, cities can support many native species, and diversity is crucial for many ecosystem services. Addressing the needs of plants and animals in urban development is vital for sustainable urban development, but is not commonly practiced. Additionally, building vegetation designs tend to focus on human benefits only, such as visual or thermal comfort.

Designing for humans and other organisms requires analyzing trade-offs to create biodiversity-friendly buildings while maintaining good standards for human life. Architectural multi-objective optimization can help to achieve this, but including non-human objectives is rare.

Here, we integrate the objective of increasing plant diversity into an architectural optimization process alongside human objectives, exploring the consequences of different weights on both stakeholders' needs. Building envelopes create extreme environments with high radiation exposure and thin soil, posing a challenge for plants from the surrounding environments, especially from forest habitats where understory plants often require shade and deeper soil. We analyzed how architecture can be used to accommodate plants of a grassland plant community and a forest fringe community, extracted from EUNIS, which differ in shade requirements. We use the local plant vegetation model 3Destiny to simulate the effects of soil depth and architectural shade on the communities and show how including plant objectives can lead to designs that better promote diversity.

Fostering Ecological Considerations in Urban Planning by Employing a Multidisciplinary Approach

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Urbanization is associated with increased sealing, habitat fragmentation, rising temperatures, and anthropogenic noise in densely built-up areas. There is no lack of research linking these impacts to both the deterioration of human health as well as their threat to natural ecosystems, causing biodiversity loss.

Various urban planning approaches already exist to account for and mitigate these impacts by transforming urban structures into resilient systems. However, such approaches often work on isolated aspects and prioritize selected disciplines over others. The concept of ecosystem services, for example, fosters human-centric design where specific trees are selected for cooling effects while neglecting their broader ecological role. Once ecological aspects are considered, they are frequently qualitative or ornamental, disregarding their quantitative ecological value for urban wildlife.

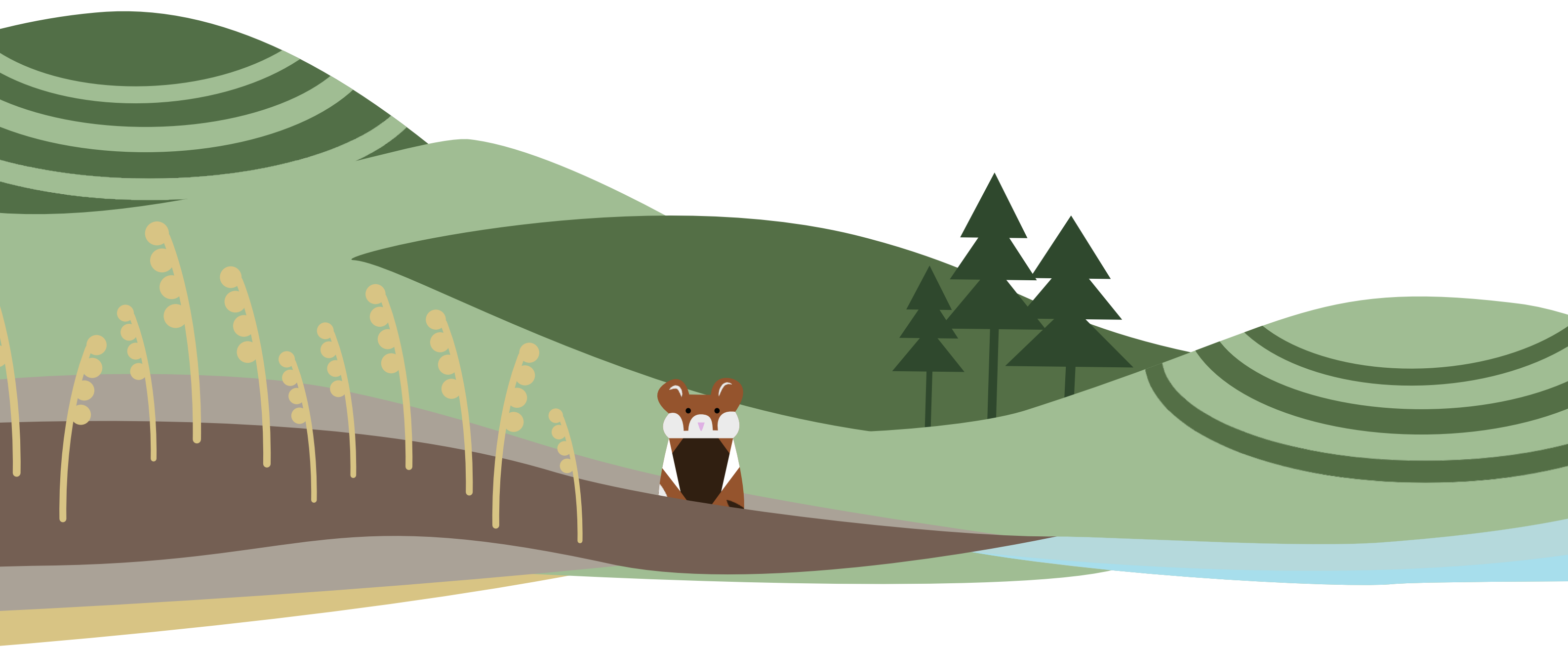
In this way, urban planning is not being understood as a multidisciplinary process but rather as a mosaic of multiple different disciplines requiring later integration. Primarily, following human-centric design, leads to trade-offs being made at the expense of ecological aspects. In contrast, early data-driven integration of multiple disciplines can uncover synergies between the different disciplines. Meanwhile, multidisciplinary, collaborative, and participatory approaches have proven effective in delivering resilient urban solutions.

In this paper, we therefore advocate for the early integration and equal importance attribution to multiple planning perspectives into one holistic approach. For this purpose, we present the Co-creative Cohabitation Network (CoCoNet) project, which aims to develop an integrated, multidisciplinary, and participatory modeling-based planning approach. By discovering and quantifying synergies as well as interdisciplinary trade-offs from planning measures, this approach will showcase desirable urban planning pathways, considering the needs of humans and urban wildlife.

As a first step in creating such a holistic approach, we perform this integration for two distinctive disciplines: We demonstrate an overlay from a traffic planning and an ecological connectivity model, and show how both planning disciplines can benefit when integrated from the beginning.

Session 35

Biodiversity patterns across scales, taxa and systems



Local, landscape and seasonal drivers shape bird communities and their ecosystem service potential in Mediterranean olive groves

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Insectivorous birds provide essential pest control services, but their diversity and ecosystem functions are increasingly threatened by agricultural intensification. For a sustainable management of Mediterranean olive groves, it is key to understand how local and landscape-scale factors, along with seasonal dynamics, shape bird communities and their ecosystem services. Using systematic point counts over two years (2022-2023), we assessed effects of local vegetation structure (olive tree diameter, shrub cover), landscape complexity (proportion of surrounding semi-natural habitat, SNH, within a 500 m buffer: <30% = low-SNH, >30% = high-SNH), and season (spring vs. autumn) on bird abundance, richness, and functional traits in 12 organically managed olive groves in Tuscany, Italy. Low-SNH groves supported higher bird abundance and functional and overall richness, as well as functional divergence, especially generalist species with herbivorous diets and understorey foraging. However, high-SNH groves supported a higher proportion of specialized insectivorous species foraging in mid-storey and canopy layers. Shrub cover increased bird abundance by 10%, while tree diameter and low shrub cover promoted mid-storey foraging birds. Species richness was 35% higher in spring than in autumn. Beta-diversity analysis revealed greater bird community dissimilarity with SNH cover, driven by nestedness. Our results highlight that managing both local vegetation and surrounding semi-natural habitats is key to integrating biodiversity and ecosystem services into productive organic olive systems and provide guidance for farmers and stakeholders seeking more sustainable land use.

Effects of vegetation cover and vegetation composition on bird diversity and abundance across Munich

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Urbanization is a major driver of global biodiversity loss, and as cities expand, this trend is expected to continue. Though many studies conclude the importance of vegetation cover and composition for bird communities in cities, the vegetation type of importance has been found to vary widely. This may be due to the fact that the effect of vegetation composition has seldom been isolated from the effect of vegetation cover. Further, most studies have been conducted in a particular type of urban green space such as parks; few studies have taken a detailed look at the effects of vegetation using a city-wide approach. This study assessed and compared the isolated effects of the cover and the composition of local vegetation on bird diversity and abundance, using tangible vegetation metrics that can be applied in city planning. Passive acoustic monitoring was used to quantify bird diversity metrics at 100 sites across Munich, and total vegetation cover and the proportions of the vegetation cover composed of grass, shrubs and trees in a 100-meter radius around the sites were estimated using high-resolution remote sensing data. Results showed that total vegetation cover had a highly significant positive effect on bird diversity. Vegetation type composition had an additional significant effect on bird diversity and explained more of the variance in the response variables than vegetation cover. Diversity metrics increased substantially with increasing proportional shrub cover and declined slightly with increasing proportional tree cover. There was also evidence that the evenness of the composition may have had an effect on the diversity metrics, where more even compositions of grass, shrubs and trees led to higher bird diversity than uneven compositions. These results suggest that local bird diversity in cities can be enhanced by increasing vegetation cover throughout the city, while ensuring green spaces are structurally diverse with a high proportion of shrub cover.

Environmental features and social insects: effects on species, traits and communities

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Social insects are an essential part of global biodiversity. They contribute to terrestrial food chains and perform key ecosystem services. They are also sensitive to changes in their environment. I am using social Hymenoptera (ants and bumblebees) as model organisms to tackle questions related to global patterns, species traits, and key ecological processes at different scales. On the global scale, my research shows that there is large variety in the sheer numbers and densities of insects across biomes, regions and habitats. On smaller scales, regional communities are associated with land use types and habitat features. In climatically challenging environments, only species with a specific suite of traits can persevere. Given the current loss of insect biodiversity in terms of species richness and abundance, it is vital to understand the relationships between insect species, their functional roles and their resilience to environmental change.

Bee diversity and sampling methods along a tropical elevational gradient

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Mountains are great study systems to understand how different factors affect species' ecology. The large differences in temperature that occur in short distances allow us to study species' adaptation to different temperatures and predict the responses to ongoing global warming. Bees (Hymenoptera: Anthophila), are known for their importance as pollinators in terrestrial ecosystems. However, in the tropics bee research is usually scarce and mostly taxonomical, often leaving ecology aside. In the Neotropics, two groups have got most of the attention, Euglossini and Meliponini, due to their abundance, but also because methods to sample them are well known. Most methods for collecting bees have been tested in temperate ecosystems and it is not well understood how they perform in tropical rainforest environments.

We studied an elevational gradient next to Manu N.P., Peru, in the eastern slope of the tropical Andes. We aimed to (1) understand the environmental drivers underlying the diversity and abundance patterns of bees along an elevational gradient and (2) evaluate the efficiency of different methodologies to sample bee communities in tropical forests.

During 11 months of fieldwork, we completed 3 rounds of sampling in 26 locations, covering the whole gradient from 3500 to 230 m asl during the wet and the dry seasons. To optimize the sampling of the bee community we used multiple methods. We caught bees actively during transect-walks and also passively using five different kinds of traps.

Abundance and diversity patterns of different bee groups were found to respond differently to the elevation, e.g. Meliponini dominate the lowland communities and occur up to approx. 2500 m while bumblebees (*Bombus spp.*) occur along the whole gradient and are more diverse in the highlands. Regarding the methods, those using both color and scent attractors performed better than the ones relying only on color, while transect walks were useful to add those species less attracted by traps.

A matter of preference: Do different taxonomic carrion-visiting groups show preferences for distinct carrion species?

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Carrion decomposition plays a crucial role in nutrient cycling and energy flow within ecosystems. Unlike plant litter, animal carcasses represent a nutrient rich ephemeral, spatially and temporally unpredictable resource. Despite their transient nature, carcasses support complex and dynamic food webs involving microorganisms, insects, and vertebrate scavengers. While numerous studies have explored interactions among these groups, there is still limited understanding of how specific carcass traits such as size and nutritional type (i.e., herbivore, carnivore, omnivore) influence the diversity of carrion-associated communities. Larger carcasses are assumed to support higher species richness based on the more-individual hypothesis, although this could not consistently been shown across taxa. Additionally, the trophic level of a carcass species affects its biochemical makeup and internal microbiome, which in turn shapes decomposition dynamics and community assembly.

Despite its ecological relevance, the role of carcass identity in structuring biodiversity remains underexplored. This study addresses this gap by examining whether distinct carrion types attract distinct visitor groups. We monitored a total of 100 carcasses of 10 carrion species during spring and summer 2021 in the Bavarian Forest National Park (50 carcasses per season). Five different taxonomic visitor groups were sampled, consisting of vertebrates, coleoptera, diptera, bacteria and fungi. We used sample coverage estimates for alpha and gamma diversity as well as for uniqueness. The preliminary results show that each taxonomic group obtains a preference for distinct carrion species (e.g., stoat obtained the highest gamma diversity for vertebrates, and beaver obtained the highest gamma diversity for coleoptera). Other than expected, small and medium sized carcasses displayed the highest overall gamma diversity for each taxonomic group. These results will be helpful for future management strategies, especially when considering protecting and supporting of specific taxonomic groups and species in ecosystems.

Drivers of myrmecophile diversity and abundance in wood ant nests (Formica rufa group)

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Mound-building Formica ants (*Formica rufa* group), commonly referred to as red wood ants (RWA), are a Holarctic group widespread in temperate and boreal forests and natural grasslands. Recognised as keystone and umbrella species, RWA provide numerous ecosystem services, and their large, organic nest mounds offer stable, resource-rich microhabitats for a diverse assemblage of associated arthropods—so-called myrmecophiles. With growing declines in RWA populations, conservation concerns for these specialised communities are increasing. We further asked whether RWA nest mounds buffer environmental gradients, thereby shaping myrmecophile diversity. To identify drivers of myrmecophile diversity and assemblage, we sampled 259 RWA nests of five species across three Bavarian regions using pitfall traps and recorded environmental and nest characteristics. Larger arthropods were hand-sorted, morphologically identified, and counted. The remaining soil material was processed using Berlese funnels to extract the mesofauna and was analysed through metabarcoding. In total, 2642 arthropods representing 44 myrmecophile species were identified. Diversity was highest in nests of *F. rufa* and *F. polyctena,* intermediate in *F. lugubris* and *F. truncorum*, and lowest in *F. pratensis*; in *F. lugubris*, diversity also increased with altitude. Polydomous (multi-nest) colonies harboured a higher myrmecophile diversity compared to nests of monodomous (single-nest) colonies, and similarly, larger nest volume was positively associated with increased myrmecophile diversity. Both ant-myrmecophile and region-myrmecophile interaction networks were generalised, with low modularity. Overall, ant species, colony type, and nest size were key drivers, while abiotic factors such as region, climatic conditions, and altitude had only marginal effects. Our study highlights the importance of protecting well-connected, polydomous RWA colonies for myrmecophile conservation.

The key role of vicariance for soil animal biogeography in a biodiversity hotspot region

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The Indo-Australian Archipelago is known as a biodiversity hotspot with a high level of endemism typically ascribed to vicariance as reflected by the "Wallace's line". However, it is unknown how vicariance has affected belowground biodiversity, especially process-based beta diversity. Here, we relate beta diversity of soil oribatid mite (Oribatida, Acari) assemblages to geographic distance as well as climatic and soil factors to explore the factors shaping the diversity of oribatid mites across eleven regions of the Indo-Australian Archipelago. We compiled a list of 2549 oribatid mite species in the Indo-Australian Archipelago and investigated the level of endemism and beta diversity of oribatid mites in the eleven regions at species, genus and family level. We then summarized the biogeographical dissimilarity patterns of oribatid mites using ordination and clustering methods, and compared the patterns with the zoological boundaries based on aboveground taxa such as the Wallace's, Lydekker's, Weber's and Holt's line. We integrated data on geography, climate and soil to reveal the key drivers of species compositional dissimilarity of oribatid mites among regions using Mantel tests. Generally, the level of endemism of oribatid mite assemblages in the eleven regions was high; they formed three groups (west of New Guinea, New Guinea and south of New Guinea) with dissimilarity changing from northwest to southeast. The patterns reflect and integrate the lines of Weber, Lydekker and Holt. Species turnover generally correlated with geographic distance reflecting the critical role of vicariance in dispersal-limited oribatid mites. Our results, for the first time, demonstrate contrasting patterns in below- and aboveground organisms in the Indo-Australian Archipelago, and elucidate how geographic distance-based vicariance has structured soil animal diversity in this biodiversity hotspot region.

Tropical land-use change prunes the tree of life

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Land-use change is currently the most important driver of biodiversity loss, particularly in tropical rainforests undergoing rapid conversion for agricultural commodity production. Yet, we know little about how this change affects evolutionary history across multiple taxonomic groups, or how its effects on community restructuring within tropical ecosystems are reflected in the tree of life. Here, we study the effects of converting tropical rainforest into agricultural systems including intermediate (agroforestry) and high intensity management (rubber and oil palm plantations) on the phylogenetic diversity of multiple taxa across different spatial scales. We used comprehensive datasets of 7 different taxa, ranging from vascular plants to arthropods and vertebrates, sampled in 32 plots in Sumatra, Indonesia. Our results show that rainforest conversion into intensive plantations has negative effects on phylogenetic γ-diversity, a trend consistent across taxonomic groups, causing a massive regional loss of 15.9 billion years of evolutionary history. After standardization for sample coverage, negative effects on phylogenetic γ- and α-diversity were supported for most groups but a few taxa (i.e., Collembola, butterflies, and bats) exhibited a positive response. Contrary to our expectations, land-use change did not consistently lead to phylogenetic homogenization (i.e., reduced standardized

Spatiotemporal variability in the diversity and composition of phyllospheric bacterial communities within tree crowns of Quercus robur

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The phyllosphere microbiome plays a pivotal role in tree health and adaptation to environmental conditions, yet its composition and seasonal dynamics within forest canopies remain poorly understood. Understanding how these communities respond to spatiotemporal changes is essential for predicting their ecological functions. In this study, we investigated the influence phenology and environmental heterogeneity within the canopy on epiphytic bacterial communities. We selected the widespread and ecologically important tree species Quercus robur as a focus species for studying natural variation in epiphytic phyllosphere microbiota using high throughput 16S rRNA amplicon sequencing. In Caldern (Hesse, Germany), we sampled leaves from shaded and light exposed canopy positions across eight trees at four timepoints in June-September each during 2023 and 2024. Both the position within the canopy and the season affected bacterial diversity and community composition. The diversity was higher in shaded than in light exposed canopy positions and increased over the vegetation period, and both canopy position and season effected the composition of bacterial communities. Distinguishing between a persistent core microbiome and transient bacterial ASV we found pronounced temporal and spatial shifts particularly within the core community. Overall, our findings demonstrate a strong impact of within-individual environmental heterogeneity and seasonality on epiphytic bacterial leaf communities, providing valuable insights into the dynamics of tree phyllosphere microbiota and forest ecology.

Understanding drivers of beta diversity fosters biodiversity conservation - examples from decomposer communities

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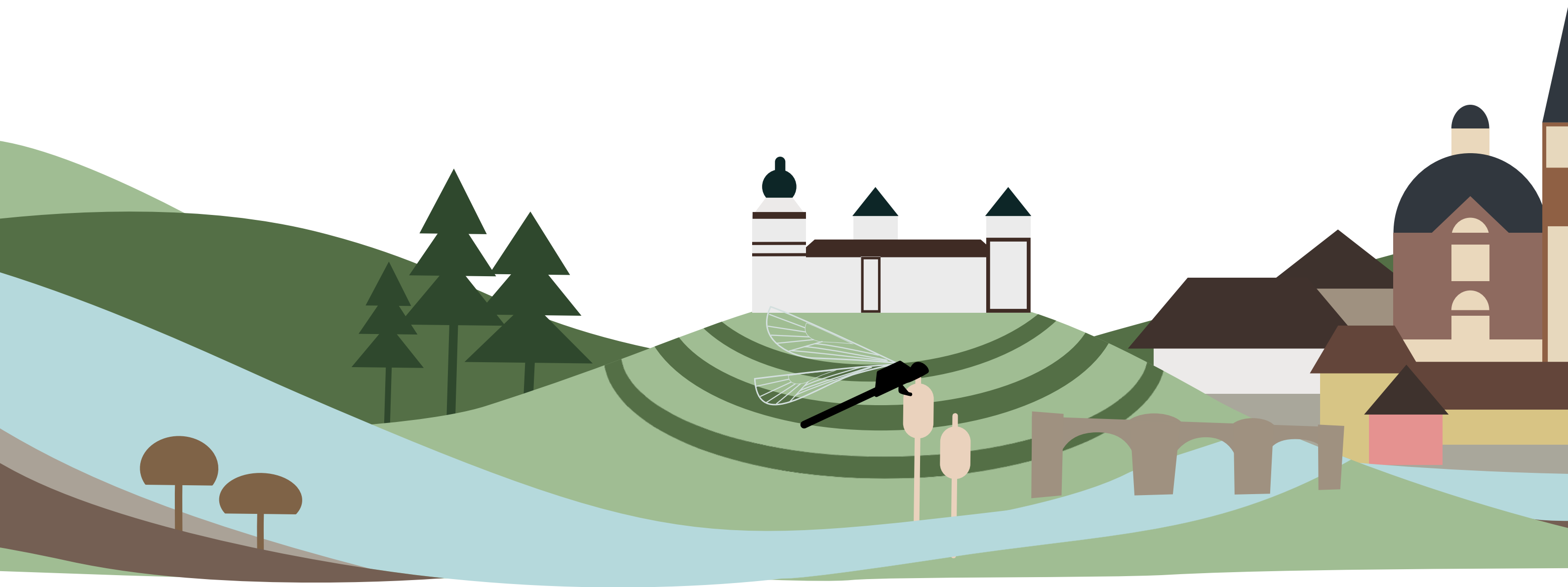
The conversion and degradation of natural habitats has caused global declines in biodiversity. Maximizing the overall outcome of conservation measures has hence become crucial for allocating conservation resources. Beta diversity quantifies differences in species communities across space and/or time. Measuring such differences is important for e.g. protected area planning, prioritization of conservation measures, and for tracking changes in species communities over time. Using dung beetles and saproxylic beetles as indicator organisms, applications of beta diversity in a conservation context are demonstrated. In particular, the importance of environmental factors determining beta diversity for decomposers is highlighted. Also, the importance of species relative abundance for beta diversity is explored using a framework of Hill numbers. The results indicate possible benefits of integrating beta diversity in biodiversity conservation of dung beetles and saproxylic beetles.

Session 36

Ecological communities: change, variation and human impacts



The global human impact on biodiversity

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Human activities drive a wide range of environmental pressures, including habitat change, pollution and climate change, resulting in unprecedented effects on biodiversity. However, despite decades of research, generalisations on the dimensions and extent of human impacts on biodiversity remain ambiguous. Mixed views persist on the trajectory of biodiversity at the local scale3 and even more so on the biotic homogenisation of biodiversity across space. We compiled 2,133 publications covering 97,783 impacted and reference sites, creating an unparallelled dataset of 3,667 independent comparisons of biodiversity impacts across all major organismal groups, habitats and the five most predominant human pressures. For all comparisons, we quantified three key measures of biodiversity to assess how these human pressures drive homogenisation and shifts in composition of biological communities across space and changes in local diversity, respectively. We show human pressures distinctly shift community composition and decrease local diversity across terrestrial, freshwater and marine ecosystems. Yet, contrary to long-standing expectations, there is no clear general homogenisation of communities. Critically, the direction and magnitude of biodiversity changes vary across pressures, organisms and scales at which they are studied. Our exhaustive global analysis reveals the general impact and key mediating factors of human pressures on biodiversity and can benchmark conservation strategies.

Response balance - a neglected mechanism stabilising ecological communities

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Understanding how ecological communities remain stable under environmental change is key to predicting ecosystem responses. While response diversity—variation in how species respond to environmental fluctuations—can buffer communities and enhance stability, its effects may vary across disturbance regimes. Using model simulations, meta-analysis, and a protist microcosm experiment, studies show that community stability is driven largely by the distribution of species' fundamental responses. A novel metric, imbalance, quantifies this variation and strongly predicts stability, with low imbalance promoting high temporal stability through population stability and asynchrony. Response diversity metrics like dissimilarity and divergence support stability under fluctuating conditions but may be less effective under pulse disturbances, where uniform resistance or rapid recovery across species enhances stability. These findings highlight that both the nature of disturbance and the structure of species responses critically shape ecological stability.

Why microbial diversity matters – and how to conserve it

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Microorganisms are fundamental to life on Earth, playing crucial and irreplaceable roles in biogeochemical cycles, climate regulation, ecosystem services, and human health. Yet their diversity and functionality are increasingly threatened by anthropogenic global change. Despite their importance, microbes remain largely overlooked in nature conservation efforts. In this talk, I will first present examples from our own research that highlight the role of microbial diversity in enhancing plant tolerance to global change and stabilizing ecosystems. I will then explore how microbes can contribute to traditional conservation goals and discuss the conceptual shifts needed to include microorganisms as explicit conservation targets. I will conclude by arguing that microbial conservation has the potential to play a pivotal role in addressing environmental crises, helping to safeguard ecosystem functions, sustain biodiversity, and support human well-being.

Spatio-Temporal Dynamics and Drivers of Plant Diversity in the European Alps: Diversification and Homogenisation Over 8,000 Years

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Global biodiversity results from regional dissimilarity in species composition. Contributing considerably to global diversity, the European Alps are a hotspot of endemic plant species. After the Last Glacial Maximum, rapidly changing climate and the glacial retreat created new environments, which may have facilitated colonisation and increased landscape differentiation in the Alps. With advancing time and stabilising climate, species likely dispersed more widely, leading to the homogenisation of alpine habitats. In recent millennia, humans introduced livestock farming that may have created diverse local habitats and potentially caused diversification, while on the other hand, potentially spreading plants and homogenising local diversity across the Alps.

It is, thus, unclear how the increase in local floristic richness scales to regional diversity as increasing local richness may be accompanied by regional homogenisation.

Using sedimentary ancient DNA data from 14 lakes in the European Alps, we demonstrate that pairwise similarity of floral assemblages has remained stable during the past 8,000 years but shows a marginal increase in the past 500 years. While richness has distinctly increased, individual plant taxa have on average constantly occupied a fourth of the lake catchments. Lake catchments experiencing none or the same land use practices tend to be more similar than pairs of catchments of which only one is used.

Past increases in richness do not clearly correlate with increases or decreases of similarity of floral assemblages. Temporary appearances and disappearances of plants resulted in both, increases and decreases, of pairwise similarity. In the past 500 years, there is a tendency of

Changes in species composition reflect reduced traditional land use in historically shaped forest and peatland communities.

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Historical land-use regimes have played a key role in shaping plant communities in Central Europe. This study assesses the impact of land-use changes over the past century on two plant communities: *Primulo-Schoenetum ferruginei* (Primrose-Sedge Mire) and *Carici-Fagetum* (Sedge-Beech Forest), both of which were strongly influenced by traditional management. Their contrasting dependencies on traditional management make them ideal for understanding how shifts in land use affect species composition and biodiversity. Based on repeated vegetation surveys from eight sites, we compared historical records with contemporary data to quantify changes in community composition. The findings reveal that changes in land use, including intensification and abandonment, have altered species composition in both communities. Peatland communities responded more sensitively, primarily due to deviations from traditional extensive land-use practices, while forests show more moderate changes in species composition, reflecting a lower sensitivity to such shifts. Our findings highlight the critical role of historical land management in preserving biodiversity. This underscores the critical role of historical land management in preserving biodiversity and highlights the need for conservation strategies that adapt and integrate traditional practices to sustain forest and peatland ecosystems.

70 years of plant community change in Bavarian grasslands

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In the last century, species have been going extinct at an accelerating rate globally. This global trend, however, does not always correspond with local biodiversity patterns. Intriguingly, some localized studies have even documented increases in species diversity. These apparent discrepancies between global extinctions and local observations may be attributed to shifting baselines, especially when analyses are limited to short time series that fail to capture long-term ecological trajectories.

Due to the scarcity of repeated local biodiversity surveys, investigating changes in local species richness and community composition often presents significant challenges. Here, we present a comprehensive analysis of vegetation surveys collected by the Bavarian State Research Center for Agriculture (LfL) across agricultural grasslands throughout Bavaria (>40,000 surveys) spanning from 1950 to 2020. These extensive records were digitized using text-recognition software and meticulously georeferenced over the past two years.

The digitalized data now enables in-depth analyses of changes in plant species richness and community composition within and between Bavaria's major natural regions. Preliminary analyses reveal that average plant species richness in Bavarian grasslands has declined consistently over the decades, accompanied by significant shifts in community composition. This pattern is evident both across individual natural regions and throughout Bavaria as a whole.

Our analysis demonstrates that biodiversity declines can also be detected at local scales when supported by sufficiently long time series, high-quality historical data, and adequate replication, thus confirming broader global trends. Future research will investigate how different functional groups within agricultural grassland ecosystems have been affected by local changes over the past 70 years and identify potential drivers of these declines.

Gypsum post-mining landscapes in Germany - Unveiling Biodiversity

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Considering European and international mandates to protect natural areas to preserve biodiversity, all unused or abandoned areas become invaluable resources. We examined the botanical and structural diversity of gypsum post-mining areas and surrounding landscapes across four major mining regions in Germany over a year-long study. We categorized our 66 study transects over 24 mining sites based on their structure and usage. Our results indicate that the vascular plant richness in rewilded post-mining landscapes is significantly higher than in the undisturbed, surrounding area. This research emphasizes the importance of these disturbed landscapes for Red List species and of recovering gypsum-mining sites in Germany for the protection of biodiversity. We also expose the strong effect of management in the value development of these areas, with particular importance being placed on rewilding and restoration projects as effective techniques to increase the nature conservation value of abandoned sites.

Local entomologists shine a light on moth communities: The value of amateur records in cataloguing long-term change

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Natural history collections contain unparalleled assemblages of knowledge spanning both space and time, and are composed of both biological specimens and associated written records. However, when donated to museums, written records associated with specimen collections are often lost or discarded. Biological specimens are increasingly used to investigate long-term environmental change; however written records also contain valuable information that can be used in similar ways and can complement specimen data. In this study we describe two new macro-moth specimen collections and written records (in the forms of diaries and field notes) donated to the University Museum of Zoology, Cambridge (UMZC), containing biological specimens and written records by four local amateur entomologists, dating from the 1920s to the early 2000s. We describe the biological specimens in relation to the existing collection in UMZC, to identify and demonstrate collector bias and specialisations, and then use the written records as a case study to demonstrate how they can be used to quantify long-term change. This included analyses to investigate changes in macro-moth phenology over an 82-year period across the UK, and species richness and abundance change over a 24-year period in Cambridgeshire. Using the written records, we detected evidence of earlier macro-moth emergence over time, and local declines in species richness and abundance. Depositing the collections of these skilled and knowledgeable local entomologists in a museum ensures that the wealth of data they contain can be preserved and used in ongoing research. With amateur collectors in decline, it is increasingly important to preserve these records for the study of long-term change, and to encourage future generations to continue to amass and share this information.

Spatial mapping of community assembly processes reveals strong filtering of specialist species across taxa

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The mechanisms driving community assembly from regional to local species pools are increasingly well understood, yet their spatial patterns remain largely unexplored. In this study, we address this gap by mapping spatial variations in community assembly processes for butterflies and grasshoppers across Switzerland. Using extensive species occurrence and trait datasets, alongside high-resolution environmental data, we quantified and mapped the hierarchical filtering of community-weighted mean (CWM) trait values — from regional species pools to local communities. We focused on traits related to mobility, body size, reproduction, foraging, dispersal, and phenology, and incorporated key environmental variables including climate, vegetation, and land use. Our findings reveal distinct spatial patterns of trait-based filtering between the two taxonomic groups, shaped by different environmental drivers. These differences reflect contrasting energy allocation strategies, specialization levels, life histories, and evolutionary pathways. Both groups, however, showed stronger trait filtering in urban environments compared to other land use types. Notably, we also observed a widespread and consistent filtering pattern for generalist species across the country in both groups, indicating a substantial shift in community composition at the national scale. These patterns point to increasing pressure on specialist species across the country which could lead to important biodiversity loss. This process is likely to accelerate with ongoing land use and climate change. Overall, mapping the spatial distribution of hierarchical trait filtering provides key information for understanding biodiversity and ecosystem dynamics, informing conservation planning, and advancing ecological theory and models.

Ground spider communities respond selectively to forest structure and prey availability in retention forestry

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1. Retention forestry is promoted to mitigate clear-cut impact on habitat sustainability and biodiversity, yet it remains unclear how structural features preserved under this approach influence ground-dwelling predators such as spiders. In particular, the mechanisms linking forest structure to different facets of spider diversity, including trait composition and trophic interactions are not well understood.

2. We studied spider assemblages across structurally variable retention forest stands in the Black Forest, Germany. We measured species richness, abundance, community composition, and functional-phylogenetic diversity in relation to forest structural features (e.g. canopy cover, conifer proportion, deadwoods, understory richness) and prey availability. We also explored community-weighted mean traits to assess individual trait responses.

3. Spider richness and abundance responded selectively to forest structure: abundance increased by 29% with higher understory plant richness, while richness declined at approximately 13% and 15% with increasing canopy and herb cover. Community composition shifted along canopy and conifer gradients. Functional-phylogenetic diversity showed no clear response to structure, but prey availability buffered the negative effect of conifer trees on spider abundance by approximately 30%. Trait-based responses were weak overall.

4. These findings suggest that retention forestry influences spider diversity in specific and dimension-dependent ways. While some habitat features support diversity, others may have neutral or negative effects. Prey availability can mediate structural constraints, highlighting the role of trophic interactions in community responses.

5. Our study shows that assessing retention forestry effectiveness requires a multi-dimensional view of biodiversity. Integrating prey dynamics and trait-based insights into forest management may enhance efforts to support predator diversity and ecological complexity.

From native giants to newcomers: What eDNA tells us about arthropod communities of different tree species"

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Forests in Central Europe are exposed to an increasing number of heat waves and droughts due to climate change. To support the resilience of forests, tree species that are considered to be more resistant to changing climate conditions are increasingly being planted in many areas. The natural range of many of these species lies outside of Central Europe (non-native tree species, e.g. Douglas fir or red oak from North America). Forests and their individual trees are important habitats for numerous animal species. Arthropods in particular are often specialists, adapted to a single plant species or genus. This study investigated whether the diversity of arthropods in the canopy of native tree species differs from that of non-native tree species. Species communities were analysed by eDNA metabarcoding of leaf wash-off from 13 different tree species across 8 different sites. A clear separation of arthropod communities was found between coniferous and broadleaved tree species and further even each tree species showed its own arthropod community. For coniferous species, the time since introduction was negatively correlated with both zOTU richness and beta diversity between tree species. That is, conifers introduced earlier hosted more diverse and distinct arthropod communities compared to recently introduced species. In contrast, no such temporal effect was found for broadleaved trees. Our findings provide early evidence that the introduction history of non-native trees may influence canopy arthropod diversity, particularly in coniferous species.

From Source to Spread: Genomic Evidence of Bottlenecks and Founder Effects in Pinus contorta Introduced to the Southern Hemisphere

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Inter-continental study systems are crucial for testing ecological hypotheses, such as the widely cited Enemy Release Hypothesis (ERH), which seeks to explain the superior performance of plant species when they are introduced to new regions. Pinus contorta (lodgepole pine), native to North America, has been extensively introduced to Europe and the Southern Hemisphere, making it an ideal tree species for studying invasion hypotheses from a biogeographical perspective. We compared foliar fungal communities, especially pathogens, of P. contorta across two native–introduced region pairs (NIRPs): a northern NIRP (from Canada to Sweden) and a southern NIRP (from the USA to Patagonia), while also examining the differences between source plantations and invasion fronts within Patagonia. P. contorta underwent significant fungal community shifts and experievnced pathogen release during its large-scale introduction from North America to Sweden and Patagonia. The fungal richness and relative abundance changes were more pronounced for the southern NIRP pair, where no closely related tree species to P. contorta are present in Patagonia. In Sweden, the presence of the phylogenetically related P. sylvestris and its associated local fungal community appears to play a role in influencing the foliar fungal communities associated with introduced P. contorta. In Patagonia, the incomplete co-invasion of fungal taxa from the USA emerges as a principal driver of the observed variability in fungal community composition and pathogen release following the introduction of P. contorta. In Patagonia, fungal community composition differences between source plantations and invasion fronts provided insufficient evidence that pathogen release occurs at this local scale. Integrating both biogeographical and phylogenetic perspectives, our study suggests that priority effects of local fungi appear to be a dominant community assembly process when introduction is done in a phylogenetically similar community; whereas, co-invasion of fungal communities is the dominant process in phylogenetically distant communities.

Poster Session 37

Agriculture, grasslands, landscape ecology

Prospect for a data basis for key components of biodiversity in agricultural landscapes – MonViA indicators

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The conservation and promotion of biodiversity is an important element in the transition towards sustainable agricultural systems. Covering about 50% of Germany's land area, agricultural landscapes provide both habitats and resources for a large number of organisms (plants, animals, micro-organisms and their communities), while crop production is also highly dependent on ecosystem services. However, there is a lack of nationwide, reliable data on the state and development of biodiversity in agricultural landscapes. To fill this gap, researchers from the Julius Kühn Institute (JKI, https://www.julius-kuehn.de/), the Thünen Institute and the Federal Office for Agriculture and Food collaborate in the joint project on the nationwide monitoring of biodiversity in agricultural landscapes (MonViA, https://www.agrarmonitoring-monvia.de/), funded by the Federal Ministry of Food and Agriculture. They developed 41 indicators associated with habitat diversity, species diversity and genetic diversity, combining classical and molecular methods as well as citizen science approaches. A first overview of all MonViA indicators is presented in the MonViA indicator report (MonViA joint project, 2024).

Six specialised JKI institutes focus on organismic indicators covering relevant ecosystem functions such as pollinators (honey and wild bees, hover flies), harmful and beneficial insects, primary producers (arable weeds), detrivoral decomposers in the soil (earthworms), as well as insect diversity in small water bodies and in viticulture. Indicators also address land use aspects as well as landscape elements to characterise habitat diversity, providing important reference values for organism-related data. When implemented as a nationwide biodiversity monitoring scheme, the indicators can provide a differentiated picture of biodiversity in agricultural landscapes, supporting the evaluation of policy measures, national strategies and action plans over time and complement nature conservation monitoring.

SUNRISE – Supporting the agroecological transition through living labs networks

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In a context of environmental degradation and agriculture impoverishment, agroecology emerges as a transformative approach that leverages both modern scientific methods and local knowledge to reconfigure farming systems. SUNRISE is a comprehensive, pan-European initiative funded by the Agroecology Partnership designed to accelerate the agroecological transition by establishing a network of Agroecological Living Labs (AELLs) across 10 countries. By integrating research infrastructures, local farming communities, industry stakeholders, and policy makers, SUNRISE will foster an environment of co-creation, experimentation, and knowledge exchange to drive the agroecological transition.

In each AELL, multi-actor teams (MATs) will bring together diverse perspectives from farmers, agricultural advisors, input suppliers, civil society organizations, and researchers. MATs will identify local agronomic challenges, set transition goals, and co-design innovative solutions addressing six key sub-themes across diverse cropping/farming systems: (i) soil health, (ii) crop diversification, (iii) reduced inputs, (iv) crop/animal production, (v) biocontrol, (vi) biodiversity and ecosystem services.

AELLs will serve as a model for participatory innovation in agroecology, providing valuable insights to inform national policies and EU strategies: future CAP schemes, EU Biodiversity Strategy 2030, regulations on organic farming and sustainable use of plant protection products. A key outcome of the project is the definition and refinement of a set of successful agroecological practices tailored to different EU contexts. Additionally, SUNRISE aims to establish a permanent network of AELL that will continue beyond the project's duration, contributing to shaping the future of EU agriculture. The project will also focus on upscaling its approaches by engaging with key actors in the agroecological sector to support the development of more sustainable food and farming systems across Europe.

Fostering agroecological transition in Europe – insights into co-design processes and ecological monitoring in SUNRISE

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The new EU project SUNRISE was launched in April 2025. This project aims to foster the agroecological transition of European agriculture. For this purpose, ten agroecological living labs across Europe will co-design, test and evaluate agroecological practices during the next three years in close collaboration with farmers and other relevant stakeholders.

In this poster contribution, we show (1) how co-design processes are initiated: from assessing the current state of each Living Lab to co-develop a joint idea of a future vision and transition pathways, (2) how ecological effectiveness and further sustainability indicators of agroecological practices are measured: from semi-quantitative questionnaires to rapid ecosystem function assessment methods which farmers implement themselves, and (3) we give first insights into our new German agroecological living lab.

Assessing the impacts of land use changes on regional biodiversity and ecosystem services– Case study: Paludiculture implementation in the Upper Rhinluch, Brandenburg, Germany

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Rewetting can sequester carbon and restore habitats that have been lost or degraded due to drainage, but it may also lead to long-lasting differences in species composition, if compared to near-natural peatlands (Kreyling et al. 2021). Investigating ecological processes in rewetting can help to find measures to prevent or minimize negative consequences for ecosystems, and ideally, create opportunities to establish diverse habitats through thoughtful management without having to forego farmers' economic value creation.

The EU-project MarginUp! is developing sustainable and circular value chains to produce bio-based industrial raw materials in innovative business models grown on marginal land in 7 countries. The German case study aims to create sustainable and biodiversity-friendly value chains with paludiculture on rewetted peatlands. In our workpackage, we focus on evaluating potential risks and benefits of rewetting for the ecosystem and compare it with alternative scenarios, such as agricultural production on non-rewetted peatland or fallow land.

Central to this assessment is the Regionally Adapted Biodiversity Indicator System (RABIS), developed to evaluate biodiversity and ecosystem impacts across multiple case studies. The scientific innovations of RABIS include the integration of various elements: 1) Objectives of nature conservation and sustainable agriculture; 2) targets/indicators for multiple spatial scales; 3) influences from the diverging landscape context; 4) multi-species/multi-indicator system for two dimensions (inside single taxa and across taxa via different trophic levels); 5) triple reference system and 6) co-design activities with regional stakeholders and experts).

The poster aims to present the scientific approach of RABIS and will demonstrate the application to the German case study, referring to the topic of peatland-rewetting and paludiculture and its impacts on ecosystems in Brandenburg, Germany.

The phylogenetic composition of plant assemblages shapes the phylogenetic composition of insect assemblages in sown wildflower plantings

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Sown wildflower plantings are a popular means to support biodiversity in agricultural landscapes. But which characteristics of sown wildflower plantings shape insect assemblages and should be fostered to increase their value for biodiversity, is little known. Using a study design comprising 22 sown wildflower plantings of varying temporal continuity and four semi-natural grassland controls, we collected flying insect assemblages with Malaise traps. We aimed to assess the role of plant assemblage species or phylogenetic composition, plant biomass, the temporal continuity of the wildflower plantings and the complexity of surrounding landscapes for flying insect assemblage composition and biomass. Based on the resulting dataset of 3091 flying insect taxa and 123 plant species, we found that wildflower planting temporal continuity affected flying insect richness and biomass, and surrounding landscape complexity was positively related to flying insect phylogenetic diversity. The phylogenetic composition of plant assemblages was positively related to the phylogenetic diversity of flying insect assemblages with a positive relationship between the phylogenetic dissimilarity of flying insect assemblages and those of plant assemblages. Our results indicate a so far largely neglected trajectory for improving sown wildflower plantings that is much easier to implement than temporal continuity or manipulating the surrounding landscape context – the phylogenetic composition of plant assemblages. Increasing the phylogenetic diversity in sown plant mixtures will help support a larger phylogenetic diversity of flying insect species. Building on our results, wildflower plantings can be improved to reach the goal of vitalising agricultural landscapes towards supporting both, agricultural production and biodiversity.

Influence of agri-environmental schemes on leafhopper diversity in grassland ecosystems

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Grassland habitats are among the most species-rich ecosystems in Central Europe. Agri-environmental measures (AES) have been introduced in many countries to promote extensive agricultural management and mitigate effects of agricultural intensification. However, previous studies did not find concording patterns regarding insect diversity concerning to AES. Given that leafhoppers were shown to be an excellent indicator group for the assessment of grassland habitats in a number of studies, we asked how local grassland AES affect leafhopper diversity.

To do so, we conducted our study in four grassland regions in Bavaria, in southeastern Germany. Within each region, six study areas were randomly chosen, and each study area included three grasslands. The three grasslands represented our treatments with three levels: control, farm-wide AES and site-specific AES. In addition, we included an index of land use extensification (LEI, calculated for each site) and the surrounding landscape. Leafhoppers (Hemiptera: Auchenorrhyncha) were caught using Malaise traps in July/August for a period of one week. Individuals were identified to species level and classified according host plant specialisation and their vulnerability (red list of threatened species).

Total leafhopper species richness in the studied grasslands was 100. Of those, 14 leafhopper species are listed as threatened. Our results indicate that local AES were not the main driver for leafhopper diversity. The influence of other environmental factors on the leafhopper communities is presented and discussed.

When to mow and how : Short - term effects of river dike grassland management on arthropod abundance, species richness, and community composition

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Species-rich grasslands and their associated arthropods have become rare across Europe. Linear green infrastructure, such as river dikes, can serve as secondary habitats and improve the connectivity among isolated grasslands. Although applied extensively on dike grasslands, mowing impairs local arthropod populations, depending on the date and the techniques applied, while leaving areas uncut over winter can support arthropods. To investigate the short-term effects of different mowing dates, hay handling techniques, and overwintering strips on arthropod abundance, species richness, and community composition, we conducted mowing experiments at eleven sites on dikes of River Inn (South Germany). We sampled carabids, spiders, true hoppers, and true bugs, and investigated combinations of mowing dates (June – 'early'; September – 'late') and hay handling techniques (raking or suction), and the effects of overwintering strips located in the middle or upper part of the dikes. Carabids were favored by late mowing and hay suction. Spider species richness profited from overwintering strips in July and showed an overall seasonal decline. True hoppers benefited from early mowing, and true bugs were insensitive to the treatments. Abundance and/or richness of all groups were favored by overwintering strips. The arthropod communities changed across the season, and the mowing dates significantly drove their assemblages. An indicator analysis revealed a non-random distribution of species among treatments. Our results indicate that there is no optimal mowing date for all studied taxa. We conclude that a spatio-temporal mosaic of mowing treatments helps to meet the needs of different arthropods in dike grasslands, and that rotational management promotes arthropod diversity.

Market-Based Instruments for Biodiversity in Agricultural Landscapes: An Evaluation of Quality Criteria in a German case study

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Market-based instruments (MBIs) for biodiversity protection and promotion have gained importance, with their success hinging on transparent demonstration of effects and implementation quality. Quality criteria help evaluate these aspects, but few studies have explored their application. This study examines MBIs in the German agricultural landscape. Criteria were defined through a literature review, applied to internet-identified MBIs, and analyzed. Methodological criteria and quality control appear less frequently than financial and legal information. Of 151 MBIs analyzed, 70% lack control and monitoring systems, leaving effectiveness unverified. Program-funded MBIs are likelier to include control mechanisms and perennial measures than those backed by direct sponsor or consumer payments. The ongoing development of MBIs reflects growing demand, with some programs operating for decades. However, without ecological monitoring, benefits to biodiversity remain uncertain. Policymakers must consider official guidelines and regulatory frameworks to standardize comparability of MBI for biodiversity.

Plant diversity effects on the seasonal dynamics of multiple soil functions

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Soil sustains life beyond water and forms the foundation of terrestrial ecosystems. Our project aims to deepen the understanding of soil stability and its pivotal role in biodiversity and ecosystem functioning (BEF). We specifically focus on the multidimensional intra- and inter-annual stability of soil properties.

This research is conducted within the framework of the Jena Experiment, where we investigate the short- and long-term effects of plant diversity on the stability of soil properties. To this end, we conducted seasonal sampling from 2024 to 2025 (spring, summer, fall, winter) at two soil depths (0-5 and 5-10 cm). By analyzing aggregate formation, soil invertebrate feeding activity, extracellular polymeric substances and phospholipid-derived fatty acids, and microbial biomass and respiration along an experimental plant diversity gradient, we explore the interplay between the biological and physical dimensions of soil stability and examine how community assembly influences BEF relationships.

Initial analyses show that most functions were sensitive to seasonal variation, particularly in the upper soil layer. Moreover, water-stable aggregate stability increased with plant species richness.

In the next months, detailed analysis on the stability of all functions will be carried out. Additionally, the interplay of these functions and their stability will be assessed by defining a multistability index. By doing so, we aim to uncover the mechanisms that stabilize soil properties and ultimately provide valuable insights into ecosystem functionality in the face of global change.

Genetic diversity of common grassland forb species as a guide for developing regionalized seed mixtures

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We present preliminary results of our ongoing project aiming to map genetic diversity of selected grassland dicotyledonous plants in the Czech Republic. Unlike grasses and legumes, which have long been the subject of intensive breeding efforts and whose populations in the field are consequently massively contaminated by cultivars, other dicotyledonous species still have a largely natural pattern of genetic variation that is essentially unknown. We aimed to determine this pattern as a guide for developing regionalized seed mixtures. We selected species so that (i) they are sufficiently common throughout the Czech Republic and constitute a important proportion of species in meadow stands, (ii) they have not been subject to breeding efforts and cultivar introductions (e.g. grasses and common legume species). In this way, we selected 14 species, namely A*chillea millefolium agg., Campanula patula, Campanula rotundifolia agg., Centaurea jacea, Galium mollugo agg., Knautia arvensis agg., Lathyrus pratensis, Leontodon hispidus, Leucanthemum vulgare agg., Lychnis flos-cuculi, Prunella vulgaris, Ranunculus acris, Sanguisorba officinalis*, and *Vicia cracca*. We are in the process of collecting samples at the target number of about 80 localities for each species (density ca one locality per 10 x 10 km), identified their ploidy level using flow cytometry and determine their genetic structure by ddRAD following the same protocol used in the recently finished project in Germany1,2. The knowledge of their genetic structure will permit to design seed transfer zones of these species (and of their mixtures) within the Czech Republic and will serve as a guide for similarly conceived work on additional grassland species. We envisage that the project will also contribute to build a Europe-wide patterns of genetic variation of grassland species, which have developed due to post-glacial migration, and, later, in close association with human activities and probably bear marks of that. Therefore, we hope in future collaboration with researchers in neighbouring countries to get a larger picture of genetic variation of a large set of grassland species.

Which areas are suitable for arable farming? A GIS approach to evaluate the potential for site adapted land use in Switzerland

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The growing human population raises concerns about future food security, especially as arable farming increasingly has to cope with challenges such as climate change, and biodiversity loss. Suitable land for arable farming is limited in Switzerland and feed-food competition is a concern. This study examined the potential of Swiss farmland that can be used as arable land for direct human consumption based on the premises that site-specific potential is used and agricultural land is managed considering the carrying capacity of the ecosystems. A spatially explicit GIS-based approach, using three scenarios characterized by a different combination of biophysical criteria (climate, soil type, topography, and erosion risk) were applied. Spatial data on the agricultural area was taken from the agricultural land use map. For scenario 1, the agricultural area was combined with the soil suitability map of Switzerland, the digital elevation model, and the climate suitability map. Areas with a high erosion risk and organic soils were excluded in scenarios 2 and 3. Ecological focus areas that make a significant contribution to farmland biodiversity remained unchanged. Summer pastures and permanent crops were also excluded. Substantial potential for arable land was indicated for scenario 1, reflected in a land use proportion of 80% arable land and 20% grassland. For scenarios 2 and 3, the analysis showed a decline in the area potentially suitable for arable land compared to the current agricultural land. However, at the regional level, spatial shifts between arable land and grassland were identified. The analysis showed that biophysical site potentials play already an important role in agricultural management but that land use adjustments may be needed at the regional level to support the goals for site-adapted agricultural management. This could support future agricultural policy discussions to promote more site-adapted land use strategies for agricultural management.

Does age matter? – On the potential of golf courses to restore or conserve structurally rich landscapes

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To address the conflict between land scarcity, conservation, leisure activities and tourism, multi-use strategies are needed for so far single-purposed recreational areas. Despite an often-negative attitude of conservationists towards intensively managed golf courses, these may contain suitable elements in such strategy due to them holding either a set of ecologically valuable habitats or potential for an ecological upgrading. Typically, 40 – 60 % of a golf course consist of semi-natural elements, which are oftentimes undisturbed. Moreover, they may even preserve historic natural elements. Yet, which factors influence the ecological potential or value of a golf course is unknown. Size, landscape context and age could be crucial. Here, we analysed the landscape structure of sixteen golf courses of different age and landscape context across Germany. The selected golf courses were built or refurbished between 1955 and 2009 and ranged from 56 to 220 ha in size. The golf courses were categorized in four classes according to their founding date and trends in the golf sector in Germany. We identified land-cover classes on present and historic aerial images on the golf courses and in a 1500 m buffer around them, where the historic aerial images show the previous land use. We calculated different metrics from the *landscapemetrics* package in R to quantify the current and previous landscape composition and configuration. Our study increases the knowledge about the functioning of golf courses in their landscape context in comparison to the previous land use. Moreover, our findings underline the need to include multi-use strategies in neglected areas such as golf courses, if we are to meet conservation goals.

Changes in arable vegetation in Germany - data collection and trend analysis

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In Germany, comprehensive analyses of change in arable vegetation composition and diversity are still limited: long-term studies are often small-scale, while national surveys focus on single crops. Data are scattered across scientific institutions, state authorities, private offices, and citizen scientists. By collecting and harmonizing these records, we aim to provide a current overview and enable future comparisons. Our initiative, open to all interested parties, will create a specialized vegetation database, with data providers retaining rights and receiving credit and collaboration opportunities. Since autumn 2024, a consortium of scientists, authorities, agricultural advisors and conservationists has formed to support diverse goals, from scientific analysis and database creation to practical guidance for farmers wishing to support arable vegetation.

Monitoring the effects of different flowering strips on plant and insect diversity

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Land-use intensification is one of the main drivers of the loss of biodiversity in plants and insects. Various measures have been developed to counteract this decline, such as Agri-Environmental Schemes (AES). In particular, flowering strips are a popular instrument. However, in practice, the large variety of methods to set up flowering strips makes it difficult to monitor their effectiveness, thus, calling for systematic experiments. This study reports on the diversity and interaction of plants and insects in five different types of flowering strips in two regions of Bavaria (Germany). The establishment types were: (i) a new seed mixture consisting of regional plants supposed to benefit insects, (ii) a commercially available seed mixture, (iii) transfer of green hay from a nearby grassland, (iv) a perennial fallow and (v) reduced crop seeding density. We sampled airborne and ground-dwelling insects in Malaise and pitfall traps to assess and compare insect diversity between the different types of flower strips. To additionally observe effects on interactions between plants and insects we used butterflies as model organisms, focusing on their behaviour in the field and the food plants of their caterpillars.

Satellite data-based evaluation of wildflower strips as restoration measure in agricultural landscapes

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Perennial wildflower strips in agricultural landscapes have been shown to benefit biodiversity and ecosystem services such as pollination and pest control. Their development and effectiveness vary depending on management and landscape context. High-resolution satellite data are a main resource for building large-scale indicators of the ecological state of agricultural landscapes. Our aim was to evaluate the application of satellite remote sensing-based indicators for agricultural landscape heterogeneity, land-use intensity and farmland habitats in the context of perennial wildflower strips as ecological restoration measure across Saxony-Anhalt, Germany.

Using a dataset from the EcoSystem Integrity Remote Sensing—Modelling and Service (ESIS) tool, we focussed on seasonal metrics from near-infrared reflectance of vegetation index (NIRv), i.e., maximum, minimum, and range of NIRv from May to October. We analysed spatial and temporal NIRv patterns since the 1980s and compared different land-use classes from a federal state biotope type mapping and the Basic Digital Landscape Model. Moreover, we evaluated spatial patterns around recently implemented perennial wildflower strips based on data from the Integrated Administration and Control System.

The first results reveal significant differences of NIRv-based metrics between different land-use classes and wildflower strips, especially for the seasonal NIRv minimum. However, NIRv-based seasonal metrics also show a high variance within wildflower strips of different ages and land-use classes, suggesting a high potential to further distinguish between soil classes and agricultural management types.

Land-use impacts on above-belowground arthropod food webs, energy flux, and multitrophic ecosystem functioning

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Global change is transforming Earth's ecological communities with severe consequences for the functions and services they provide. Land use is one of the most important global-change drivers. Its effects on grassland communities have overall been well studied, but two aspects remain poorly understood: the interdependencies and interactions between above- and belowground compartments, and the impact of land-use intensity (LUI) on ecological interactions, the resulting food webs, and energy flux, which form the basis for central ecosystem processes.

We are using the large-scale observational land-use intensity gradient of the Biodiversity Exploratories' temperate grasslands to i) simultaneously and spatially-quantitatively study above- and belowground arthropod communities, ii) use a novel stable-isotope based method (compound-specific stable isotope analysis of amino acids) to unravel land-use impacts on basal resources and energy channels of arthropod consumers, and iii) assemble plot-specific trophic networks to assess land-use impacts on food-web structure, energy flux, ecosystem functioning, and multifunctionality. Knowing how above-belowground interdependencies and ecological interactions change with land-use intensity and how this mechanistically impacts important ecosystem processes, will allow us to assess current and mitigate future land-use impacts on grassland ecosystems to strengthen them for the challenging future ahead of us.

The poster will illustrate our project outline together with preliminary results.

Diversified clover-herb mixtures, their flowering times and nectar supply for pollinating insects on organic farms in Germany

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Clover-grass leys are a common crop rotation component on organic farms and have the potential to serve as a rich food resource for pollinating insects. However, in instances of overly intensive management, characterized by species-poor mixtures, this potential is not being fully exploited. As part of this study, field trials were carried out in 2024 at two locations in North Rhine-Westphalia to investigate the effects of (i) increasing the number of plant species in the mixture and (ii) reducing cutting intensity on the flowering times and nectar supply. The parameters evaluated included the extent of flowering cover, flowering phenology and nectar quantity per plant species. This research revealed that conventional mixture partners, including red clover (*T. pratense*) and white clover (*T. repens*), possess considerable potential due to their extended flowering periods (May to August) and substantial nectar quantities (15 - 18 µl/flower head). Also, species such as alsike clover (*T. hybridum*) and crimson clover (*T. incarnatum*) have the potential to contribute positively to a mixture. For the evaluation of the food resource, it is essential to consider the combination of nectar quantity, flowering times and flower cover. The study demonstrated the efficacy of supplementing other species in standard mixtures, for example crimson clover as an early blooming species, to ensure sufficient nutrition for pollinating insects throughout the vegetation period.

BiodivAgrar – AI-supported biodiversity monitoring

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Pollinating insects are crucial for the stability of agricultural ecosystems and food security. In the face of insect decline, innovative monitoring methods are important for effectively assessing population stability and evaluating biodiversity-promoting measures. The BiodivAgrar project uses two novel cameras and deep learning systems (EcoEye, Insect-Detect) to monitor wild bees, hoverflies, and other beneficial insects at large spatial scales. The project compares two AI-based detection systems with traditional entomological methods, such as pan traps and sweep net catches. The identification quality of the technical monitoring systems usually differs depending on the technology used and the monitored species groups. Therefore, we will evaluate available systems and different AI platforms to provide recommendations for large-scale monitoring of beneficial insects. The cameras are set up at arable fields accompanied by wildflower strips and hedges distributed across the federal state of Saxony-Anhalt. Crop fields with conventionally managed grassy field margins are used as controls. The quality of insect habitats and the surrounding landscape complexity will be analysed to evaluate the performance of the systems in relation to insect diversity and environmental variables. The evaluation will differentiate between different beneficial insects, focusing on wild bees as the most important pollinator group. The results will advance the automated, landscape-scale monitoring of biodiversity and improve measures to promote biodiversity and food security in agriculture.

Explaining and transferring patterns of grassland diversity using machine-learning

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European grasslands exhibit high levels of biodiversity and provide important ecosystem services. However, they are threatened by anthropogenic influence. Knowledge about the most relevant drivers of grassland biodiversity and their functional relationship to grassland diversity is essential to predicting landscape-scale biodiversity patterns and thus to protect and restore grassland diversity.

Based on extensive long-term measurements of grassland properties established in the Biodiversity Exploratory project, we developed machine-learning models predicting several grassland properties -- plant species richness and Eveness, as well as plant biomass and nutrient concentrations in the biomass. Using methods of interpretable machine-learning (IML), we disentangled the influence of several environmental drivers on these grassland properties. Furthermore, we plan to apply the developed machine-learning models to the larger landscape surrounding the Biodiversity Exploratories, and thus to make spatially continuous predictions.

With this contribution, we present the relationships learned by the model, as well as first results regarding their transferability. The machine-learning models showed high explanatory power when predicting the plant species richness inside the Biodiversity Exploratories, but low accuracy when predicting Evenness. The main drivers of plant species richness were soil fertility, characterized by plant-available phosphorus and nitrogen, as well as the land-use intensity. Hereby, increasing values of soil fertility and land-use intensity resulted in exponential and abrupt declines in predicted plant species richness, stressing the importance of protecting low-nutrient and extensively managed grassland habitats. The developed models are valuable for deriving spatially continuous predictions of grassland properties, which can then be used to inform grassland conservation.

Tracking pollinators through the lens of automated cameras in agricultural landscapes

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Pollinating insects are vital for agricultural productivity and biodiversity, yet standardized, automated monitoring methods for long-term, large-scale use in agricultural landscapes are still lacking. While automated camera traps offer a promising approach, their application in such settings has been limited and methodologically underdeveloped. To establish a robust method for automated pollinator monitoring across different landscape structures and crop types, we established eight Insect Detect camera traps based on Sittinger et al. (2024) across three Bavarian regions in 2024. These traps recorded pollinator activity from May/June to October at four daily intervals, with each session lasting 40 minutes. Each insect visiting the flower platform was assigned an individual ID and photographed at one-second intervals throughout its visit.

This study presents preliminary data from the 2024 season and outlines adjustments and goals for continued data collection in 2025. The error rate of the camera trap images analyzed so far is around 10-15%. Initial data revealed a dominance of Diptera, raising concerns about the representativeness of the pollinator community attracted by the current flower platform design. To address this, we will test different flower compositions in the 2025 field season, allowing for a comparative analysis of insect abundance and species richness across landscape types for both 2024 and 2025.

The camera trap system holds great potential for standardized pollinator monitoring and for providing recommendations to improve floral resources in agricultural systems during crop rotation phases.

Occurrence and toxicity of Epichloë endophytes in German grasslands

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Epichloë endophytes are symbiotic fungi in cool-season grasses, producing alkaloids potentially toxic to grazing animals. While livestock intoxications are well-documented in New Zealand, Australia, and the US, their prevalence and impact in European pastures, especially Germany, remain unclear. This study investigates the distribution and toxicity of *Epichloë* endophytes in German grasslands to estimate potential risks for livestock. The role of *Claviceps spp.*, a related fungal genus producing similar alkaloids and symptoms, is also considered.

Grass samples were collected from 90 sites across two German regions, including cattle and horse pastures, sites with previous equine laminitis, semi-natural grasslands, and football fields - covering a gradient from non-sown to intensively managed areas. About 5,000 individuals from 15 grass species were sampled between July and September 2024, focusing on *Lolium perenne* and *Festuca arundinacea*, key hosts linked to livestock toxicity. Stems and inflorescences were collected for *Epichloë* and *Claviceps* detection, respectively. The fungi get detected using Multiplex-PCR, with positive samples analyzed to quantify the concentrations of ten alkaloids, including Lolitrem B and Ergovaline, via HPLC-MS and GC-MS.

It is hypothesized that never-sown semi-natural grasslands reflect the natural abundance of *Epichloë,* while sown grasslands may show higher prevalence due to endophyte-infected seeds, especially football fields, where stress tolerance is desired.

Results are pending, but PCR detection is established and first results will be available in September. This study will provide critical data on *Epichloë* and *Claviceps* prevalence and alkaloid profiles in German grasslands, with important implications for grassland management and animal health, especially as climate change may increase the relevance of endophyte-related livestock risks in Europe.

ConservES - Conserving biodiversity and maximising ecosystem services in Europe's agricultural landscapes

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Agricultural intensification has often led to cropland expansion at the expense of landscape complexity and biodiversity, posing potential risks to ecosystem stability under global change. Agri-environmental schemes aim to counteract this trend by enhancing habitat structure and plant diversity, thereby supporting biodiversity and associated ecosystem services such as pollination and natural pest control. However, their effectiveness varies depending on local, landscape, and climatic conditions. The European research project ConservES investigates how flower strips and hedgerows (alone or in combination) affect the diversity of arthropods, birds and mammals across landscapes landscape complexity. Flower strips were sown in cereal fields in autumn 2023, and animal communities—pollinators, ground-dwelling and canopy-active predators, aphids, cereal leaf beetles, birds and mammals—have been monitored since. We observed that flower strips were positively associated with increased insect activity and diversity, particularly among pollinators, with approximately 20% of recorded wild bee species observed exclusively within the strips. Higher floral diversity within both flower strips and grassy field margins correlated with greater wild bee species richness, underscoring the importance of promoting diverse floral resources. Ground beetles emerged as the most species-rich group among the taxa surveyed with different field edge elements supporting distinct species assemblages. The combination of flower strips with hedgerows did not significantly reduce insect pests such as aphids, but neither did we observe higher pest infestations. Notably, vertebrates — particularly deer and some groups of birds — appeared to benefit from the structural complexity offered by the combination of hedgerows and flower strips.

Landscape, Climate, and Soil Influences on Crop Biomass: A Random Forest–Remote Sensing Approach in Bavaria

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Understanding how environmental variability shapes crop biomass is essential for enhancing yield stability and promoting climate-resilient agriculture. To investigate this relationship, we compared biomass estimates from a semi-empirical light use efficiency (LUE) model with predictions from a remote sensing–machine learning approach that incorporates environmental variables. Specifically, we integrated the LUE model with a random forest (RF) algorithm to estimate mean biomass for winter wheat (WW) and oilseed rape (OSR) from 2001 to 2019 across Bavaria, Germany, using a 5 km² hexagon-based spatial framework. Environmental predictors included the Shannon Diversity Index (SHDI) of land cover, small woody features (SWF), elevation, slope, aspect, soil potential, and seasonal (growing-season) mean and standard deviation of temperature, precipitation, and solar radiation. The RF model, trained on LUE biomass and validated against district-level yield and test-set data, outperformed the LUE model alone ($R^2 = 0.87$, RMSE = 2.85 dt ha^{-1} for WW; $R^2 = 0.86$, RMSE = 1.24 dt ha^{-1} for OSR). Variable importance plots showed that WW biomass was strongly influenced by landscape and topographic factors, while OSR was more responsive to solar radiation and soil potential. SHDI and SWF promoted biomass in Franconia and the Tertiary Hills Region, but limitations from slope and climate were evident in alpine and hilly zones. Biomass gains were associated with SHDI > 0.80 and SWF coverage near 7%, highlighting the ecological value of moderate landscape diversity and structural features. However, high SHDI levels were linked to reduced biomass. Crop-specific growing-season temperature thresholds were identified: WW biomass declined beyond 21°C, OSR beyond 12°C, reflecting differing thermal tolerances. This hybrid modeling approach offers an ecologically informed, scalable framework for biomass prediction and highlights landscape structure and climate as key levers for sustainable land management.

Disentangling moxidectin routes of exposure to non-target taxa: a multi-approach study

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Moxidectin, a macrocyclic lactone anthelmintic widely used in livestock farming, targets gastrointestinal parasites but is poorly metabolized, leading to significant excretion in dung. This increases environmental exposure for non-target organisms, particularly through soil contamination via treated manure. While negative effects on dung-dwelling arthropods are known, less is understood about broader ecological impacts, including indirect effects on aboveground species and interactions.

This project investigates direct and indirect pathways of moxidectin exposure affecting non-target taxa, including various arthropods and crop plants. A combination of outdoor and indoor experiments assessed moxidectin's impact on soil, plants, and arthropod responses. Outdoor trials focused on moxidectin uptake in crops and its effects on vegetative and reproductive development. Indoor studies evaluated pollinator performance and reproduction when interacting with treated plants. Germination assays examined potential carryover effects on seeds from exposed plants.

Our results reveal that moxidectin exposure can impair early plant growth and reproduction. Treated plants exhibited reduced height, leaf and flower production, and branching. Seed germination and root development were also negatively affected, indicating phytotoxic effects at environmentally relevant concentrations. Indirect effects on herbivores were observed, including delayed development and stunted growth in individuals feeding on exposed plants. However, impacts on other arthropods varied, with some species showing altered reproduction or unchanged survival, suggesting species-specific sensitivities.

These findings highlight the ecological risks posed by veterinary pharmaceuticals like moxidectin, which may extend beyond their intended targets. With increasing global use and limited environmental oversight, understanding and mitigating unintended effects is critical. This research supports improved pastureland management and the development of monitoring strategies to protect beneficial non-target species and maintain ecosystem services.

Influence of farming practices and climate conditions on soil-plant-microbes interactions under water stress

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Global climate change stressors are increasingly degrading soil health and threatening crop productivity. One promising yet underexplored area is the concept of microbial stress memory, particularly regarding its influence on plant resilience. In this study, we investigated how soil microbiomes shaped by different farming practices (organic vs. conventional) and climate histories (ambient vs. future) affect wheat growth under water stress. Soil samples was collected from long-term experimental plots and used to extract microbial communities, which were then inoculated onto two wheat cultivars—drought-sensitive *Nordkap* and drought-tolerant *SU Fiete*—grown under controlled drought conditions in greenhouse. Results revealed that inoculated plants showed significantly higher aboveground biomass than non-inoculated controls, with cultivar-specific responses. Moreover, the interaction of conventional farming and future climate history produced the most beneficial microbial effects, particularly in *Nordkap* affected with drought. Rhizospheric microbial profiling of bacterial communities were found to be influenced by farming, climate, and water stress, while fungal communities responded only to farming history. Increased abundance of key plant growth-promoting taxa such as *Bacillus, Rhizobium, Mesorhizobium, Burkholderia, Nocardiodes, Talaromyces*, and *Humicola* correlated with improved plant performance. These findings suggest that soil microbiomes carry legacy effects from environmental conditions that can enhance stress resilience, thus, offering potential for developing stress-adapted microbial inoculants for sustainable agriculture.

The potential of agroforestry systems to promote insect pollinators in agricultural landscapes

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Intensive land use is threatening important pollinator groups such as bees, butterflies, and hoverflies. Agroforestry and the associated integration of woody plants into the agricultural landscape offer a promising approach to combining pollinator restoration and agricultural production on field. In northern and eastern Germany, the diversity and abundance of three pollinator groups were recorded using transect surveys in agroforestry systems with and without flower strips and on control plots . Our results show that agroforestry systems had little effect on the pollinator groups surveyed compared to monocultural cereal crops. Agroforestry-flowering strip combinations, on the other hand, had significantly higher numbers of hoverflies, bees, and butterflies as well as more diverse bee species. Moreover, agroforestry systems with a higher diversity of flowering plants in the herb layer supported more diverse pollinator species. The results provide evidence that the potential of temperate agroforestry systems for promoting pollinators can be significantly increased by integrating flower strips or flowering plants in general. Future studies should consider the influence of other design factors of agroforestry systems on their potential to support pollinators and investigate long-term effects, e.g., on nesting habitat.

Insectivorous Bats as Pest Control in Organic Date Plantations

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Nature-Based Solutions (NBS) are used for addressing environmental challenges such as biodiversity loss and enhancement of natural enemies for biological pest control. One such NBS is wildflower strip adjacent to agriculture, a known method to enhance biodiversity. However, this method has rarely been studied in arid environments.

We used wildflower strips in date plantations investigating their efficiency in enhancing biodiversity and promoting pest control ecosystem services by insectivorous bats. Our goal is to evaluate whether flower strips can increase the feeding activity of insectivorous bats in date plantations and hence enhance their bio pest control services against date pests. Using passive acoustic monitoring, we compared the activity of insectivorous bats in six plots with flower strips and without (control) in the date plantations of Samar in the hyper arid area of the Arava Valley, Israel. The strips were planted with natural flowers from the region and the species of bats in these plantations feed on major pests, the lesser date moth (LDM).

The study is ongoing, but first results show that the total number of species was 12 and 10 in the flower strips and the controls, respectively, among them are rare species such as *Rhinolophus hipposideros*. Furthermore, our results indicate that the foraging activity of the bats increased when the density of LDM in the plantation increased as well. Flower strips have the potential to enhance several ecosystem services in the date plantations, hence our findings will contribute to sustainable desert agriculture and will provide farmers with practical nature-based solutions.

Effects of Ivermectin and Moxidectin on diversity and development of coprophagous beetles.

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The use of anthelmintics on grazing livestock has been shown to have a negative impact on the faunistic and floristic diversity of pastures, as active compounds are released into the environment through the manure. The substances can harm plants and animals, especially coprophagous insects such as dung beetles. These insects on the other hand provide crucial ecosystem services on pastures, such as relocation and decomposition of dung, which is crucial for nutrient cycling and growth of forage plants. Generally, Ivermectin is considered to be more toxic for dung organisms than Moxidectin, but comparative field studies on resulting insect quantity and diversity remain limited.

This study investigates how the treatment of cattle with the anthelmintics ivermectin and moxidectin affect the dung beetle community. In particular, we are focusing on the diversity and development of beetles in the treated dung over time following treatment. For this purpose, dung samples were collected on five sampling days [day 3, 5, 7, 14 and 21 p.t.] in spring 2025 and exposed on a pasture for three-day colonization periods. Half of the samples were used to determine the number and species composition of colonizing adult beetles. The second half was set aside for an eight-week incubation period to determine the number and diversity of developing adults as well as remaining larvae. The findings of the experiment are expected to highlight potential trade-offs between parasite control in livestock and biodiversity conservation in agricultural landscapes.

Designing a case study for grassland ecosystem productivity across trophic scales: relationships between agricultural practices, invertebrate resource availability and bird's reproductive success

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Agricultural intensification and monoculture lead to a dramatic decrease in insects and birds breeding in agricultural landscapes. More recently, dramatic declines in both became a focal research area, dealing with the identification of the drivers and mechanisms leading to population declines in insectivorous birds. Particularly threatened are migratory birds which are subject to multiple threats such as reduced resource availability, its seasonality and potential timely mismatches as well as the availability of undisturbed and suitable habitat structures for nesting. With this case study, we will thoroughly track agricultural practices and monitor the seasonal availability and abundance of invertebrates to ultimately model the population density and reproductive success of the Eurasian skylark *Alauda arvensis* breeding in agricultural grasslands of Northern Germany, Havelland, Brandenburg. We will collect data in the field in two agricultural landscapes with differing management practices. With this, we combine data of multiple ecological disciplines to investigate the productivity of grasslands on a landscape scale. The results are a valuable contribution to improving management strategies for sustainable landscapes and can be used to inform stakeholders and agricultural practitioners.

Comparing landscape heterogeneity metrics for explaining biodiversity variation in space and time

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Landscape heterogeneity (LH), which describes the diversity and spatial arrangement of land cover, influences species diversity via controlling ecological processes such as movement, predation, pollination, or pest control. Interest in LH has been growing over the last decades, and a wide range of metrics has been developed to quantify LH. However, the effectiveness of these metrics for explaining biodiversity variation in space and time remains unclear.

In this study, we aim to quantify LH using spaceborne remote sensing data across the German federal state of Bavaria, an area with a high variation in landscapes, from mountainous forests to plain arable land. Furthermore, we aim to compare the effectiveness of different LH metrics for explaining insect biodiversity trends.

To quantify LH, we will use two data sources: (1) ready-to-use land cover classification maps, like CORINE, and (2) raw spectral indices like the Normalized Difference Vegetation Index (NDVI), which avoid categorization through human interpretation. By comparing these, we evaluate their effectiveness in capturing LH. To compare LH changes at different geographical scales and assess how it has changed over time, we will calculate LH over multiple spatial and temporal scales.

To assess the practical applicability of the previously developed methods and data, we then apply them to a long-term monitoring dataset of insect biodiversity. We hypothesize that LH is positively correlated with insect occupancy trends, i.e. we expect more stable or increasing trends in areas of higher LH. By improving our understanding of the influence of LH on biodiversity, this research may support the development of informed conservation and land management strategies.

Poster Session 38

AI, data, computational biology & ecoinformatics

Potential of UAV-derived high-resolution snow depth models to advance arctic ecological research on Svalbard

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Snow is an essential climate variable and a crucial determinant of Arctic ecosystem functioning. Its high albedo and seasonal variability drive thermal gradients that globally affect atmospheric temperature. Snow also has strong local impacts: Acting as an insulating layer, snow depth regulates subnivean temperature and active layer thickness, protects vegetation from icing, and impacts water and soil nutrient availability during melt. It thereby affects plant growth dynamics and phenology, influencing resource availability for herbivorous wildlife, such as reindeer. At the same time, snow depth can constrain forage accessibility for herbivores and increase the energetic costs of moving and feeding during winter. However, local ecological effects of snow are still not fully understood, largely owing to a lack of snow depth data at ecologically relevant spatio-temporal scales. Such are challenging to cover adequately through traditional in-situ snow depth measurements. In this study, we investigate the potential of high resolution, spatially continuous UAV-derived snow depth data to advance Arctic ecological research. Using a fixed-wing, LiDAR-enabled Uncrewed Aerial Vehicle (UAV), we derive snow depth as the difference between digital surface models recorded under snow-covered and snow-free conditions, with a spatial resolution of 2.5 cm per pixel, for two study sites in high-arctic Svalbard. We validate the model with 340 in-situ snow depth measurements temporally synchronous to UAV acquisitions, showing high model accuracy. Using a semi variogram approach, we demonstrate that UAV-based snow depth models can capture fine-scale snow depth heterogeneity that otherwise would have been hard to derive using conventional in-situ sampling. In addition, we analyze how UAV-derived snow distribution compares to standard proxies (e.g., terrain ruggedness, elevation) conventionally used in Arctic ecology research when spatially continuous snow data are unavailable, quantifying the added value of our approach. Our findings suggest that UAV-derived snow depth data can contribute to a better understanding of the impact of snow depth on Arctic ecosystem dynamics.

Enabling use of biodiversity monitoring data in local land-use and conservation management

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Local land-use and conservation management practices are key drivers of bending the curve of biodiversity change. However, the integration of biodiversity data into local-scale conservation management decisions is not straightforward, and biodiversity data that exist at the local level among practitioners and authorities rarely feed into biodiversity data infrastructures to inform broader research on management practices and policy. Enabling data flows among conservation management actors, biodiversity monitoring schemes and national, European and global data infrastructures is of utmost importance.

Project ENABLElocal follows three research objectives: 1. Identify needs and questions in local land-use and conservation management decision-making that may be informed by biodiversity data, and social challenges of a data integration. 2. Match biodiversity data demands with existing data, and identify gaps and assess capacities to fill gaps via remote sensing. 3. Enable data integration across scales by providing instruments and build up capacities among local conservation practitioners.

To address these objectives, we employ a transdisciplinary research approach with stakeholder participation in all phases of the research process. A series of workshops and interviews with local practitioners in land-use and conservation management, as well as researchers and decision-makers, will identify practice-relevant research questions, develop a mutual exchange of knowledge and generate policy recommendations, products and tools for application and outreach. The stakeholder participation takes place in three case studies located in the partner countries, focusing on conservation and land-use practices in a) a biosphere reserve (CZ), b) wild bee hotspot areas on sandy grasslands (SE) and c) extensive apple orchard meadows (DE).

Effective Research Data Management for Biodiversity and Environmental Research: A Self-Paced Online Course by NFDI4Biodiversity

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In NFDI4Biodiversity, we have developed a self-paced online course on Research Data Management (RDM) for biodiversity and environmental research. The course is available as an Open Educational Resource (OER) in English and is openly available as a LiaScript course, an Ilias course, and in a text version. Our target audience are researchers, PhD students as well as Bachelor and Master students, i.e. anyone interested in basics of RDM. Depending on prior knowledge and interest, we offer many options for further reading.

Our goal was not only to convey good RDM content, but also to make the course, i.e. the training material, itself as FAIR as possible: the implementation as a LiaScript course facilitates the maintenance and further development of the course, the cooperation within our consortium with over 50 partner institutions, the collection and implementation of feedback from our consortium and beyond, as well as reuse. The LiaScript version can be exported as a SCORM-file for a large number of Learning Management Systems (LMS) such as e.g. Ilias or Moodle.

The course is designed to give an overview of RDM for biodiversity and environmental science, as well as deep dives into selected topics. Learners that are interested in even more details on a specific topic are guided to useful resources outside the course. The chapters are structured after the Data Life Cycle (DLC) and can be used individually, too. This allows for the straightforward integration of additional chapters, e.g. on Open Science (available soon).

We are looking forward to share and improve this course, and to develop new courses with interested partners. Possible topics could be a RDM course adapted for Citizen Science projects, AI & ecology, a course on legal aspects in biodiversity research, and many more. Please contact us if you are interested in a collaboration!

From physical herbarium specimens to extended specimens: First steps towards the implementation of Digital Collectomics

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Scientific collections, such as herbaria, are experiencing an ongoing renaissance as their physical specimens not only provide taxonomic value, but also spatiotemporal ecological information from the recent past that can also contribute to the understanding of human-driven biodiversity changes. The multidimensionality of specimen-related data, such as morphological and functional traits, genomic and distribution information, and biotic interactions, has been summarized under the concept of the Extended Specimen (ES). The technical implementation of the ES within rapidly developing methods and their application in data-driven biodiversity science and bioinformatics paves the way into "Digital Collectomics" (DC), a term that originated at Senckenberg. At the Senckenberg Institute for Plant Form and Function Jena (SIP) we are working on the realization of DC and to decipher, understand, and manage the changes of biodiversity in the Anthropocene – with the Herbarium Haussknecht (JE) at the center of our collection-based research. Here, we present recent efforts to integrate non-invasive or minimally invasive methods under the umbrella of DC. These approaches are intended to serve as a basic framework for establishing future pipelines for high data throughput. The framework depicted here includes (automated) extraction of trait information from specimen using near-infrared spectroscopy (NIRs) for leaf nutrient levels, and digital (DM) and scanning electron microscopy (SEM) for the extraction of functional traits such as stomatal distribution, density and sizes, or hair and papillae density. Eventually these methods will be linked to approaches to extract this information using AI and machine learning-based segmentation models (plant organs and their measurement, label data, phenology). Future steps will address the integration and linking of these specimen-derived data in public databases to ensure data mobilization and compliance with the FAIR principles.

To what extent and for what reasons do university libraries make student theses in ecology available?

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In graduate programs, students receive both theoretical and practical training in their fields and undertake research projects under the guidance of a supervisor. However, only a small subset of these theses is published in peer-reviewed journals and thus accessible for use in evidence synthesis. As a result, much valuable knowledge remains hidden. Little is known about how often, or under what conditions, student theses are made publicly available. In this study, we contacted libraries and registrar's offices of universities with study courses in the field of ecology across Germany, Austria, and Switzerland to investigate whether, and under what circumstances, universities make student theses publicly available, and to explore the reasons behind their practices. Preliminary results indicate that only 5-15% of universities make their student theses publicly available. Thereby, universities risk losing opportunities for knowledge integration and innovation. Addressing these gaps could reduce research waste and better align institutional practices with the standards of open science, though further efforts are needed to overcome existing barriers.

PhotoDB: a customizable platform for image data management, processing, and annotation

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Automated monitoring methods, in particular camera-based approaches, have become increasingly important in ecological research. While promising, the resulting large datasets also pose unique challenges for data management and analysis. Coherent processing of images and associated metadata at all points in the processing pipeline is vital to ensure accurate results and reproducibility. Several software solutions designed to automate these tasks already exist. However, these solutions seldomly cover the complete processing workflow, which ranges from initial data collection, data cleaning and image preprocessing to image annotation and export. Moreover, existing solutions have been developed primarily for specific use cases, particularly focusing on large mammals, and therefore lack flexibility and broad applicability. We present an open-source platform, called PhotoDB, which is designed to cover the complete image processing pipeline. PhotoDB offers a flexible framework for image data management, which can easily be customized to fit various study designs, including but not limited to classic camera trap studies. It includes preprocessing as well as annotation functionalities that allow for manual annotation and the integration of custom machine learning classification models. PhotoDB allows its users to interact with individual image metadata through any programming language, which offers the possibility to automate the complete image analysis workflow. We demonstrate the functionalities of PhotoDB with a case study on phenological monitoring, in which PhotoDB is used to manage a multi-step automated classification workflow.

Biodiversity Factor Monitoring with Intelligent Acoustic Sensors (BioIntAkt)

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Biodiversity is a crucial indicator of ecosystem resilience, and the ongoing decline of entomofauna has become a major concern in both public and scientific discussions. Effective biodiversity monitoring is essential for sustainable land use and agricultural strategies such as integrated pest management (IPM). However, current methods for insect identification are time-consuming, resource-intensive, and require specialist knowledge, often capturing only selected insect groups depending on the approach used. Despite significant advances in digital tools and artificial intelligence (AI), their application in entomofauna monitoring remains limited. This project aims to develop an AI-supported, digital system for monitoring insect biodiversity based on acoustic recordings. The approach includes the development and validation of an efficient and autonomous sensor system for recording, analyses and classification of insect acoustic signatures. Field tests include real-world data collection for calibration and evaluation in diverse agro-ecosystems. Additionally, the integration of citizen science through a smartphone app will enable broader regional data collection and raise public awareness of biodiversity issues. By combining sensor-based acoustic monitoring with AI-driven species identification and community involvement, this project seeks to provide a scalable, efficient, and cost-effective tool for insect biodiversity assessment, contributing to long-term ecological monitoring and more sustainable agricultural landscapes.

Multiple sensor application in commercial bumble bee colonies to disentangle multiple pressures relevant for pollination services

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Pollination is essential to both natural and agricultural ecosystems. However, especially wild bees as important pollinators are declining worldwide, with severe implications for biodiversity and food security. Habitat loss, pesticide use and climate change have been identified as the main risk factors. Yet, improved monitoring methods are urgently needed to gather real-time information at various spatial and temporal scales.

As part of the EU-project PHENET (https://www.phenet.eu/en), I am working on a use case that explores the potential of bumble bee colonies as bioindicators for environmental pressures and pollination services. To investigate this, commercially available bumble bee hives equipped with automated monitoring devices – a scale for continuous weighing of the colony, microphone for recording internal sound activity, camera for measuring forage activity times of individually marked specimens, a brood temperature logger and a logger for temperature and humidity - are deployed across four landscape test sites with varying degrees of agricultural intensification in Saxony Anhalt (Germany; UFZ observatory within the TERENO network, https://www.tereno.net).

The goal is to identify and predict colony performance and health. To this end, AI-driven methods are aimed to be developed based on data collected from the field study with colonies exposed to ambient conditions in the landscape context and experimentally controlled colonies exposed to heat, food availability and pesticides as stressors related to climate change and land use.

Training Convolutional and Multimodal Neural Networks with the cito R Package

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Convolutional neural networks (CNN) and multimodal neural networks (MMN), which combine satellite imagery and environmental data, have shown great potential in improving species distribution models. However, progress on this frontier is impeded by the fact that implementing CNN and MMN requires expert knowledge of deep learning and its frameworks. Here we present cito, an easy-to-use R package for deep learning that provides extensions for CNN and MMN. cito allows flexible modification of deep learning models and the combination of different network architectures, allowing users to test and apply most modern deep learning techniques without extensive knowledge of deep learning. We demonstrate how cito can be used to fit MMNs for species distribution models, and how tools from explainable AI can be used within cito to explain MMN, and to reveal patterns in complex data (e.g., satellite images) that are important for predicting species distributions.

A Metabarcoding Pipeline for the Biodiversity Community

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DNA metabarcoding offers great potential for rapidly and efficiently capturing species diversity across different ecosystems. This method enables the monitoring of almost the entire species diversity of a habitat and provides semi-quantitative information on the frequency of species in the samples.

Based on this, our goal within NFDI4Biodiversity is to provide a user-friendly pipeline for the analysis of metabarcoding data from various sources.

We rely on the APSCALE pipeline to analyze the data. In cooperation with the NFDI consortium NFDI4Microbiota, a workflow was developed for the cloud-based workflow manager CloWM, which handles the entire execution of the pipeline and is available on the production instance clowm.de.

The computing resources provided by de.NBI enable the analysis of large datasets, regardless of the users' individual technical setups, and allow for direct transfer of data into long-term archives. Long-term support and regular updates to the pipeline are assured, while best practice recommendations are being developed for the different organismal communities.

Initiatives are already underway for collaboration between the DNA metabarcoding community and the Global Biodiversity Information Facility (GBIF) network to seamlessly publish analyzed metabarcoding data and integrate it into GBIF and the Living Atlas of Nature Germany, another NFDI4Biodiversity use case.

Poster Session 39

Climate and climate change

Climatic stress along elevational gradients outweighs biotic interactions in threatening European beech (*Fagus sylvatica*)

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Species distributed across extensive geographical areas face varying ecological challenges and benefits, making it imperative to discern their optimal performance zones. Among the pivotal broadleaf trees in temperate forests, the European Beech (*Fagus sylvatica*) spans a significant altitudinal gradient. While studies anticipate a future range shift towards higher altitudes, the fundamental question of whether beech trees perform better in these elevated environments remains unresolved. In our investigation, we gauged the performance of beech trees through leaf fluctuating asymmetry (FA), conducting a comprehensive study across the elevational gradient of Germany. Our findings unveil a notable reduction in leaf FA for beech trees at higher elevations. Furthermore, these elevated zones offer a reprieve from climatic stressors such as elevated summer temperatures and diminished soil humidity. Paradoxically, higher elevations present heightened challenges, with increased leaf herbivory and intensified intra-specific competition. Our study posits that climatic stress along elevational gradients poses a more formidable threat to European beech trees than biotic interactions.

Bon Appétit! – Tracking the activity of social insects using automated cameras

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Behavioral studies often require long-term observation and tracking of animals—tasks that typically exceed the endurance or capacity of human observers. For small organisms such as insects, which are too tiny for traditional GPS tracking, emerging technologies that combine camera-based observation with deep learning and computer vision are rapidly transforming the field. Here, we present recent advances in the development of an automated camera system capable of tracking the foraging activity of ants attracted to baits by individually marking each ant as it appears and tracking its movement across a bait station. Using these automated cameras, we analyze how foraging behavior varies with temporal and environmental conditions.

Behavioral responses of butterfly communities to daily temperature variation in different habitat types in Central Europe

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Climate change threatens global biodiversity through changing environmental factors like temperature. Such environmental alterations impose challenges for the survival of species if species' ecological niches remain unchanged. Thus, to cope with rapid climatic changes, animals often rely on behavioral responses like thermoregulation or dispersal.

Butterflies serve as useful bioindicators in ecological research, due to their visibility and sensitivity to different environmental factors. However, behavioral responses of butterflies to change in climatic conditions are critically understudied.

In this study, we classify species' thermal activity niches in different grassland habitats. We classify species as thermal generalists or specialists, and their preferred temperature range of activity. Furthermore, we investigate how habitat structure, complexity, and microclimate influence butterfly community composition. Lastly, we assess which species-level traits are influential for the temperature range of species activity.

To investigate that, three different grassland sites in Würzburg that differ in vegetation and microclimate are sampled once per week. On each site one transect (200 m in length) is sampled from 8am to 8pm every two hours over the span of 20 minutes with regular temperature and humidity recordings every two minutes. During the sampling butterflies are identified, their activity is documented, and local weather conditions are recorded.

With these data, we hope to identify the thermal activity niche of butterflies and model the species daily active behavioral window, and quantify the community composition of active species of habitats under different temperature conditions. This study will improve our understanding of the consequences of climate change on butterfly behavior and thereby contribute to protect threatened species and habitats.

Interacting effects of climate and land use on landscape multitaxonomic β-diversity

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Exacerbating rates of climate and land use changes have led to massive species losses in recent decades. Especially for arthropods, rapid declines in biodiversity have raised concerns across the scientific community as well as the general public. Although we have a profound knowledge about the effects of climate and land use change on selected species performances and α-diversity patterns, we still have much to learn in the field of β-diversity. There are hints that land use as well as climate change can lead to biotic homogenization on a landscape scale. Yet, it is unknown if these homogenizing effects of climate change might be amplified by land use and vice versa.

By taking advantage of a large scale, multitaxonomic biodiversity dataset (viz. the Landklif dataset), comprising 60 landscape patches across Bavaria, representing five different climate zones and three different landscape types (agricultural, urban, semi-natural), we were able to analyze the interacting effects of climate and land use on arthropod taxonomic and phylogenetic β diversity. At least for the study area located in the Central European, temperate region, climate yet seems to have no overall homogenizing effect on biodiversity. Land use, in turn has significant effects, with forest contributing most to landscape scale β-diversity. By combining climate and land use effects, we got evidence for an amplifying effect, with climate leading to biotic homogenization especially in urban-agricultural areas.

Too Hot to Hatch? Summer temperatures and the development of Colletes cunicularius

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The majority of wild bee species are ground-nesting and spend most of their lifetime belowground. Soil and belowground conditions are difficult to study and to date there is no well-established model organism for investigating the ecology of ground nesting bees, e.g. how they are influenced by environmental changes, such as rising temperatures during extreme summer heats. We use *Colletes cunicularius*, a common early-spring solitary bee nesting belowground while forming aggregations, to test the effects of increasing summer temperatures on their development and survival. For this pilot study, we will excavate *C. cunicularius* nests, from various locations across Hesse, Germany beginning shortly after their flying period has ended. We will monitor their development stages and expose some of the nests to temperature treatments resembling heatwaves. We hypothesize that heatwaves impact the development may be lethal if temperatures exceed the bee's thermal tolerance. Here, we present preliminary findings on how heat stress influences the development of *C. cunicularius* and discuss possible challenges of keeping ground-nesting bee nests under controlled laboratory conditions.

A Framework for Identifying Species Vulnerability to Extreme Weather Events

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Climate change is not only altering average environmental conditions but also increasing the frequency and severity of extreme weather events. While the ecological consequences of gradual climate shifts are relatively well understood, the impacts of short-term climatic extremes on biodiversity remain less explored. This study investigates how extreme weather events—droughts, heavy precipitation, heatwaves, and cold spells—affect the occupancy patterns of 132 bird species of conservation concern across Central Europe (Germany, Austria, and Switzerland). Using over 7 million bird occurrence records from eBird and Ornitho, combined with high-resolution environmental data, we implemented a Bayesian Nested Dynamic Weather Model that separates the long-term effects of climate and habitat structure from short-term influences of weather and habitat condition.

Species occupancy was modeled at a monthly temporal resolution and a spatial resolution of 1 km², accounting for seasonal dynamics and observation biases across data sources. The model was used to predict species' responses under four types of extreme weather scenarios, based on 19 years of historical data. Our findings aim to improve understanding of how extreme weather events influence biodiversity patterns and to support conservation planning by identifying species and traits associated with increased vulnerability to climatic extremes.

Herbivory and drought stress influence volatile emissions and leaf metabolites in black poplar (Populus nigra)

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Climate change is leading to more frequent and severe climatic events, such as droughts and heavy rainfall, which can increase stress on trees and alter ecological interactions within them. In recent years, prolonged droughts have also become increasingly common in temperate latitudes, contributing to pronounced stress responses in trees. Currently, little is known about the effects of drought stress combined with biotic stress such as insect herbivory on metabolic changes in woody plants. Here, we investigated the response of black poplar (*Populus nigra*) to different levels of drought combined with specialist *Chrysomela tremulae* herbivory in a full factorial design using three *P. nigra* genotypes. We measured morphological traits, volatile organic compound (VOC) emissions, and leaf and root phenolic profiles. Our results show treatment- and genotype-specific differences in qualitative and quantitative VOC emissions, as well as changes in organ-specific metabolite profiles. Our results suggest that the combination of drought stress and herbivory, with the resulting metabolic changes in the leaves, could have a significant influence on trophic interactions in black poplar trees.

Heating up parasitoid-host interactions: increased ladybird mortality is caused by lowered survival of late-instar braconid larvae

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Host-parasitoid interactions are strongly influenced by biotic and abiotic factors. With ongoing climate change, temperature-dependent outputs of host-parasitoid interactions can strongly affect ecosystem functioning. We tested the effects of low, optimal and high temperatures on development, survival, and body size of the braconid parasitoid *Dinocampus coccinellae* and longevity and recovery probability of its host, the invasive ladybird *Harmonia axyridis*. High temperatures strongly reduced parasitoid survival (no adults emerged) as well as host recovery and longevity, which was reduced even by the exposure to the parasitoid. At optimal temperature parasitoid larval development was necessary to reduce host longevity, while at low temperature effects of parasitoid exposure and larval development were additive. Elevated temperature resulted in increased parasitoid mortality during late larval and pupal stages. Host sex also influenced parasitoid pupal success, female ladybirds produced more adult wasps, and parasitoid body size, as smaller wasps hatched from male hosts. In addition, parasitized male ladybirds survived and recovered less than females at low temperatures. This study clearly demonstrates how temperature- and stage-specific parasitoid mortality could impact host longevity and rarely investigated recovery probability, i.e., the ability of hosts to overcome paralysis induced by parasitoid-transmitted RNA virus and restore feeding and mating behaviour

Modeling long-term soil carbon sequestration from biochar and rock powder application: LiDELSv2 insights from a 1000-year simulation

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The integration of wood-derived biochar and basanite rock powder into sandy soils offers a promising pathway to enhance soil functionality, support plant growth, and deliver durable carbon sequestration. Yet, the long-term ecosystem-scale impacts of these amendments—especially their interactions with vegetation and carbon fluxes—are not fully captured by short-term field or laboratory studies. The LiDELS (LiBry-DETECT Layer Scheme) model addresses this gap by providing a process-based framework for simulating the complex feedbacks between soil, vegetation, and atmosphere under diverse environmental conditions.

This study presents the capabilities of the updated LiDELS model, which now includes modules to simulate both the long-term effects of biochar and the weathering dynamics of silicate rock powders such as basanite. Applied to sandy soils under northern German climatic conditions, LiDELS captures key changes in water retention, thermal properties, net primary production (NPP), and carbon cycling metrics. Preliminary results show strong agreement with observed data and indicate significant improvements in soil water availability and CO_2 dynamics following amendment application. LiDELS emerges as a robust and versatile tool for evaluating the climate mitigation potential of soil-based interventions, supporting science-based decision-making in sustainable agriculture and carbon management.

Wing fluctuating asymmetry in alpine bumblebees due to environmental stress

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Cold-adapted alpine bumblebee communities are sensible to global warming and are facing multiple threats regarding climate change. Environmental stressors affect the development of bumblebees, leading to small random deviations in their morphometric properties and bilateral wing symmetry. This fluctuating asymmetry (FA) has been shown to be a sensitive biomarker for environmental instability. Too much variation requires more energy for locomotion and decreases the overall fitness and survival of bumblebees. I will analyse the effects of local habitat, climate factors and altitude on wing morphology and test the hypothesis that FA should increase with altitude. So far, studies have only investigated FA along an urban gradient; here I investigate wing morphometry in alpine bumblebees along an elevation gradient in the Australian Alps. Different bumblebee species were collected from 900-2400m a.s.l., which represents a wide difference in temperature (8°), elevation and habitats. The FA of wing size, wing loading, wing shape and aspect ratio were analysed using geometric morphometrics. There was a multifaceted change in the measures of wing morphometry along the gradient, with a marked difference between the high alpine and lower elevation bumblebees. Given the global decline of bumblebee species and their important role in pollination, it is important to understand the impact of the changing climate on the current and future morphology of species and their capability.

Poster Session 40

Forests

Effects of reserve size, landscape habitat amount and habitat quality on gamma diversity in forest reserves

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To reach and maintain global conservation goals, such as "30by30" by COP15, there's a need to understand landscape and reserve-based drivers of forest biodiversity. To assess how reserve size, landscape habitat amount and habitat quality affect diversity, we selected 44 protected forest areas of different size in three dominant forest types in Bavaria (riparian, upland and mountain) and assessed beetles, spiders, birds and fungi. To improve comparability between reserves, the number of sample plots was chosen proportionally to reserve size and gamma diversity per reserves was calculated within the Hill-Chao framework using coverage-based standardized diversity for each taxon. We analyzed all species, and forest specialists separately. Results show generally an increase of diversity with reserve size for beetles, spiders and fungi, but mixed results for forest share in the landscape and the interaction of both. Especially for birds, the diversity increased with reserve size only in low forested landscapes. For forest specialist diversity, the effects of reserve size and landscape forest share disappeared. Assessing the role of different forest structural and compositional characteristics, we found that especially beetle and spider diversity was affected by habitat quality in upland and fungi diversity in mountain forests. In summary, we show that the effect of forest share in the landscape is relevant for beetles and birds, whereas habitat quality is especially important for beetles and spiders in upland and fungi in mountain forest reserves. Overall, forest diversity profits from higher reserve area. Thus, our results contribute to a better understanding of factors influencing diversity of different taxa across different forest types, which can support decision- and policymakers in achieving and maintaining conservation goals.

Ecological insights from forest biodiversity experiments

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Planting forests can be a winning strategy to increase forest cover and one of the most effective strategies for climate change mitigation globally. With the emerging of the manipulative forest biodiversity experiments, it opens the door to answer the question “how tree diversity change impacts ecosystem functioning” and provide science-based solution for planting forests. In this review presentation, we summarized the findings gained from the forest biodiversity manipulation experiments all over the world from five key aspects. That includes 1) the various ways that tree diversity impacts ecosystem functioning; 2) the change of these effects through stand age; 3) the diversity of multitrophic biodiversity in mediating these effects; 4) the context-dependent biodiversity effects on ecosystem functioning; 5) linking the experimental findings to the real-world practice. In the end, we proposed the future perspectives for biodiversity experiments.

Effects of forest reserves on the conservation of saproxylic species: 8-year monitoring of saproxylic beetles and fungi in Swiss forest reserves

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The establishment of natural forest reserves is a key strategy for conserving biodiversity in Central European forests. By discontinuing forest management and timber harvesting, these reserves promote natural dynamics that gradually lead to an increase in late-successional stages, characterized by old and dying trees and high volumes of dead wood. These conditions are expected to increase occurrences of rare and endangered dead-wood dependent species by improving habitat conditions to their requirements.

In Switzerland, natural forest reserves are planned to cover at least 5% of the forest area by 2030. To evaluate the impact of this conservation strategy on biodiversity, we compared saproxylic beetle and fungal communities between forest reserves and managed forests using a paired design. We inventoried beetles and fungi in 16 pairs of reserves and managed stands in lowland beech (Fagus sylvatica) and montane spruce (Picea abies) forests throughout Switzerland. In total, both saproxylic groups were studied on 352 plots for two years each, from 2017 to 2024. In parallel, forest structures such as the amount of dead wood and canopy openness were inventoried on each plot.

Besides significant correlations of species richness with forest structure, forest reserves hosted higher species richness of saproxylic fungi than managed forests in both beech and spruce forests. For saproxylic beetles, a similar pattern was observed in beech forests, but not in spruce forests. This contrasting observation highlights the importance of a multi-species approach when assessing the effectiveness of conservation measures. It also highlights the importance of forest reserves in lowland areas, where saproxylic beetles are known to be particularly vulnerable.

Diurnal patterns of leaf gas exchange and sap flow in Fagus sylvatica, Quercus robur, Larix decidua, and Pseudotsuga menziesii

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A detailed understanding of physiological processes is crucial for analyzing carbon and water dynamics in forests. However, parameters at the leaf level are often measured on saplings or seedlings, which limits the direct applicability of findings to adult trees. Physiological correlations established from these measurements may not directly translate to mature trees, as factors like age, tree size, and stand interactions—such as competition—can significantly influence these processes.

As part of the FeMoPhys project, gas exchange measurements were conducted in a mixed beech forest in northern Germany using a canopy crane to investigate physiological processes in adult trees throughout the day. Sampling was performed on the crowns of three individuals per species: *Fagus sylvatica* (European beech), *Larix decidua* (European larch), *Pseudotsuga menziesii* (Douglas fir), and *Quercus robur* (pedunculate oak). Stomatal conductivity for water vapor and photosynthetic rates in the light-exposed canopy were measured at multiple times throughout the day across different dates over the year.

This poster exemplarily presents key results from diurnal measurements in July 2024, highlighting interspecific differences. Notably, *Q. robur* exhibited a more rapid increase in photosynthetic performance after sunrise and tended to reach a higher maximum photosynthetic rate compared to *F. sylvatica*.

Additionally, in combination with sap flow sensors, temporal relationships between water transport at the stem base, stomatal conductance, and photosynthetic rate were analyzed. Since sap flow measurements at the stem level require relatively little effort, their potential application for estimating gas exchange at the leaf level is explored. The observed temporal lag between sap flow on the trunk and gas exchange in the crown—in our data more pronounced in conifers compared to deciduous species—is also considered. As an outlook, methodological challenges associated with gas exchange measurements in adult trees under field conditions are illustrated.

Conifer shoot growth response to severe drought dependents on hydraulic safety and efficiency traits

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Estimation of drought response values (resistance, recovery and resilience) from shoot increment changes is a novel and cost-effective approach in tree ecophysiology. Here, we tested how interspecific differences in key hydraulic traits relate to the inter-annual drought stress response. The measurements of annual shoot increments (2008-2023), sapwood-to-leaf area ratio (Huber value), xylem embolism resistance (P_{50}) and stomatal closure point (P_{gs90}) were conducted on nine coniferous tree species from three genera. Additionally, the stomatal safety margin (SSM_{P50}) was calculated. The species showed low interspecific variability in P_{50}, but high interspecific variability in P_{gs90}, SSM_{P50} and Huber value. We found that there was a strong trade-off between drought resistance and recovery among species. Moreover, both drought resistance and recovery were related to P_{gs90} and SSM_{P50}. Species with higher P_{gs90} and larger SSM_{P50} had higher drought resistance but lower recovery compared to smaller SSM_{P50} species, showcasing the differentiation between conservative and opportunistic stomatal closure strategies. Recovery and resilience correlated positively with Huber value, therefore higher leaf area per sapwood area has negative impact on recovery and resilience of trees. Stomatal response strategy and relative leaf area to sapwood define the divergent drought stress resistance and recovery capacities among coniferous tree species.

$^{13}CO^2$ pulse labelling reveals species-specific shifts in carbon allocation under heat stress in *Fagus sylvatica* and *Pseudotsuga menziesii* seedlings

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While the impact of drought has been in the focus of research in recent years, significantly less is known about the effect of heat stress on carbon allocation in plants. In this study, we exposed well-watered seedlings of *Fagus sylvatica* and *Pseudotsuga menziesii* to air temperatures of 35°C for eight days. Control plants were measured at 25°C. On the 4th day of heat stress, we applied a $^{13}CO^2$ pulse label to heat and control plants to study carbon allocation patterns. We continuously measured leaf gas exchange, isotopic discrimination ($\delta^{13}C$) and the emission of BVOCs by PTR-TOF-MS. Real-time measurements were complemented by tissue samples of water-soluble organic matter (WSOM) in phloem and leaves, and gaseous BVOC samples for compound-specific $\delta^{13}C$ analysis.

For both species, net assimilation significantly declined under heat, while relatively more carbon was directed to respiration and BVOC emissions. *F. sylvatica* mainly emitted monoterpenes, which were strongly labelled with ^{13}C under heat ($\delta^{13}C$: +153.0 ± 108.0‰ vs. –11.6 ± 40.3‰ under control). For *P. menziesii*, BVOC emissions were also higher under heat, however more ^{13}C was incorporated into BVOCs of unstressed plants (heat: –21.1 ± 23.0‰, control: +3.7 ± 84.2‰), most likely caused by the lower overall net assimilation rates and ^{13}C uptake of heat stressed plants. WSOM in leaves and phloem only showed a slight enrichment in ^{13}C, yet the mean residence time (MRT) differed between species. In *P. menziesii*, the MRT in needles was shorter under heat (14.1 h) compared to control (35.1 h), while for *F. sylvatica*, this trend was opposite with longer MRTs in WSOM in leaves under heat (21.6 h) compared to control (12.8 h). Our study clearly illustrates a species-specific shift in carbon allocation under heat towards higher respiration and BVOC emissions, which potentially serve as protective mechanism against heat. This illustrates potential changes in the carbon cycling modulated by plants under a warming climate.

Ecological and economic trade-offs of bark treatments for European Spruce Bark Beetle regulation across scales

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Increasing disturbances, climate warming, and outbreaks of the European Spruce Bark Beetle (*Ips typographus*) led to unprecedented amounts of Norway spruce timber (*Picea abies*) damaged in recent years. To fulfill forest protection goals, damaged or weakened spruce trees are either salvage logged or made unsuitable for breeding by debarking. Manual debarking is not efficient enough for large amounts and the extraction of dead wood can compromise biodiversity. This highlights the need for innovative pest management strategies that can treat large quantities of wood while preserving forest functionality. We research mechanical bark treatments as alternatives to salvage logging for bark beetle regulation, while controlling for variations in management and climate across Germany. We quantified pest control efficiency, economic effort, wood properties and effects on species richness as well as community assembly of saproxylic beetles, fungi and bacteria over the first two years. The repeated handling of logs with the harvester for bark removal, indicates efficient reduction in bark beetles, which is important for the treatment of large amounts of calamity wood. Additionally, we confirm motor-manual bark gouging and debarking as effective methods for low quantities. With increase in bark removal intensity, saproxylic beetle as well as bacteria richness decreased while for fungi we observed an increase. Differences in moisture content between treated and control logs was found as main driver for changes in fungi and bacteria community assemblages, while other elements and the calorific value remained constant. After a triple harvester treatment (large volumes) or motor-manual bark gouging (small volumes), logs can be left for intermediate storage to buffer economic bottlenecks during landscape disturbances. *I. typographus* is effectively reduced while adverse effects on saproxylic biodiversity can be minimized.

Inter-kingdom wound care between *Pseudomyrmex spinicola* and its host *Vachellia allenii*

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Mutualistic ant-plant relationships play a crucial role in biodiversity and ecosystem stability. Through coevolution, myrmecophyte plants provide shelter and food, while the ants offer protection from herbivores and pathogens. As sessile organisms, plants are vulnerable to injuries that can get infected and significantly affect their fitness. While some ants exhibit intraspecific wound care, their role in tending plant wounds remains unclear. Our study shows that the myrmecophyte *Vachellia allenii* experiences injuries on both leaves and bark, with mutualistic *Pseudomyrmex spinicola* ants accumulating at these wounds. At bark wounds, ants engaged in biting and allogrooming. Soil material had little effect on ant accumulation, but at leaf wounds, after 40 minutes ants spent more time on contaminated wounds, suggesting they distinguish between clean and dirty wounds. These findings suggest that ants actively interact with plant wounds, indicating a potential role in wound care. It is conceivable that myrmecophytes have partially reduced their immune system and rely on ants—similar to social insects, which evolved weaker immunity in favor of social immunity. Recognizing that ants tend to plant wounds to improve the survival of the host plant may redefine our concept of social immunity and reshape our understanding of mutualistic relationships.

A walk in the park? – Floristic richness in Brandenburg's rural manor park remnants compared to seminatural deciduous forests

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Natural habitats have declined all over Europe due to intensification of agricultural land use, abandonment of traditional practices and an ongoing increase in urbanization, leading in turn to a decline in biodiversity within agricultural landscapes. Small forest patches (>1 ha, < 50 ha) embedded in the agricultural matrix are an important aspect for maintaining species diversity therein. In Central Europe, some of these small forests are remnants of manor parks, which have been an integral part of Europe's cultural landscape since their creation during the 17th to 20th centuries. Even though many of the estates have been destroyed, rural Brandenburg (Germany) still features almost 300 manor parks in various conditions, which are mainly considered cultural heritage sites. However, there is evidence from other European countries that manor parks host more biodiversity than the surrounding landscape and provide refuge for ancient trees and their related biological communities. Therefore, we wanted to find out whether forested manor park remnants may function as refugial habitats for characteristic forest flora and ancient trees in Brandenburg.

We surveyed the vegetation and measured DBH of selected trees in 30 forested manor park remnants and 30 seminatural forests in the Prignitz region, comparing plant species richness and tree sizes between them.

Results show that forested manor park remnants do contribute to the preservation of forest flora within an intensively used agricultural landscape. They appear equal to small deciduous forests and harbor similar proportions of forest specialists compared to seminatural forests in the same region. Regarding trees, forested manor park remnants feature older ones with a significantly higher DBH compared to seminatural forests.

We conclude that these forest-like park remnants are an important part in creating a more heterogenous landscape, allowing for more diversity. As such they are a valuable biotope in Brandenburg.

La Gamba Field Station: Advancing Research, Conservation, and Education in a Biodiversity Hotspot

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The La Gamba Field Station, operated by the University of Vienna, Austria, is located at the edge of Piedras Blancas National Park in southern Costa Rica. Established in 1993, it serves as a vital platform for research, conservation, and education in one of Central America's most species-rich lowland rainforests.

The station hosts interdisciplinary, long-term research on tropical biodiversity, restoration ecology, and sustainable land use to address the impacts of deforestation, habitat fragmentation, and climate change. Initiatives combine ecological monitoring, reforestation, agroecology, and functional ecology to promote ecosystem resilience and sustainable land management.

The Biological Corridor La Gamba (COBIGA) exemplifies applied conservation by restoring forest connectivity through native tree plantations, grounded in scientific and local knowledge. Research methods include field surveys, experimental plots, and remote sensing to study plant-animal interactions, species distributions, and ecosystem dynamics.

Collaborative projects have established reforested areas, improved biodiversity monitoring techniques, and contributed to scientific literature on tropical ecology. Ecological datasets generated at the station inform regional conservation planning and policy. Through training programs for students, local communities, and early-career scientists, the station fosters education, capacity building, and international collaboration.

La Gamba shows how field stations integrate research, conservation, and engagement to support biodiversity and sustainability.

Decadal impact of tree diversity and mycorrhizal associations on topsoil carbon dynamics

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Soil organic carbon (SOC) is a critical regulator of terrestrial ecosystem functions, impacting soil fertility, water retention, and climate through carbon sequestration. Understanding how tree species diversity and symbiotic mycorrhizal associations influence soil carbon storage over time is essential for sustainable forest management. Utilizing the long-term MyDiv experiment in Germany, which provides a well-controlled platform to investigate the intricate relationships between tree diversity, microbial communities, and soil biogeochemistry, this study analyzed total soil carbon, soil inorganic carbon and SOC contents in the topsoil across all experimental plots. Our findings revealed that SOC constituted the dominant fraction of the total soil carbon pool, with comparatively low soil inorganic carbon levels. Temporal dynamics showed an initial decrease followed by an increase in the total soil carbon pool over time. While tree richness and mycorrhizal type exhibited limited impact on overall soil carbon pools compared to the effect of time, fast-slow life strategies and mycorrhizal types mediated the influence of tree diversity on soil carbon dynamics. These results underscore the importance of considering tree species diversity and fostering beneficial mycorrhizal symbioses in forest ecosystems to enhance long-term soil carbon sequestration and improve ecosystem resilience. This research offers valuable insights for optimizing forest management and restoration practices aimed at maximizing soil carbon storage.

Towards an Accurate High-Resolution Global Canopy Height Model

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Accurate, high-resolution data on global vegetation height distribution is essential for monitoring Earth's carbon stock, fluxes, and forest ecosystem dynamics. Additionally, the vertical structure of vegetation has been shown to predict biodiversity across various taxa. Given the critical importance of these tasks in the context of climate change and the biodiversity crisis, there is an urgent need for a reliable, high-resolution, and easily updatable global canopy height model (CHM).

Since 2018, two spaceborne laser altimeters, the Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) and the Global Ecosystem Dynamics Investigation (GEDI), have been operational, collecting terrain and surface elevation data with near-global coverage. While ICESat-2 provides general elevation data, GEDI is specifically designed for vegetation mapping. Two global CHMs with resolutions of 30 m (Potapov et al. 2021) and 10 m (Lang et al. 2022) have been developed, utilizing machine learning models to fill gaps in sparse GEDI measurements based on optical satellite imagery. More recently, Tolan et al. (2024) integrated GEDI data with airborne LiDAR to produce a 1 m resolution global CHM. However, our recent comparative study has revealed significant and systematic biases in all of these products, indicating that accurate global mapping of vegetation height remains a challenge.

In this contribution, we introduce an improved method of canopy height modeling based on GEDI and Sentinel data that significantly increases accuracy over existing global models. We further provide a detailed analysis of the factors influencing this accuracy, including the relative importance of different predictors (e.g., optical, radar, or terrain variables). Finally, we discuss pathways for further improvement and demonstrate the method through case studies from three topographically diverse regions.

The influence of dispersal on diversification dynamics in pines

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Dispersal is a key process known to influence both speciation and extinction, but the nature of these relationships appears to be scale- and context-dependent. Dispersal on ecological scales inhibits speciation due to increased gene flow, whereas dispersal across major barriers may increase speciation due to new opportunities for ecological specialisation and radiations. Similarly, low dispersal abilities have been linked to increased extinction rates, yet in meta-populations, high levels of dispersal have also been linked to higher extinction risk due to synchronized population responses. We tested these hypotheses at a macroevolutionary scale in the genus *Pinus.* Using seedmass, dispersal syndrome and plant height as proxies for past dispersal ability, we applied state-dependent speciation and extinction models to assess how dispersal influences diversification in pines. We found that both speciation and extinction rates are lowest at intermediate levels of dispersal. This suggests that speciation and extinction might be correlated at large scales. Low dispersal increases extinction risk, likely due to limited capacity to respond to environmental changes, but may also increase speciation by reducing gene flow and promoting local adaptation. Conversely, high dispersal could provide rare opportunities for speciation in distant environments, but simultaneously increase extinction risk by impeding local adaptation. Our results indicate that intermediate dispersal stabilises diversification dynamics by reducing both speciation and extinction rates.

Simulating management strategies to optimize the climate regulating function of German forest ecosystems

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Forests play a critical role in regulating the Earth's climate through biophysical and biogeochemical processes. While future carbon dynamics have been quantified by a large number of studies, only few simulation studies address other climate regulating services. In this project, we use the individual-based forest landscape and disturbance model "iLand" to simulate forest dynamics and associated changes in multiple climate-regulating services across 14 ecoregions in Germany. Our project is one of the first to simulate an environmental gradient from the warmer and drier lowlands to the colder and wetter mountains, covering all major forest types in Germany. Our simulations also take into account the complex interactions between different forest management strategies, climate change projections and natural disturbances. By calculating net radiative forcing, we can integrate both biogeochemical (carbon exchange) and biophysical (albedo and latent heat) effects to derive effective management strategies tailored to specific forest types and regions. This will help to optimise the future climate regulating function of forest ecosystems beyond current carbon management recommendations.

As we cover all major European forest types, our results will have implications beyond German forestry. By taking into account the complex interactions between forest vegetation, disturbances and climate change, and by simulating the impact of management on multiple climate-regulating services simultaneously, our project represents an important and novel contribution to improving European forest policy and to crediting systems for the valuation of the climate-regulating function of forest ecosystems.

Methane uptake and emission by tree stems depend on tree-internal processes

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Forests play an important role in regulating atmospheric greenhouse gas (GHG) concentrations. While their function as net carbon dioxide sinks through photosynthesis is well established, the significance of methane (CH_4), the second most potent GHG, is often overlooked in forest carbon balances.

Recent research has indicated tree stems contribute to ecosystem CH_4 fluxes by emitting or/ and taking up CH_4. However, it is unclear whether tree stem CH_4 fluxes are entirely microbial, or whether tree internal processes also contribute. To address this knowledge gap, we measured CH_4 fluxes at two stem heights on beech (*Fagus sylvatica*) and spruce (*Picea abies*) during winter and spring 2025. Measurements were conducted at air temperatures ranging from -1° C to +25° C using a custom tree stem chamber coupled with a multi-gas analyser.

At air temperatures close to 0° C, stem CH_4 fluxes were negligible for both tree species. However, *Picea abies* showed significant CH_4 uptake on warm winter days, especially when air temperature exceeded 15 °C. By contrast, no CH_4 fluxes were detected in beech while the trees were dormant – even when temperatures exceeded 15ºC. However, after leaf flush in spring, both species, *Picea abies* and *Fagus sylvatica*, showed net CH_4 emissions.

These findings suggest that tree activity is essential for CH_4 fluxes and seasonal differences in tree internal processes need to be considered. Future research should therefore consider interactions between microbial and tree internal processes to identify mechanisms of CH_4 uptake by forests.

Influence of parent rock on the drought and heat resistance of beech saplings: Water status regulation and embolism resistance of plants originating from sandstone or limestone

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European beech (*Fagus sylvatica L.*), the most abundant tree species of Central Europe's temperate forests, is increasingly exposed to climatic and physiological stresses that exceed its tolerance thresholds. Mortality rates have risen, particularly on shallow soils, due to drought- and heat-induced damage. In this study, we assessed the drought and heat tolerance thresholds of beech at different growth stages (juvenile vs. mature) and from different soil types (lime stone vs. sandstone).

We measured xylem water potential at turgor loss point (Ψ_{TLP}), and the photochemical efficiency of PSII, embolism resistance (Ψ_{50}) and minimum conductance (gmin). Additionally, in a desiccation experiment with potted saplings from both soil types, we measured stomatal conductance (g_s) and xylem twig water potential (Ψtwig) to determine differences in time to critical thresholds.

Soil type had no significant effect on the hydraulic traits overall; however, mature trees from limestone-derived soils exhibited slightly lower Ψ_{TLP} than those from sandstone. Conversely, saplings on sandstone had significantly lower Ψ_{TLP}. Interestingly, mature trees displayed markedly lower gmin and Ψ_{TLP}, and greater embolism resistance (more negative Ψ_{50}), and higher thermal tolerance compared to juveniles. During the desiccation, limvestone-derived saplings maintained gs and high Ψ_{twig} longer and reached critical Ψ_{twig} values later than saplings from sandstone-derived soils.

We conclude that soil type may influence drought and heat acclimation through soil water availability and nutrient supply. Thermal sensitivity likely invloves additional factors beyond transpiration cooling. The pronounced differences in $\Psi_{TLP}$and thermal tolerance between mature trees and saplings suggest that mature trees have a higher acclimation potential than saplings.

In situ analysis of heat tolerance and leaf regeneration of Central European tree species utilizing A-Ci curves

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To mitigate the effect of global climate change on forests, a better understanding of the response of trees to changing temperatures and extreme weather events is vital.Heat tolerance measurements have been predominantly conducted on tropical tree species, and mainly with the dark fluorescence method. This limits our current knowledge to only a small part of the photosystem's performance. In such studies, eaves are also often removed from the plant. Possible leaf-external responses or regulatory elements (hormone, water, or nutrient transport) remain ignored.

In this study, we observe the photosynthetic performance of five important Central European tree species (*Fagus sylvatica, Quercus petraea, Pseudotsuga menziesii, Picea alba, Pinus sylvestris*) utilizing A-Ci curves. In contrast to other methods, this will allow us to gain insight into the response of the Rubisco carboxylation rate (Vcmax) and electron transport rate (Jmax) to heat. A comparison between plants exposed to a simulated heatwave and untreated plants will show us how long-term heat stress affects photosynthetic heat response of chosen tree species. Measurements will also be repeated over time to see if the leaves can return to their usual performance – and at which temperature they experience irreversible damage. An in situ approach furthermore increases comparability with natural conditions.

Scale Matters: How Ground Cover Type Shapes Near-Ground Microclimates in North German Forests

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Microclimate research often relies on measurements at a 2 m screen height—a scale inherently attuned to human experiences. However, this approach may overlook the near-ground conditions that immobile organisms such as small plants, insects, fungi, and bacteria actually experience. By examining how within-stand microclimatic variability is modulated by different ground cover types, our study seeks to unravel the mechanisms that foster niche creation and sustain diverse forest flora and fauna. This perspective becomes even more critical with increasing uncertainty about the capacity of forests to buffer climatic extremes.

Within the WaldPULS monitoring network in Mecklenburg-Western Pomerania, we selected 21 stands across 19 locations for year-long monitoring (March 2024–February 2025). In each stand, three adjacent 2 m² patches representing open ground (vegetation and litter removed), herbaceous vegetation, and tree regeneration were monitored. On each patch we recorded air temperature and relative humidity at 15 cm and soil temperature at -6 cm, while a 2 m reference sensor captured the surrounding forest microclimate.

Summer season data reveals that ground cover significantly influences near-ground microclimates. At midday, open patches recorded soil temperatures about 1 °C higher and up to 6% lower relative humidity, with air temperatures moderately higher (0.1–0.2 °C) compared to vegetated areas. Among the vegetated patches, regeneration areas tended to be slightly cooler than herbaceous covers. At night, open patches remained warm—with regeneration patches 0.3–0.5 °C cooler—while humidity differences persisted (2–3% lower over open ground).

Our findings demonstrate that small-scale variations in ground cover create distinct microhabitats that shape living conditions for ground-dwelling organisms. Recognizing this heterogeneity refines our understanding of forest microclimate dynamics and informs management strategies for enhanced resilience under climate change.

Influence of leaf age, climate and non-structural carbohydrates on foliar hydraulic traits of mature European beech and European ash

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Climate change has increased unpredictability in the incidence of intense drought and heat timing, thereby, increasingly exposing plants to stress. The plasticity of functional traits to these stressors determines their resistance and resilience and is crucial to be understood for designing future forest management activities.

We measured nine hydraulic traits in European beech (*Fagus sylvatica L.*) and European ash (*Fraxinus excelsior L.*). Additionally, we tested how seasonal changes in leaf non-structural carbohydrate (NSC) concentrations drive trait plasticity. Sampling was conducted four times each in 2023 and 2024 in Hainich National Park, Germany.

Leaf age, the number of days since full leaf expansion, was found to be the best predictor for the bulk modulus of elasticity (ε), with older leaves being less elastic. Foliar drought resistance did not increase with progressing leaf maturity. Higher average relative extractable soil water (REW) relieved midday water potentials (Ψ_{MD}). Increases in minimum leaf conductance (g_{min}) and lowered osmotic potentials at turgor loss (Ψ_{TLP}) were associated with higher daily temperature maxima (Tmax). Leaf xylem embolism resistance decreased (higher leaf water potential at $_{50}$ and $_{88}$ % embolism; Ψ_{50}, Ψ_{88}) under a higher evapotranspiration ratio (ET/PET). High amounts of residual variance in linear mixed effect models were attributed to the variability between and within the two sampled species. Overall, we found traits characterizing the initial drought stress response to be more sensitive to seasonal changes in microclimate than those for drought resistance constitution, e.g. Ψ_{88}. A higher availability of glucose over starch coincided with higher Ψ_{MD}, osmotic potentials at full turgor (Ψ_{FT}) and at 12 % embolism (Ψ_{12}) in both species.

Our results show that European ash apparently has a higher capacity to dynamically respond to wet and dry summer conditions with osmotic adjustment and a higher leaf metabolic activity than beech.

Tree diversity increases the diversity of soil nematodes and the density of persisters in a temperate deciduous forest experiment

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While tree diversity declines worldwide, the consequences for soil invertebrate communities remain unclear. Nematodes span all trophic levels and are valuable indicators for soil biodiversity, food web structure, and soil health. Here, we examined the effects of tree diversity on nematode diversity, community composition, and nematode based indices in a tree-mycorrhiza diversity experiment with temperate, deciduous trees. Experimental treatments included tree communities with only arbuscular mycorrhizal (AM) species, or only ectomycorrhizal (EcM) species with (1, 2 or 4 tree species), or a mixture of both (AM+EcM; 2 or 4 species). We found that total nematode density, taxonomic richness, and Shannon-Wiener diversity increased significantly with tree species richness. Moreover, nematode taxonomic richness and Shannon-Wiener diversity were significantly higher in AM tree communities than in the other mycorrhizal treatments. These effects were primarily driven by persisters (K-strategists) rather than colonizers (r-strategists). Additionally, AM tree communities, characterized by acquisitive life strategies, likely supported a more mature and complex soil food web with higher Maturity Index values than EcM communities. However, we only observed additive effects on nematode communities in AM+EcM mixtures rather than synergistic effects of different mycorrhizal types. Our results suggest that tree communities with higher species richness create a more suitable environment for soil food webs with more persisters, characterized by longer life cycles, which contribute to higher soil biodiversity. These findings provide empirical support for increasing tree diversity in forest restoration and management.

Disentangling effects of structural deadwood characteristics on fungal and bacterial diversity and assembly

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Forest ecosystems face increasing demand for wood and threats from global change, forcing forest management into action. However, we still have important knowledge gaps about the ecological consequences of forest management in times of global change. Deadwood is recognized as an important contributor to forest diversity and therefore an essential tool for conservation. Forest management and natural disturbances create complex deadwood structures, but the relative importance of their features for fungal and bacterial diversity has not been quantified.

We experimentally simulated different types of deadwood predominating after disturbance events to test effects on fungal and bacterial diversity and assembly processes using molecular and classical sampling: (i) log residues with soil contact resembling fallen logs or stumps, (ii) uplifted objects without soil contact resembling snags, uprooted logs, or deadwood in the canopy, (iii) debarked deadwood, e.g., due to mechanical removal or abiotic and biotic effects (e.g., insects, sunburn), and (iv) those with intact bark. Deadwood was exposed under open versus closed canopies, resembling canopy disturbance and, thus, strong variation in stand-scale microclimate conditions.

We found that bark retention had stronger effects on microbial alpha and beta diversity than soil contact and stand-scale canopy cover. Debarking increased fungal and bacterial species diversity but decreased fungal fruiting diversity. Molecular diversity responses to bark retention were similar across stand-scale canopy cover levels, except for fruiting diversity. Among treatments, debarking had the greatest effect on assembly processes. Communities within debarked wood were more dissimilar than expected, indicating limiting similarity as the dominant process explaining diverse communities. Deeper explorations revealed that differences in moisture conditions caused the observed diversity patterns.

License to kill – or thrive? Pathways of biodiversity development under different forest disturbance agents

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Forest disturbances change the availability of resources within ecosystems: They create deadwood, change light regimes or erode topsoil providing access to bare mineral soil. A multitude of taxa can use these resources, ranging from herbaceous plants thriving under additional sunlight, over saproxylic beetles, to bees nesting in the opened soil and using pollen and nectar from newly established herbaceous plants. Thus, disturbed forests are considered highly diverse ecosystems. However, the disturbance regime is changing under climate change. Bark beetle disturbances and windthrows are expected to increase, while avalanches will probably decrease within the next decades. Disturbance agents change resource availability in different ways: Windthrows and bark beetle disturbances produce deadwood, while human interventions in disturbed forests reduce the amount of deadwood by salvage logging and avalanches leave low amounts of deadwood in most of their parts. Instead avalanches extensively open the ground, while root plates of trees uprooted by windthrows produce open soil at a smaller scale. These differences in resource availability might have a direct effect on communities which appear after the forest disturbance. To study this effect, we monitored bees, hoverflies, butterflies, grasshoppers, beetles and herbaceous plants in forest gaps caused by windthrows, bark beetle disturbance (salvaged and unsalvaged) and avalanches between 1999 and 2011 in the montane zone of Berchtesgaden National Park. The study design allows us to compare the different disturbance agents regarding their value for biodiversity considering varying resource availability for the surveyed taxa and the effects of management. We expect high topsoil erosion, high deadwood availability and low canopy cover to contribute positively to α- and β-diversity in different disturbed forests. Our results might shed light onto the value of different forest disturbances for biodiversity and help reevaluate management of such disturbances under changing disturbance regimes.

46 years of vegetation succession after a forest fire in Scots Pine plantations - Deciduous forests are making a comeback

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Forest fires have been a rare disturbance agent so far in forests of Central Europe but will increase in frequency and magnitude in the future because of climate change. Coniferous forests such as Scots Pine plantations (*Pinus sylvestris*) will be mainly affected.

Experiences on vegetation dynamics from former burnt sites are rare but will become increasingly important in the future to guide forest management decisions. Here I present a long-term data set from a former burnt site in northwestern Germany. A large forest fire hit the area dominated by *Pinus sylvestris* in 1975 and burnt ca. 8000 ha of forested land. Already in 1976 vegetation surveys on a permanent study site (2.4 ha), left for natural succession, started and have been repeated frequently since then (1977-79, 1981, 1983, 1985, 1987 and 1995). A last re-survey was conducted in 2021, 46 years after the fire event.

A tree layer was first recorded in 1981 and showed a continuous increase in cover and richness with a dominance of the deciduous tree species *Betula pendula* and *Quercus robur.* This indicates a natural succession towards a Betulo-Quercetum. In general, species of deciduous forests dominated over coniferous specialists in all vegetations layers supporting the intended transition to deciduous forests in Germany. The invasive alien species *Prunus serotina* also benefited from the disturbance and should be continuously monitored.

Such long-term studies can give important implications on the succession speed and trajectories after fire events and can inform forest management on suitable future management operations such reforestation.

Reforestation type alters the body size distribution of ground-dwelling predators

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Deforestation is one of the major causes of global change, having a negative impact on biodiversity and ecosystem functioning. Recognition of these adverse effects has led to widespread global reforestation efforts. However, the ecological outcomes of different reforestation strategies remain variable, partly due to limited understanding of how these approaches influence ecosystem processes. Among these processes, the body size distribution within predator communities plays a key role, influencing predation rate, diet composition and intraguild interactions. Investigation of the effect of reforestation management on body size distribution in predator communities may therefore provide insight into how reforestation management affects ecological processes. In this study, we compared the body size distribution in communities of ground-dwelling predators (arachnids, ants, and predatory beetles) in dry evergreen forests and two reforestation types, namely *Eucalyptus* plantations and secondary forests in northeastern Thailand. We found that the body size distribution of predators differed among all forest types. The dry evergreen forests were the most diversified as they hosted large-, medium-, and small-bodied predators. In contrast, the Eucalyptus plantations were largely dominated by small-bodied predators. The secondary forests were dominated by small- and large-bodied predators. The results indicate that reforestation type alters predator-prey interactions by modifying body size distribution in predator communities. Moreover, no studied reforestation has restored the natural body size distribution in the predator community, which has implications for conservation. Effective conservation strategies in tropical Southeast Asia should aim to establish protected areas of pristine forests rather than relying solely on reforestation. The study was supported by the Specific University Research Fund MENDELU (Reg. No. IGA24-FFWT-TP-006).

Mycorrhiza in Tree Diversity-Ecosystem Function Relationships: the first ten years of the iDiv experimental platform MyDiv

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The widely observed positive relationship between plant diversity and ecosystem functioning is thought to be driven by complementary resource use of plant species. Biotic interactions among plants and between plants and soil organisms are suggested to drive key aspects of resource-use complementarity. The young tree diversity experiment MyDiv aims to integrate biotic interactions across guilds of organisms, more specifically between plants and mycorrhizal fungi, to explain resource-use complementarity in plants and its consequences for competition and multitrophic interactions. Our overarching hypothesis is that ecosystem functioning increases when more plant species associate with functionally dissimilar mycorrhizal fungi (arbuscular and ectomycorrhizal fungi). Here, we present an extract of results from the ten nine years of MyDiv. We investigated tree mycorrhization with classical and novel techniques as well as different ecosystems functions ranging from tree productivity to herbivory and energy fluxes through food webs as affected by tree species richness and mycorrhizal type. The studies largely showed that tree species richness and identity effects dominate over mycorrhizal type effects in the early stage of the experiment. Furthermore, tree communities with two mycorrhizal types experienced rather additive effects that were in between that of arbuscular and ectomycorrhizal communities. We showed that plant communities differ in their preferred fungal communities. Overall, the results of the first ten years of the experimental platform reveal strengthening distinct mechanisms of the two mycorrhizal types with time driving life strategies of trees and biodiversity-ecosystem functioning relationships.

Exploring oak-nematode interactions in plant-soil feedbacks

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Our understanding of the intricate relationships between trees and their holobiont partners in the soil community is significantly expanding. Soil biota is intimately connected to the health and adaptation and acclimatation of plants under the threat of climate change and support plants by enhancing nutrient and water availability; however, drought can also alter soil biota composition by favoring drought-resistant microorganisms, whether beneficial or harmful. However less is known about the effect of trophic interactions on these biotic drivers. In particular, nematodes represent a wide range of trophic groups in the soil community, including plant parasites, bacterial and fungal feeders, predators and omnivores, making them an indicator of both direct and indirect influences on tree health.

This study, as part of the PhytOakmeter research unit, aims to quantify the effect of soil biota on oaks and how it regulates belowground herbivores such as root-lesion and root-knot nematodes and its impacts on tree performance. Furthermore, it aims to assess the impact of tree mortality due to severe drought on the soil biotic community. To do this, we are studying *Quercus robur*, a foundation tree species of European forests with highly diverse biotrophic interactions. Specifically, we are growing DF 159 *Q. robur* clones in greenhouse conditions, manipulating soil biota abundance, all of which will be subjected to drought stress conditions, thereby assessing the role of the soil biota, the direct and indirect effects of soil nematodes on tree growth and health in response to global change.

Keywords: plant-soil feedback, soil nematodes, severe drought, tree mortality

Legacy Impacts of Drought: Legacy Fine-Root Biomass Reduction after a four year-long drought experiment in Single-Species and Mixed-Species Arrangements of European Beech and Norway Spruce.

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Extreme weather events such as droughts are increasing both in frequency and severity. This raises questions about long-term impacts on forest ecosystems and the ability of forests to possibly acclimate to repeated drought events. In this study, we investigated the legacy effects of past throughfall exclusion, which was conducted over five growing seasons, on an established experimental site in south-eastern Germany (KROOF: Kranzberg forest roof experiment). To minimize forest vulnerability, we require a better general understanding of legacy impacts of repeated drought events on mature forests, as reductions in fine-root biomass will only be a part of the greater legacy impacts on future stresses.

120 soil cores were taken in late autumn 2024 in a grid like pattern across the experimental plots to a depth of 30 cm. Fine-root biomass and vital root tips (<2mm) were determined for the two target species. Additionally, a deuterium labelling experiment was undertaken.

Even after a 4-year-long drought-recovery period. European beech and Norway spruce showed significantly reduced fine-root biomass per soil core volume compared to controls. Unlike the Norway Spruce, the European Beech was able to establish much more fine-root biomass in the vicinity of neighbouring species.

This suggests recovery trajectories of belowground components might be prolonged or even permanently changed. Considering future climate scenarios, our results indicate the importance of long-term legacy impacts as these are of influence when evaluating recovery and resilience of forests. Furthermore, differently behaving species might be able to make use of niches left behind from neighbours influenced by legacy effects.

We conclude that anisohydric beech trees benefit from the water savings of more isohydric spruce trees during drought, by effectively rooting into the soil under spruce.

Comparing Tree Parameter Measurements Across LiDAR Platforms for Forest Management Planning

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Accurate and efficient forest inventory is essential for sustainable forest management, ecological monitoring, and timber resource assessment. Remote sensing technologies, particularly Light Detection and Ranging (LiDAR), have increasingly become valuable tools for analysing forest structure at both the stand and individual tree levels. This contribution focuses on the use of LiDAR data to analyse structural attributes of European beech (Fagus sylvatica) in an unmanaged mature forest stand in the Spessart, Germany, with the goal of providing LiDAR-derived structural metrics that support and enhance forest inventory operations. To evaluate the suitability of different acquisition methods, LiDAR data were collected using a range of platforms: uncrewed aerial vehicles (UAV), stationary terrestrial laser scanning (TLS), airborne laser scanning (ALS), and a mobile backpack LiDAR system. Each sensor type offers unique advantages in terms of spatial resolution, coverage, and operational feasibility in forest environments. Parameters derived from the LiDAR data include diameter at breast height (DBH), total tree height, stem quality characteristics according to the German framework agreement for roundwood trade ("Rahmenvereinbarung für den Rohholzhandel", RVR), and wood volume. The LiDAR-based estimates are validated against comprehensive field measurements to assess accuracy and operational applicability. A central objective of the analysis is to segment individual tree stems into log sections and estimate their economic value using the RVR classification standards. By combining sensor comparison with tree- and stem-level analysis, this study provides insights into the strengths and limitations of various LiDAR platforms for high-resolution, economically oriented forest inventory applications.

Tools for Tomorrow: evaluating expert-based Decision Support Systems and Dynamic Forest Models

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Rapid climate change presents major challenges for forest management, highlighting the need for robust Decision Support Systems (DSS). While many forestry DSS are expert-based and static, Dynamic Vegetation Models (DVMs) may offer additional insights concerning species shifts under changing environmental conditions, but they are rarely used as DSSs. We compare a static tool (TreeApp) with a DVM (ForClim) across 30 Swiss forest stands spanning a wide environmental gradient, under current climate conditions and scenarios of mild to severe climate change. We assess (1) how consistently the two tools predict equilibrium species composition under present and future climates, (2) how quickly these changes are likely to unfold throughout the 21st century according to the DVM, and (3) how the climate space of forest site types in the Swiss National Forest Inventory aligns with future conditions at the 30 sites, as projected by TreeApp.

Under current climate, both TreeApp and ForClim yield broadly consistent species distributions. However, under severe climate change (RCP8.5), TreeApp and ForClim diverge markedly. TreeApp projects strong shifts in dominance towards drought-tolerant species in the absence of marked reductions of summer precipitation. In contrast, ForClim—through its mechanistic treatment of climate–soil–plant interactions—yields gradual transitions and often retains less drought-tolerant species, which appears more plausible.

Our results underscore the need for caution when using static, analogy-based DSS like TreeApp in climate-adaptive forest management. DVMs such as ForClim, by capturing essential ecological processes, may offer more reliable insights on forest responses to climate change. Ultimately, this study supports the integration of process-based approaches in forest management planning for a more robust, proactive response to an uncertain climatic future.

Do different types of disturbance lead to different pathways of forest reorganization?

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Disturbances are expected to increase in frequency and severity and are catalyzers of forest change. The reorganization phase after disturbances determines future forest trajectories. To better understand forest reorganization, we studied regeneration dynamics of disturbed montane forests in Berchtesgaden National Park. We focused on disturbance events that occurred between 1999 and 2011, analyzing disturbances caused by wind, bark beetles and avalanches. To contrast natural post-disturbance forest development with trajectories in managed forests we also included bark beetle disturbances that were salvage logged and planted with *Abies alba* in the analysis. We hypothesized that the different disturbances have distinct patterns of disturbance legacies, particularly varying in their impact on top soil and deadwood. We expect the highest amounts of deadwood on wind and bark beetle disturbances, with lower values in avalanche tracks and on managed sites. Furthermore, we expected the maximum top soil disturbance on avalanche tracks and windthrown areas, while bark beetle disturbances do not affect the top soil. We expected that different disturbance agents and their distinct legacies alter post-disturbance forest reorganization. Specifically, we expect the highest regeneration diversity in structure and composition after disturbances with an intermediate disturbance to the topsoil (I) and an increasing regeneration density with increasing levels of downed deadwood (II). We also hypothesized that post-disturbance management results in a post-disturbance forest development trajectory that differs significantly from unmanaged forest development (III). Overall, our results provide insights into the effects of different disturbances on forest development, and highlight the importance of disturbance legacies for forest development. Our study highlights that altered disturbance regimes in response to changing climate and management can substantially reorganize forest ecosystems.

Towards a new categorization of the anatomical structure of lenticels

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Bark is among the least studied components of a tree, in particular the outer bark, i.e. the periderm and rhytidome [1]. This is despite the importance of bark for overall tree function and survival, which has largely been overlooked until a recent revival of interest e.g. [2-4].

Recent research in tree physiology focuses not only on leaf and wood hydraulics but also on empirical estimation of water loss and water uptake via periderm and eventually the lenticels, e.g. [5-6]. Potential regulatory mechanisms in lenticels for bark transpiration and liquid water uptake remain, however, an enigma [4]. In order to understand functional aspects of lenticels, we intend to investigate their design and also the anatomy of the tissues beneath them. Lenticel structure has been so far analyzed only in ~0.1% of the ~73,000 globally existing tree species and - regarding the high variability in bark anatomy [2] – we need to gain greater knowledge on how conserved lenticel types are within monophyletic clades in order to understand their functional aspects.

Within the frame of the project “Smart Bark”, the anatomical lenticel design of ~200 different tree species will be histologically analyzed and thereafter tested if the categorization of [7] in three lenticel types holds true or if this classification needs fine-tuning according to potential functional aspects.

By gaining more knowledge on the structural variability of periderm and lenticels, we expect hints on potential opening and closing mechanisms and on bark porosity for water vapor and liquid water.

From the garden to the forest – How evergreen neophytic shrubs invade deciduous forests in southwest Germany

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Evergreen, non-native shrubs such as cherry laurel (*Prunus laurocerasus*) are popular garden plants in Central Europe. However, such plants are not restricted to their intended planting locations. Some species are often found to spread beyond gardens into forest areas. There, they have the ability to form a dense understory, dominating the shrub layer and possibly exerting negative effects on other organisms. So far, information on the occurrence of these species is however scarce, thus making it difficult to evaluate their impact.

To find out more about the distribution, abundance and population structure of evergreen neophytic shrubs and the environmental factors that influence them, we performed an extensive field study in deciduous forests near settlements across Baden-Württemberg. At 80 sites covering different winter hardiness zones, all evergreen neophytic shrubs, including also Bambusoideae, were recorded and their height and cover was measured within a 1-ha plot located at the forest edge and along a 500-m transect leading into the forest. Stem samples from the thickest individuals were collected to gain information on population age.

In total over 6000 individuals of 12 species of evergreen neophytic shrubs were recorded, occurring at 73 of the 80 sites. On 45% of all sites more than three species were recorded. The most common species were *Prunus laurocerasus* (76% of all recorded plant individuals), *Mahonia aquifolium* (16%) and *Viburnum rhytidophyllum* (7%). In the next step, we will assess the influence of climatic factors on distribution, abundance and age structure.

This study documents the high abundance and range of the three most common species. Given the extent of their occurrence, it is crucial to investigate possible negative effects on native flora and forestry species, which will be done in subsequent steps of our project. The findings of this regional study are relevant for large parts of Central Europe and beyond.

BorFIT and POINTR: LiDAR-based Individual Tree Detection and Multi-Sensor Data Fusion to Reveal Northern Boreal Forest Structure Changes

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Forests are vital carbon sinks, absorbing and storing significant amounts of atmospheric carbon and partially offsetting human emissions. However, climate change is increasing stress and disturbance to forests worldwide, especially in northern boreal ecosystems. This region is experiencing rapid environmental changes, leading to shifts in biomass distribution, the spread of broadleaf species into former stands, as well as rising tree mortality, fires, droughts, and pest outbreaks. Forest development and health are reflected in their 4D structure-the spatial and temporal organization of trees-which indicates condition, functionality, biodiversity, and evolution.

Our BorFIT forest structure benchmark dataset contains more than 16000 individual trees that were manually segmented and assigned a species using machine learning based on UAV LiDAR transects from expeditions to Alaska, NW-Canada, and Eastern Siberia. BorFIT, enables training AI models to detect and classify individual trees within LiDAR point clouds from Northern Boreal forests, assigning each tree a species label. We will upscale tree-level forest structure and species to 3D forest structure maps, which serve as reference data for radar (SAR) data. By upscaling AI-driven tree identification with radar remote sensing, we can enable more accurate large-scale mapping of forest structure.

We plan to extend 3D forest structure maps to 4D by using radar time series, to track structural changes over time and to identify early warning signals of changes. Furthermore, we will collect and integrate UAV point cloud data (LiDAR and Structure from Motion (SfM)) from other researchers across the circumboreal region to build a comprehensive database, enabling representative, detailed forest inventories at a large scale.

Effects of irrigation on declining forest stands in the Hessian Ried

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Groundwater-influenced forest sites are increasingly threatened by anthropogenic alterations to the hydrological cycle, compromising forest ecosystem services. In the Hessian Ried, Germany, long-term groundwater abstraction and land-use changes have caused a persistent decline in groundwater levels, leading to significant losses in tree vitality, reduced productivity, and increased mortality across numerous forest stands. To assess the potential of irrigation as a management strategy for the restoration of historically wet forests affected by drought, we conducted a field experiment (2021–2024) in a protected Sub-Atlantic oak-hornbeam forest (FFH habitat type 9160), examining how temporary surface irrigation during the growing season affects aboveground tree traits and ecosystem-level responses.

Improved tree vitality was observed in the irrigated plots compared to the control, while negative legacy effects of the record-hot and dry 2022 growing season in the control remained evident in tree vitality during subsequent wetter years. Pedunculate oak (*Quercus robur L.*) and European hornbeam (*Carpinus betulus L.*) showed reduced defoliation, increased leaf area index, delayed autumn leaf senescence, and increased stem diameter growth in irrigated plots. The tree response to irrigation was particularly pronounced in the dry year 2022, but even in wetter years 2023 and 2024, the positive effects of irrigation on tree vitality status remained evident. At the ecosystem level, irrigation caused a decrease in tree mortality by 23 %, while species composition of the ground vegetation remained unchanged so far.

In this experiment, we showed a short-term improvement in tree vitality in the Hessian Ried. However, long-term studies are needed to determine whether the irrigated plots can achieve enhanced resilience and to what extent temporary irrigation contributes to the sustainable stabilization and revitalization of damaged groundwater-influenced forests.

Drivers of foliar fungal endophyte communities in subtropical forests

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The phyllosphere comprises the tissues and the surface of plant leaves and their microbiomes. Despite its ecological significance, the factors shaping foliar endophyte communities and their interactions with trees and shrubs remain largely unexplored. Here we use the biodiversity-ecosystem functioning (BEF) research platform BEF-China, where trees were planted in a broken-stick design along a tree diversity gradient. The aim of this study is to elucidate the composition of fungal and bacterial communities in the phyllosphere of shrubs, as a function of tree diversity in the local neighbourhood, and to disentangle the underlying drivers, such as leaf traits of the host tree, direct spillover effects of microbes from heterospecific neighbours and negative density effects of conspecific neighbour species, as well as indirect effects of neighbour tree composition via microclimate. Using leaf surface sterilization followed by next generation sequencing, the Internal Transcribed Spacer 1 (ITS1) rRNA gene region and the 16S rRNA gene region were analysed for fungal and bacterial communities, respectively. We hypothesized that [H1] the removal of epiphyllous microbes through surface sterilization has a major influence on the microbial community structure of the phyllosphere, because of a prevalence of microbes on the outside of the leaves. Furthermore, we expected that [H2] the tree neighbourhood diversity has a strong effect on the foliar microbial community composition and diversity, due to spillover and dilution effects. Finally, we expect that [H3] neighbourhood tree species richness increases the stability of the microclimate for shrubs, due to a denser canopy and increased structural diversity. There was evidence in support of all our three hypotheses, which reveals the complex interplay of different drivers in phyllosphere community assembly, which directly or indirectly depend on the local diversity of host trees.

Productivity and Ecophysiological Responses of European larch (Larix decidua Mill.) under Alpine Conditions

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Climate change is expected to impact photosynthetic productivity of European larch (*Larix decidua Mill.*), a key species of the European alpine ecosystem, with largely unknown consequences. To better understand such effects, we identified and investigated environmental differences among larch trees exhibiting high and low photosynthetic activity.

Fieldwork was conducted in July 2024 within the treeline ecotone of the southwestern European Alps at three sites, two in France and one in Italy, with altitude ranging from 2150 to 2500 m a.s.l. Porometer and fluorometer measurements were taken on 150 larch trees alongside microclimatic readings. Composite topsoil (0-5 cm) was sampled to assess belowground conditions around sample trees. Based on a light-saturation threshold of 800 μmol m-2 s-1 and light use efficiency (ΦPSII), trees were classified into four response groups defined by the relationship between electron transport rate (ETR) and incoming solar radiation: (i) light limited, (ii) light and other limited, (iii) light saturated, (iv) limited by other factors.

Across the four classes, we found that elevation, soil water content (SWC), vapour pressure deficit, tree height, soil and leaf temperature, and soil C:N ratio significantly ($p < 0.05$) differed, suggesting their potential role in modulating photosynthetic performance. Using a linear mixed-effects model, we further identified significant ($p < 0.05$, R2 = 0.32) effects of SWC, leaf temperature, and tree height on ETR, with noticeable contribution of random variable (site-level) to model variance. These findings suggest the important role of local site conditions in shaping tree physiological responses under current climate conditions of the alps.

We conclude that soil water content and leaf temperature are critical determinants of larch photosynthetic activity of trees in the alps, both of which are highly sensitive to ongoing climatic changes.

Adaptive responses of Fraxinus excelsior seedlings under ash dieback: Reciprocal transplantation between forest stands with differing dieback severity

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Ash dieback continues to threaten the future of European ash (*Fraxinus excelsior*) in forests across Central Europe. While breeding tolerant ash genotypes is a key conservation strategy, natural selection within forest ecosystems may also drive adaptive responses. To investigate evolutionary dynamics and local adaptation under pathogen pressure, we conducted a reciprocal transplant experiment with natural ash rejuvenation from forest stands differing in dieback severity.

In 2020, we collected ash seedlings from ten (formerly) ash-rich forest sites in Northern Germany - five severely damaged and five moderately damaged stands. Seedlings were reciprocally transplanted back into all sites at four planting densities and three replications per site, allowing for the assessment of origin and target site effects.

After four years, 75 % of transplanted ash were still alive. Survival declined significantly at higher planting densities, indicating density-dependent mortality. Leaf necrosis occurred in 48 %, but stem necrosis only in 7 % of seedlings. Notably, stem infection was associated with reduced growth, whereas leaf necrosis correlated with increased growth, suggesting a possible tolerance strategy or resource reallocation response. In general, seedlings originating from severely damaged sites were more likely to show ash dieback symptoms, yet exhibited higher survival and growth than seedlings from moderately damaged sites. Although these trends are apparent overall, they are only significant within a given target stand damage class, e.g. seedlings from severely damaged stands survive significantly better than seedlings from moderately damaged stands when planted in severely damaged forest stands.

These patterns suggest context-dependent local adaptation under pathogen pressure. Our results provide early evidence that natural regeneration may contribute to evolutionary resilience in ash, with implications for in situ conservation strategies under ongoing disease pressure.

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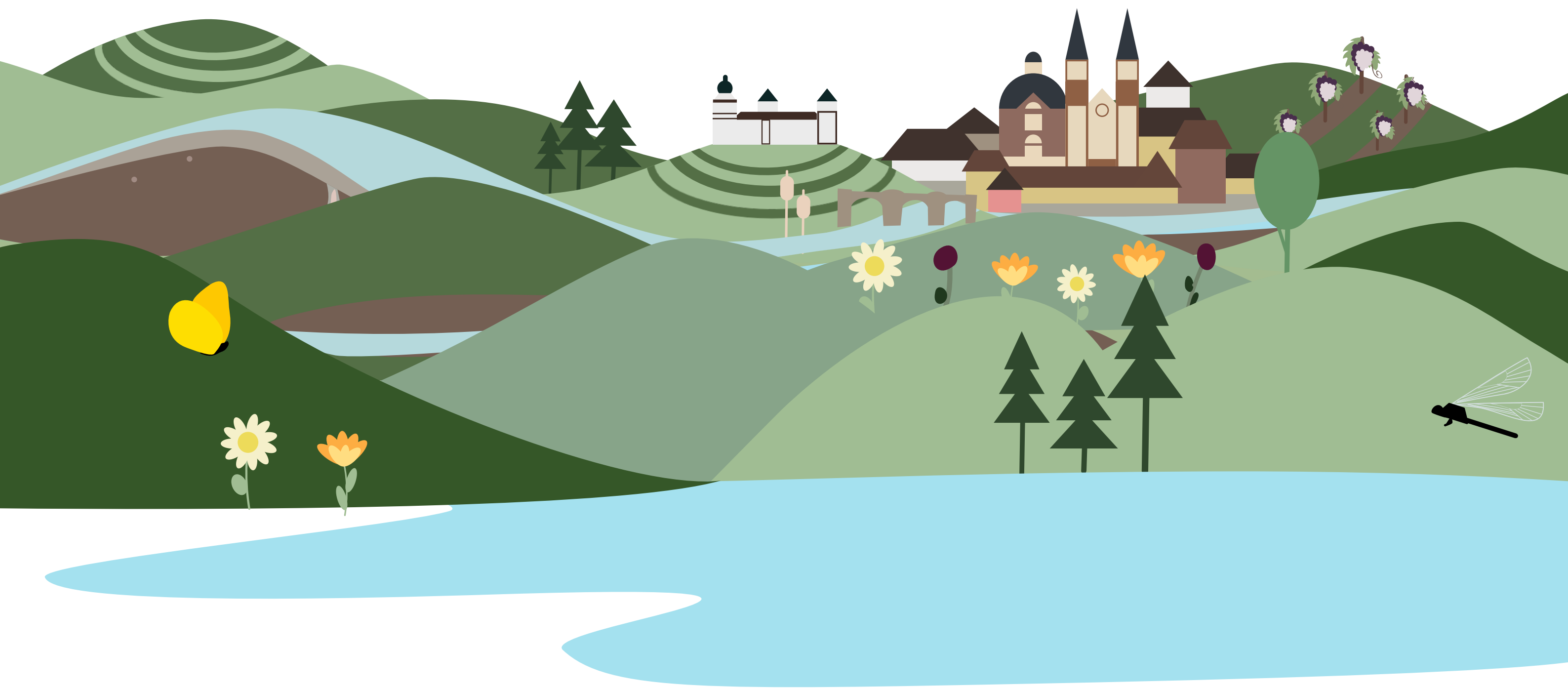
Insects and other animals



Designing flowering strips: maximising pollinator gains and minimising weed risks

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Designing effective flowering strips to reconcile agricultural productivity with biodiversity conservation remains challenging, as their success depends on balancing pollinators, weeds, and cost-effective long-term maintenance. This study aimed to identify optimal seed mix compositions for flowering strips to maximise pollinator benefits and ensure plant community stability.

Over three consecutive years (2022–2024), we monitored pollinator communities (bumblebees, butterflies, hoverflies), evaluated flowering resource availability, and surveyed vegetation composition at 17 intensive arable fields distributed across eight agricultural regions in the Czech Republic. Each strip was divided into six segments sown with seed mixes consisting of varying proportions of a commercial flower mix ("basic") and an enriched, grass-rich mix ("enriched": 0%, 10%, 20%, 40%, 60%, or 80% grass content).

Our findings demonstrated that all flowering strip mixes significantly enhanced pollinator abundance and species richness compared to crops, with flowering strips playing an especially crucial role in sustaining bumblebee populations even at low nectar levels. Grasses in the seed mix promoted greater overall plant species richness while suppressing the cover of noxious weeds.

Our study indicates that flowering strips incorporating moderate grass proportions (~40%) compromise long-term stability and nectar provision, serving as a basis for designing more durable flowering strips.

Spatio-temporal patterns of oligolectic bees, their food plants and interactions in Baden-Württemberg

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Worldwide species richness declines over time due to habitat loss, fragmentation and climate change. This decrease is well documented in insects and plants, and more abrupt in species with specialised foraging niche. However, the decline in the context of species interaction still remains poorly explored. To overcome this, we used data from long surveys assessing temporal changes (pre- versus post- 2000) and drivers of different facets of interactions of oligolectic bees and their plant hosts in the state of Baden-Württemberg, Southern Germany. To establish the regional species pool and built a plant-pollinator metaweb, we used records from the floristic mapping of Baden-Württemberg and records from Wildbienen-Kataster and Stuttgart Staatliches Museum für Naturkunde collection for bees distribution. The data is spatially organised in grids of 6 km by 6 km covering the whole state. Local webs were defined based on plant-bees spatial and temporal co-occurrence for the two-time blocks. We calculated the network properties for local webs for assessment of changes in taxonomic richness and interactions as well as the environmental drivers of these changes over the time spatially explicitly. Overall, we found there is an increase in species richness over time which is also observed in modularity of the networks. Further, the other properties of interactions remained invariant. We used all bioclimatic variables plus topographic and anthropogenic as predictors of changes in the taxonomical and interactions properties and found that temperature is the main predictor of changes in diversity. Habitats used to be colder are nowadays more suitable to species occurrence, while the warmest areas going on the other direction being out of optimal occurrence niche of oligolectic bees. Additionally, our results highlight the importance to assess interactions, since they do not necessarily follow the same pattern as taxonomical diversity.

Pollen genotyping reveals that fewer than half of honey bee visits can cross-pollinate a self-incompatible crop

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More than 60% of plants are pollen limited. Pollen limitation occurs when insufficient pollen, or the wrong genotype of pollen, reaches the stigma. Many studies have investigated the pollination efficiency of flower visitors, looking at the amount of pollen deposited during a single visit or their on-flower behaviour. The genotypes carried as pollen have rarely been identified, although many crops depend on or benefit from cross-pollination rather than self-pollination. Cross-pollination occurs when pollen from a genetically different plant is deposited on the stigma, which in many crops means that pollen has come from another cultivar.

We developed a method that detects SNPs in the pollen carried by single bees, using a customised single allele base extension reaction (SABER) with MassARRAY, to distinguish genotypes that contribute only a small fraction to a mixed-genotype pollen sample. We used this method to identify the cultivars of pollen carried by honey bees at increasing distances from a cross-pollen source in two multi-cultivar macadamia orchards, one with wide and one with narrow single-cultivar blocks.

We found that many honey bees carried exclusively self-pollen in both orchard designs, one where single-cultivar blocks were 5 rows wide and another where the single-cultivar blocks were more than 40 rows wide. Only 30–53% of honey bees carried cross-pollen, representing the maximum that potentially contributes to crop production in self-incompatible crops. Distance from a cross-pollen source did not significantly affect the proportion of honey bees carrying cross-pollen.

This study demonstrates significant potential to increase the effectiveness of honey bees as pollinators. Orchards can be re-designed to interplant cross-pollen sources and maximise the number of honey bees contributing to crop production. Improving pollination effectiveness will help to alleviate the growing shortfall in the supply of beehives required for crop pollination.

eBeam as an alternative to gamma-irradiation for sterilization of navel orangeworm (A. transitella) used in sterile insect technique

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Navel orangeworm (*Amyelois transitella*) is a major pest on pistachios, almonds and walnuts in California. There, it causes massive losses in revenue for growers, not only by destroying crops (up to 30 % of total yield is possible) but also by higher management costs. Californian growers have spent 471 million USD in 2022 alone on conventional navel orangeworm management, which includes orchard sanitation and pesticides.

As part of an integrated pest management program, a sterile insect technique program focused on navel orangeworm is being developed and implemented in California. Navel orangeworm are mass reared, sterilized with a gamma-irradiator and then deployed to threatened areas, where they are supposed to mate with wild individuals and not produce offspring, therefore reducing the overall population.

Since the use of a gamma-irradiator carries inherent risks, dangers and additional costs, the US government is seeking alternatives to phase out gamma irradiators all around the country. Recently, electron beams have also moved into the spotlight since they operate on similar principles and are already in use to sterilize all kinds of goods in large quantities.

In this presentation, we want to show the effects of eBeam (electron beam) sterilization on flight ability, longevity, mating ability, fecundity and fertility of navel orangeworm. These are important factors in determining if the sterilized navel orangeworm are competitive in the field and can mate with wild individuals as intended.

We found that eBeam irradiation was able to reduce fertility by 100 % at doses of 200 Gy or higher for females and 300 Gy or higher for males, while not affecting any other parameters for both sexes. This shows that eBeam irradiation can be a viable alternative to gamma-irradiation for the sterilization of navel orangeworm.

Selective attractiveness: The effect of different wavelengths of artificial light on nocturnal insects

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Artificial light at night (ALAN) is among the fastest-growing forms of environmental pollution and poses a serious threat to biodiversity, especially to arthropods that perceive light as a key ecological cue. Negative impacts of ALAN include altered behavior, disruption of physiological rhythms, and shifts in community structure, with varying sensitivity among arthropod taxa depending on light wavelength. To effectively mitigate ALAN impacts, it is crucial to understand how specific spectral ranges affect different taxonomic groups. In a field experiment conducted at five sites in the Czechia we tested the attractiveness of six types of precisely predefined LED lights (360–410, 410–460, 460–510, 510–560, 560–610 and 610–660 nm, equal intensity of emitted light) arranged along 50 m transects to nocturnal arthropods. During the 2023 season (March–November) each site was visited eight times. Using standardized conditions, we aimed to determine which wavelengths are most attractive to nocturnal arthropods and how responses vary among groups. The highest numbers of individuals were captured at lights below 460 nm, while the fewest were recorded above 560 nm. However, responses varied considerably among taxa – some showed strong preferences for shorter wavelengths, whereas others displayed high positive phototaxis across broader spectral range. Notably, some groups (e.g. Lampyridae) were more attracted to longer wavelengths. These differences suggest that reducing short wavelengths in public lighting may significantly lower insect attraction, though such measures may not suit all arthropod groups.

Bumblebee immunity: investigating the role of personal and social immunity

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Social insects evolved complex immune strategies that balance personal and collective immunity. While honeybees and ants engage in well-documented hygienic behaviours, little is known about how bumblebees (*Bombus spp*.) respond to injuries. Preliminary observations in commercial *Bombus terrestris* colonies suggest that injured individuals do not receive wound care from nestmates, raising the question if bumblebees compensate for the absence of social wound care with enhanced personal immunity or if they are more vulnerable to injury.

To test whether this is a general trait or an artifact of commercial breeding, leading to lower pathogen exposure, we will compare commercial *B. terrestris* colonies with those reared from wild queens. By analyzing large hymenopteran datasets, we will investigate whether injuries occur in the wild and correlate with sociaity. Survival experiments will reveal how injuries and infections affect individuals in isolation and within colonies, revealing the role of the social environment in recovery.

Understanding how bumblebees cope with injury will help clarify the evolutionary trade-offs between personal and social immunity in social insects. If bumblebees rely primarily on individual defenses, this suggests that social wound care is not a universal consequence of group living but an adaptive trait shaped by species-specific ecological pressures.

Evolution and physiological constraints of ant leg amputation

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Ants frequently suffer injuries during foraging or competition, exposing them to high infection and mortality risks. To deal with these threats, some ant species perform wound care behaviors. Megaponera analis for instance treat infected wounds using antimicrobial secretions from their metapleural glands. Others, such as some Camponotus species, which lack the metapleural gland, have been observed to reduce injury mortality by amputating infected legs instead.

We hypothesize that wound care strategies depend on species-specific morphological and physiological traits. Predatory ants, such as many ponerines, possess thick cuticles for protection but relatively weak bite force. As a result, they may be physically incapable of amputating legs and instead depend on antimicrobial treatment. In contrast, species with stronger mandibles but lacking chemical defenses may have evolved amputation as a mechanical alternative.

In this project, we investigate the evolutionary and morphological basis of ant leg amputation. Using micro-CT scanning, we create detailed three-dimensional models of head musculature across several German ant species, with a focus on the muscles controlling mandible movements, as a proxy for bite force.

This morphological and physiological data is then linked to behavioral observations of wound care behaviours: while Formica cf. rufibarbis, Tapinoma sp. 1, Lasius alienus, and Tetramorium sp. 1 exhibit amputation behavior, Lasius fuliginosus does not. By comparing species that perform amputations with those that do not, we aim to identify specific muscle configurations, mandible forms, or size thresholds that may enable or constrain leg amputations.

Our findings will contribute to a better understanding of how morphology and physiology interact to complex social behaviors in ants, offering insights into the evolutionary pressures shaping cooperative health care in ant colonies.

Effect of plot-level Tanacetum vulgare (Tansy) chemotype richness on interacting insect communities

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Plant interaction with their environment is heavily mediated by plant chemistry. Differences in plant chemistry are observed inter- but also intra-specifically, indicating that two plant individuals of the same species within the same population can show differences in their interactions with their living environment. Several studies have shown the role of intraspecific plant chemical diversity in shaping of specific groups of interacting insect communities (e.g. pollinators and herbivores), however, very few studies look - more holistically - at the entire insect community. We hypothesized that increasing plant chemical diversity and chemotype richness increases overall insect diversity whilst having varying effects on the abundance of different insect groups (e.g. positive effects on pollinators and other plant beneficial insects, negative effects on herbivores). *Tanacetum vulgare* (Tansy) exhibits high intraspecific variability in the compounds, blends and (relative) abundances of terpenoids. In a Tansy chemodiversity experiment in Jena, Germany, in which 84 plots were planted with six Tansy chemotypes combined in different proportions (plot level chemotype richness), we sampled the above ground insect community in each plot by vacuum suction in a net cage in August 2024. We observed that total insect abundance and diversity was not affected by plot-level chemotype richness. However, the abundance of some specific insect orders i.e. Nematocera increased with increasing plot level chemotype richness. We show that though Tansy chemodiversity and chemotype richness affects the dynamics of specific insect groups, it is not a major driver of insect diversity and abundance at community level.

Seasonal differences in ant diversity in a West-African forest-savannah mosaic

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Tropical biodiversity studies have traditionally focused on forest habitats, even though savannahs account for approximately 20% of the tropical landmass and are more heterogeneous, endangered and diverse than previously assumed. One such complex habitat is the forest–savannah mosaic, which dominates the Comoé National Park in Côte d'Ivoire. This mosaic consists of three primary habitat types: island forests, gallery forests, and the surrounding savannah. In this study, we aimed to investigate ant diversity and its seasonal variation across these habitats, and to determine whether certain ant species shift their habitat preference between seasons - To assess not only taxonomic but also functional diversity, morphological traits were measured for all collected morphospecies. The ants were systematically sampled during both the dry and rainy seasons using 300 pitfall traps. Across both seasons, a total of 122 ant species belonging to 25 genera and 5 subfamilies were identified. Our results reveal significant differences in species composition among the different habitats and between the two seasons. The rainy season generally supported higher species richness, particularly in the savannah habitats, likely due to increased resource availability and foraging activity. These results show the role of seasonal dynamics, habitat heterogeneity, and species adaptability in influencing both the taxonomic and functional structure of ant communities.

The potential of passive acoustic monitoring in solar farms - methods & recommendations for bird surveys

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Passive acoustic monitoring (PAM) in ecology is rapidly increasing and promises to be a time and cost efficient survey tool. This trend is driven by decreasing price of acoustic recording units (ARU), rapid software development, often with open access (f. e., BirdNET), and more efficient data storage possibilities. PAM is already a well-established method for species and habitats with difficult access or cryptic behaviour (e.g., bat species, nocturnal bird migration).

Today, solutions for many obstacles exists to apply PAM in new habitats and research fields. However, ARUs differ in their record quality, which is dependent on the taxa and habitat of application. One new application possibility of PAM are bird surveys in solar farms due to the increasing demand on green energy and the difficulties of standard bird surveys in this habitat (f. e., access, blocked view by solar panels). Though, only few studies exist on the influence of solar farms on bird species and evidences on the possible effects of solar panels are needed to evaluate the impact of this land-use change, especially for species of conservation concern. However, knowledge and recommendations regarding the use of ARU in solar farms and open grassland are lacking.

We studied the influence of solar panels at ground-mounted solar farms with grassland habitats on the quality and detection rate of bird songs recorded by ARUs and compared it with the ARU application in open grasslands. We conducted a playback experiment in eight solar farms in northern Germany: we used 22 AudioMoth devices (ARU) and recorded the playback of 11 bird songs from species selected based on their possibility to use solar farms as habitat, their song frequencies, sound structure and volume. We used a set of three commonly used cases of AudioMoth devices (original case, self-made cable sockets, plastic bag, no case). The ARUs where placed at different distances and heights and recorded simultaneously the playback. Here, we present first results and recommendations for the bird surveys with AudioMoth in solar farms.

Vertical Stratification of Beetle Diversity in Native and Non-Native Temperate Forests

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Forests are complex three-dimensional ecosystems where organisms are distributed along horizontal and vertical gradients. While forest floor communities have been extensively studied, the vertical stratification of arthropods, particularly beetles, in temperate forests remains underexplored. A better understanding is crucial, as beetles contribute to essential ecosystem processes like nutrient cycling, litter decomposition, and food webs. Additionally, their status as conservation targets makes them valuable for biodiversity research. With climate change driving biodiversity loss and forest diebacks, adaptive forest management strategies, including the introduction of non-native, drought-tolerant tree species, are gaining importance. However, the ecological impacts of such tree species on forest biodiversity are poorly understood.

In this study, we investigated the effects of monocultures and mixtures of native European beech (*Fagus sylvatica*) forests with economically important conifers — non-native Douglas fir (*Pseudotsuga menziesii*) introduced from North America and Norway spruce (*Picea abies*), planted outside its natural range — across 40 temperate forest plots in northwest Germany. We analysed beetle communities' vertical stratification across three strata (ground, understorey and canopy), considering environmental factors and forest structure data.

Our findings reveal that beetle assemblages respond differently to stand type across vertical strata, with canopy communities being more influenced by stand characteristics than those in the understorey and ground. This study underscores the importance of integrating vertical stratification and forest structural data in biodiversity assessments and demonstrates how beetles from multiple functional groups can reveal the diverse impacts of non-native tree species on forest arthropods, driven by habitat complexity in temperate forests.

Monitoring of solitary hymenopterans in artificial trap nests by citizen scientists at golf courses

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Conventional methods for assessing the abundance and species diversity of hymenopterans often rely on lethal trapping techniques, which pose ethical and ecological challenges. This study presents a non-lethal approach using trap nests covered with transparent films. This method enables Citizen Science Volunteers (CSV) without taxonomic expertise to contribute to biodiversity monitoring. This study is part of the project GolfBiodivers, which focuses on the ecological enhancement, monitoring and communication of biodiversity on golf courses. The research questions examine the ecological impacts of previously implemented habitat enhancements on golf courses. Methodological hypotheses focus on identification accuracy and the participants' knowledge gains. The goal of our study is to expand the amount of data and simplify data collection while simultaneously raising awareness of biodiversity among golf club members. A key objective is to investigate how the enhancement measures influence the species diversity and nesting behavior of wild bees and wasps. An aspect of the study was assessing the CSVs' prior knowledge through a questionnaire before data collection, followed by a follow-up survey measuring knowledge gains and increased awareness of biodiversity. On twelve golf courses, six trap nests were installed at each location and monitored monthly by CSVs from April to August. Volunteers photographed the trap nests, identified species using an app, and uploaded the data to a central platform for validation. Preliminary results indicate that species can be reliably identified using the app, with identification accuracy improving as the monitoring progresses over the months. Additionally, initial trends suggest an increase in the number of brood cells compared to the previous year when no enhancement measures had been implemented. Moreover, an increase in participants' knowledge is anticipated, contributing to broader ecological awareness both on and beyond golf courses

Effects of species-rich mixtures of grass clover leys on pollinators

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Grass/clover leys are cultivated for various reasons. In organic farming, legumes are mostly used for nutrient supply and soil improvement, but they can also provide further ecosystem services. In particular, various forage legume species could serve as abundant food resources for pollinators, but this potential may currently not be fully exploited.

We investigated how a more diverse ley species mixture may affect pollinators. Sampling was carried out 2022 - 2024 in three on-farm trials in Bavaria by collecting pollinators every 3-4 weeks (May - September); transects were walked for 30 minutes, actively collecting insects using a hand-held net.

Results confirm a positive effect of the species-rich mixtures on flower visitors compared to a red clover dominated reference mixture. Especially, flowering of crimson clover in May had a positive effect on the abundance of pollinating insects.

Influence of Flowering Legume Species on Pollinator Diversity Across Three Organic Farm Sites in Germany

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Pollinators support food production but face major declines due to habitat loss, pesticides, and climate change. Organic farming can help counter these effects via pollinator-friendly practices. The FINDIG project investigates if diversification in green fallows (rotational grass-clover leys) promotes pollinators, identifies key plant species, and evaluates ecological and economic benefits of extensification of such leys.

This study explores two questions:

1. Does species richness of legumes and pollinators differ between diversification treatments?

2. Is there a correlation between pollinator and flower counts across sites?

Three organic research farms were studied: Kranzberg, Neuhof, and Hohenkammer. We established two treatments: 1) "Reference" (3 grasses + 3 legumes); and 2) "Diversity" (7 legumes, 6 herbs, 3 grasses). From May to September 2022, floral and pollinator diversity were assessed. Floral resources were recorded using a 0.25 m² Göttingen frame, distinguishing blooming vs. non-blooming plant species. Pollinators, including honey bees, bumblebees, hoverflies, butterflies, and wild bees, were surveyed in 30-minute transects per treatment. Weather conditions including temperature, wind speed, and whether it was cloudy or not,were also documented. Results indicate that flower diversity positively affected pollinator diversity in organic systems.

A world on every plant: plant derived eDNA reveals fine-scale arthropod community structure in grasslands

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The decline of arthropod populations has been strongly linked to the loss of plant diversity in grassland ecosystems. Even the disappearance of a single plant species can result in the loss of numerous specialized arthropod species. To better understand this dynamic, it is essential to study plant–arthropod interactions at a detailed level. However, such interactions are often difficult to detect, as they typically require direct observation of individual plant visits. Environmental DNA (eDNA) offers a promising alternative approach. In this study, we assess the potential of plant-derived eDNA to capture the fine-scale structure of arthropod communities in German grasslands. By collecting eDNA from 13 plant species, we compare community composition both between plant species and between different plant parts (flowers vs. vegetative tissue). Our results demonstrate that eDNA can reliably detect highly detailed community patterns. Both plant species identity and plant compartment significantly shape arthropod community composition, with particularly strong effects observed for herbivorous taxa. These findings suggest that terrestrial eDNA is deposited very locally, making it a powerful tool for resolving fine-scale ecological patterns. Given the high specificity revealed by our approach, we highlight the importance of incorporating detailed vegetation surveys into future arthropod monitoring programs.

Exploring climate-related gut microbiome variation in bumble bees: An experimental and observational perspective

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Rising temperatures affect bumble bee fitness directly through physiological stress and indirectly by disrupting key mutualisms with plants and microbes. Gut microbial symbionts, vital for host health and nutrition, may be a potential bottleneck in bees' thermal responses due to their own temperature sensitivity and role in mediating plant and pathogen interactions. To assess environmental impacts on microbiomes, we analyzed gut bacteria in six bumble bee species from varied elevational niches in the German Alps using 16S rDNA amplicon sequencing. We first examined whether differences in microbiomes align with species' elevational ranges, which vary in temperature, floral resources, and likely pathogen loads. A reciprocal translocation of *Bombus terrestris* and *Bombus lucorum* between climatic zones assessed short-term microbiome changes. Additionally, bees were subjected to cold and heat wave scenarios in climate chambers to isolate temperature effects. We found that interspecific microbiome variation exceeded intraspecific differences. Microbiome stability (lower within-group variance) was higher in species from lower elevations, while higher-elevation species showed greater variability. Translocated bees displayed minor but consistent microbiome shifts, notably increased Lactobacillaceae in warmer sites, whereas lab temperature treatments did not alter the microbiome. Our results suggest that microbiome composition and stability vary by species and elevation, potentially influencing resilience to climate change. Less stable microbiomes at high elevations may reflect greater pathogen sensitivity, while species like *B. lucorum* and *B. terrestris* may better cope with change by integrating new microbes quickly.

Disentangling and mapping the drivers of butterfly community assembly across space and species

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Community assembly results from a complex interplay of species sorting, dispersal, biotic interactions, and stochastic processes. While substantial progress has been made in understanding these processes at the metacommunity scale, the specific contributions of individual species and sites remain poorly understood. In this study, we applied a joint species distribution modelling framework (JSDMs) to disentangle the spatial, environmental, and biotic drivers of butterfly community assembly across Switzerland. We further evaluated whether species' functional traits can predict their contributions to these processes. Our results reveal clear spatial signatures in community assembly mechanisms at the country scale and demonstrate that functional traits can help explain species- and site-specific contribution to biodiversity patterns. These findings highlight the variability in species responses to biotic and abiotic factors and underscore the predictive potential of trait-based approaches. Insights like these contribute to a better understanding of biodiversity patterns and may help inform conservation and landscape management strategies at larger spatial scales.

Elevation and land use gradients drive food web structure and trophic connectivity

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Species—in their search for food—move through landscapes, linking other species and multiple habitats in a complex flow of energy and material which begets many ecosystem functions. To investigate how environmental gradients and habitat fragmentation influence food web structure and multi-species connectivity, we constructed 18,099 catchment-level food webs across Switzerland using a combined species distribution model and metaweb approach. We additionally develop a metric to quantify trophic connectivity by integrating species movement costs with their trophic dependencies. Our results show that food web properties such as species richness, modularity, food web diameter and the fraction of apex species vary along land use and elevation gradients, with interactions between elevation and human impact further shaping food web structure. We found that habitat fragmentation was driven primarily by an inverse elevation-human footprint gradient. Additionally, trophic connectivity was revealed to be driven by biotic (species richness, modularity), abiotic (land use intensification, precipitation) and structural connectivity (core area of habitat, proximity to urban areas) variables. These findings highlight the need for conservation strategies that go beyond preserving habitats only for singular species. It is essential to also account for the complex interactions between species and their environment to maintain biodiversity, ecosystem connectivity and functionality in fragmented landscapes.

Variable drivers shape ant diversity at different elevations

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Given the dramatic impacts of climate change on biodiversity and ecosystems, it is fundamental to be able to predict the response of species to such changes. Investigating species richness patterns along altitudinal gradients over time is crucial in this regard, as they provide long-term and large-scale data on how species track climatic change and which strategies they develop. Ants are particularly valuable in this sense, being quasi-sessile, common in many ecosystems and with different ecological functions. Here we assessed ant species richness patterns along an altitudinal gradient and their changes over the years, and aimed to disentangle the role of the potential drivers. Ants were sampled with pitfall-traps along an elevational gradient from 250 to 1450 m in the Bavarian Forest in 2006 and 2016.

After 10 years, temperatures were higher at low altitudes and lower at high elevations, while canopy cover increased its tendency to drop at very high elevations. Ant species richness was higher at the lowest and highest altitudes but not in the middle of the gradient. At low elevations it was positively correlated with the increase of temperature registered over the years, while going up along the gradient this driver progressively lost importance and at high elevations ant diversity was only negatively correlated with canopy cover regardless of the year. The shift of the species over time was heterogeneous, with species from lower altitudes tending to shift downwards (according to their thermophilic nature) and those from higher altitudes moving upwards and occurring under increasingly open canopy.

Our results highlight the complexity of the environmental effects of climate change, with different drivers affecting ant communities at different elevations.

Interplay of edge effect and light pollution on nocturnal insects inferred from light trap catches – a case study in the National Park Donau-Auen (Austria).

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Wild and domesticated pollinators are facing global declines caused by the synergy of different anthropogenic factors. For nocturnal pollinators, artificial light at light changes the natural light environment across the globe. Fragmentation and artificial light at night tend to occur in parallel when natural landscape transforms to agricultural or urban structures. We explored the responses of nocturnal insects on light traps at the margin of the floodplain forest in the National Park Donau-Auen in Central Europe, Austria. Specifically, we examined the abundance and biomass of nocturnal insects and described the community composition and diversity of moths with respect to the local habitat. During the study, 58 species were observed with 21 unique records on the forest edge and 9 unique records on the interior. On the contrary, moth assemblages tended to be more diverse at the edge sites. We attribute this to the high number of singletons indicating that the edge might act as an ecological trap, where individuals of species were attracted from the surrounding areas. Surprisingly, nine species (15.5% of the total) represented unusually late records of moths that have their main flight period in summer. We interpret this finding as a consequence of ongoing climate change, with ever warmer periods occurring in autumn. Overall, we observed higher moth species diversity on the forest edge while insect biomass and abundance of moths were higher within the forest. This can have several long-term consequences on the local communities, ranging from altered populations to an expansion of specific species. Together with synergistic effects of climate change, it seems even more urgent to consider light pollution as a potential evolutionary driver in future community focused studies.

Opposing body mass responses to competition of two mass-asymmetric species

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Body size, as a fundamental trait and a key component of species fitness, is influenced by multiple environmental factors. Most studies have focused on how body size responds to environments, yet the biotic environment organized by competitors themselves is often overlooked, despite its important role, particularly in size-asymmetric competition. In this study, we examined the effects of intraspecific and interspecific competition on offspring body size in two common *Drosophila* species. Using a mesocosm experiment, we manipulated the density of parental *Drosophila melanogaster* and *Drosophila immigrans* (which is approximately 2.5 times larger than *D. melanogaster*) to establish a response surface experimental design.

Our results revealed that for the larger *D. immigrans*, intraspecific competition primarily constrained body size by reducing per capita resource availability through increasing total offspring number. In contrast, interspecific competition promoted body size by shortening developmental time. The reduction in *D. immigrans* body size maintained a constant per capita reproductive output. Meanwhile, for the smaller *D. melanogaster*, intraspecific competition had negligible effects on body size, while interspecific competition with *D. immigrans* imposed a slight positive impact. However, this positive effect did not imply weaker competition but rather resulted from opposing pathways affecting *D. melanogaster* offspring via per capita reproductive output and developmental time.

Overall, our findings demonstrated how size-asymmetric competition asymmetrically influences body size in competing species and exerts differential effects on distinct fitness components. Furthermore, asymmetric competition can shape species' life-history strategies, highlighting the evolutionary significance of interspecific competition.

Automated Acoustic Monitoring of Bird Communities Along the Vjosa River: A Tool for Conservation Planning

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Passive acoustic monitoring is an increasingly valuable method in biodiversity research, yet its use in conservation remains limited—particularly in biodiversity hotspots such as the Balkans. This study evaluates the potential of AI-assisted acoustic monitoring for bird conservation in the Vjosa River National Park, one of Europe's last free-flowing rivers. We assessed the accuracy of AI-based species identification compared to field observations, examined how bird functional traits influence classification accuracy, and explored temporal niche overlap to understand mechanisms of species coexistence. Bird recordings and field surveys were conducted in parallel during the breeding seasons of 2023 and 2024, generating over 1,000 hours of audio and circa 10000 individual bird observations. Species were identified using the BirdNet deep learning algorithm, with classifier performance validated against manual records. Results showed strong agreement between automated and manual species lists, with acoustic monitoring detecting additional species missed during field surveys. Species with frequent and distinctive vocalizations were classified with higher accuracy, whereas smaller, less vocal species received lower confidence scores, indicating trait-based detection biases. Temporal niche analyses revealed that riverine specialists and species from adjacent habitats exhibited distinct activity patterns, reducing interspecific competition and supporting species coexistence. These findings demonstrate the potential of AI-assisted acoustic monitoring as a scalable, non-invasive tool for biodiversity assessment, providing valuable support for long-term bird monitoring and evidence-based conservation strategies in ecologically sensitive regions.

Keywords: Passive acoustic monitoring, AI-assisted bird identification, functional traits, temporal niche overlap, biodiversity assessment, Vjosa River, national park

Linking niche dimensions: Changes in the trophic and multidimensional stoichiometric niche of detritivores along an altitudinal gradient

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Knowledge on a species' trophic niche is critically important for understanding species diversity and ecosystem functions. Nitrogen (N) and carbon (C) stable isotopes are effective tools for characterizing trophic niches, but may be complemented by multidimensional stoichiometric niches. However, the potential of combining two different niche frameworks remains little explored, especially in belowground communities. Here, we combined stable isotope analysis and multidimensional stoichiometry to analyze the niches of five functional groups of soil detritivores (millipedes) across an altitudinal gradient from 800 to 1850 m on Changbai Mountain, northeastern China. The results indicated significant differences in litter-calibrated ^{13}C and ^{15}N values of millipedes with increasing altitude, reflecting changes in the use of basal resources and trophic positions. These variations were closely related to changes in litter element concentrations. Additionally, element concentrations of millipedes reflected shifts in their trophic position and nutritional status, with primary decomposers exhibiting higher concentrations of calcium and elevated ^{13}C values. Overall, our study highlights that combining stable isotope analysis with multidimensional stoichiometry offers a powerful approach for elucidating the complex interactions in soil food webs, thereby enhancing our understanding of biodiversity and ecosystem functions.

The state of insect communities in Switzerland: The INSECT project

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Insect decline has become a major concern in recent years, with several studies showing strong declines in insect richness, abundance, biomass or distribution over just a few decades or even years. As more studies are published, it is becoming increasingly clear that temporal trends are highly dependent on the ecosystem, time period or taxonomic group studied. A multi-faceted approach is therefore needed to assess the state of insects. The INSECT project uses such an approach by integrating data from different ecosystems, time periods and taxonomic groups to assess the state of insect communities in Switzerland. Before 1980, the range of many butterfly and beetle species shrank considerably, with agricultural mechanization playing a major role. While forest-dependent beetle species have recovered their ranges in recent decades, many butterfly species remain rare compared to their distribution in the 1930s. Since the 1980s, communities of several insect groups, such as butterflies, moths, beetles and dragonflies, have undergone significant compositional changes. Many of these changes can be attributed to the acceleration of climate warming over the past 45 years. Warm-adapted species have expanded, while cold-adapted species have declined or moved to higher elevations. At the same time, specialist species tend to remain rare or continue to decline, indicating the continuing threat of past and ongoing habitat loss. Based on several insect community datasets with different temporal and spatial coverage, we present first insights from the INSECT project into the state of insect communities in Switzerland.

Projected climate and land-use change impacts on habitat suitability of British bumble bees

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Bumble bees are among the most important pollinators in temperate regions, but many species have suffered from range declines over the last few decades or are predicted to decline in the future. Agricultural intensification and the associated loss of habitats have been identified as major drivers of the observed dynamics, amplifying pressures on bumble bee populations from a changing climate. While there is evidence of the climate impact on bumble bee population and range dynamics, the impact of land-use decisions, agricultural management and associated consequences on pollination services at large scales is highly uncertain, mostly due to an insufficient representation of land-use and land management and their relation to bumble bee habitat in existing models. Here, we take a step on improving the representation by integrating high-resolution correlational habitat suitability models with land-use/management information from the CRAFTY-GB agent-based model. We use machine-learning methods to map CRAFTY-GB land-use and land-management information to CORINE land cover, which allows us to provide projections of the European land system based on the CORINE legend and project the future habitat suitability for British bumble bee species under various socioeconomic and climatic developments. Preliminary results show that the future habitat suitability for British bumble bees is more sensitive towards climate than land-use change. However, land-use impacts seem highly variable across species and scenarios, while especially the habitat of rare species tends to be disproportionally affected by changes in future land use. Higher-resolution land-use information and integrated modeling of land-use and climate effects therefore seems a promising way ahead to improve the understanding of the impact of land-use decisions on bumble bee populations and their associated pollination service, thus supporting the design of effective conservation policies.

The role of water temperature and food availability in shaping immunity and body condition of Odonata: Impacts of deprivation on larval development

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Global climate change and intensified human activities significantly impact aquatic ecosystems, including dragonflies, whose life cycles and physiology are closely linked to the quality of the freshwater ecosystem and to environmental conditions such as water temperature and food availability. While changes in distribution and abundance are well documented, physiological responses to anthropogenic stressors remain less understood. Dragonfly larvae, as key freshwater predators, may respond to these stressors in ways that influence their condition, growth, and immune function, which are crucial factors for their survival and interspecific interaction.

In this ex-situ laboratory study, we examined the effects of water temperature and food availability on *Aeshna cyanea* larvae by measuring their body condition and immune function. For two months, larvae were reared at either 21 °C or 17 °C. Within each group, half were fed three times weekly, while the rest received food only once per week to simulate food shortage.

Higher water temperature negatively affected several fitness traits, including fat content and immunity, highlighting the potential risk of climate warming for aquatic insect populations. Food deficiency further reduced fat content and body size. Although the combination of higher temperature and higher food supply promoted rapid growth, it came at the cost of weakened immunity and reduced body condition, suggesting a trade-off between growth, immunity, and energy storage under thermal stress. A significant interaction between temperature and food availability indicated that sufficient food could mitigate temperature-induced immune suppression.

These findings provide insights into how environmental stressors shape larval performance during a critical stage of development - knowledge essential for understanding dragonfly declines and improving freshwater habitat management.

Resource over-exploitation lead to endangerment of the extremely philopatric ringlet butterfly Erebia pronoe glottis

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A mark-recapture study of the subspecies *Erebia pronoe* glottis in the Pyrenees was conducted to survey its ecological demands and characteristics. An area intensively used by beekeepers and shepherds was studied. Population structure analysis revealed a small population of low density. Significant differences between both sexes were found in population density (males: 48/ha; females: 23/ha), sex-ratio (2.1) and behaviour (75.4 vs. 20.5% flying). Both sexes used a wide range of nectar plants (Asteraceae, 40.6%; Apiaceae 34.4%; Caprifoliaceae 18.8%). Despite the wide range of nectar plants, the available resources did not seem to allow for greater abundance. Compared to an extensively used pasture, a significant increase in flight behavior, but not in range, was observed. Movement patterns show the establishment of home ranges, which significantly limits the migration potential, which was low for both sexes (male: 101 m ± 73 SE; female 68m ±80 SE). A sedentary species such as *Erebia pronoe* does not seem to be able to avoid the pressure of resource shortage by migration. As a late-flying pollinator, *Erebia pronoe* competes seasonally for scarce resources. These are further reduced by grazing pressure and exploited by the superior competitor *Apis mellifera*, resulting in low habitat quality and abundance.

How do landscape diversity, management, pollen diet and microbial composition influence mason bees' health in apple orchards?

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Organic farming practices can promote the abundance and diversity of bee pollinators that provide essential pollination services to wild plants and crops. However, biodiversity benefits of organic farming largely depend on the landscape context. But the underlying mechanisms why bee populations benefit from organic farming or increased landscape diversity are yet not well understood, including their nutritional status or bee health.

Our project aims to investigate the health status of solitary bees in apple orchards in middle Saxony, Germany. As a model system, we focus on wild cavity-nesting solitary bee species of the genus *Osmia* which are important pollinators in apple orchards in central Europe.

We analysed direct and indirect effects of landscape diversity and farming practices, on different indicators of bee health. Bees were recorded from nesting aids that were placed in 15 conventionally and 15 organically managed apple orchards located along a landscape diversity gradient. The nesting aids were located in the center and at the edge of the orchards. During apple bloom, we sampled pollen to investigate the bees' diet based on ITS2-metabarcoding. We recorded the sex ratio, number of offspring, body size and reproductive success of about 200 *Osmia* nests.

Preliminary results suggest that landscape diversity promotes *Osmia* reproduction in conventional apple orchards. We observed that more brood cells were built in conventionally managed orchards within an increasing landscape diversity gradient than in organically managed orchards.

Our study contributes to a better understanding of mechanisms that determine bee reproduction and bee health in managed agricultural landscapes. Ultimately, the findings can guide farmers and conservation authorities to informed decisions affecting agricultural practices and nature conservation interventions.

The Bumblebee Challenge: A potential treasure trove of bumblebee-plant interaction data in Germany

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Bumblebees (*Bombus* spec.) are key pollinators of wild plants and crops, but their populations are declining worldwide. To better understand the development of bumblebee populations at national level, large-scale data collections including Citizen Science (CS) approaches have been implemented in recent years (e.g., https://wildbienen.thuenen.de/). Among them, the Bumblebee Challenge (BuC) provides unstructured data from app-mediated casual observations (ObsIdentify by Observation International) of bumblebees feeding on plants, with voucher photographs of all observations being validated by experts. Here, we aimed to evaluate plant use and preferences by bumblebees in agricultural landscapes of Germany, and explore the stability of these patterns in BuC data of 2022 and 2023.

To present bumblebee–plant interaction networks, we constructed pairwise interaction matrices at different taxonomic resolutions, and applied a bipartite network approach to quantify species-level roles and temporal shifts in network structure. Sampling completeness analysis ensured that observed patterns reflect sufficient interaction coverage for robust ecological inference.

Initial results indicate consistent associations between *Bombus* species and aggregates with wild plants from the tribe Cardueae and the genera *Centaurea, Cirsium*, and *Trifolium,* suggesting them as key floral resources in agricultural landscapes. Network metrics indicate relatively stable bumblebee communities between years, with a small increase in modularity and specialization, and a decrease in evenness in 2023. This might reflect changing community structure or resource use, such as shifts in flower availability, bumblebee activity, or phenology. Our preliminary results show that the BuC is not only a remarkable tool to record bee species, but also biological interactions for a better understanding of pollination dynamics in agricultural landscapes at national scale.

Investigating identification techniques and sample sizes effect on soil nematode community assessment

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Nematodes are abundant and diverse in soil, and they can influence microbial community composition, plant performance, and nutrient cycling, serving as vital bioindicators for soil ecology and health. While metabarcoding techniques have become highly standardized in the identification of microbial (i.e., bacterial and fungal) communities, similar techniques are still under development for soil animals. As metabarcoding techniques become increasingly popular for characterizing soil animals, establishing protocols that are adapted to larger-bodied organisms is necessary. To optimize nematode metabarcoding workflows, we assessed how different identification techniques and soil sample sizes influence community composition estimates.

We compared three identification techniques: traditional morphological identification, and two molecular methods based on either nematode-extracted DNA (“nematode soup”) or total soil DNA. Each technique was tested across varying soil sizes. DNA was amplified using nematode-specific 18S rRNA primers (Nemf/18Sr2b) and sequenced on an Illumina MiSeq platform. Sequencing data obtained from different protocols were filtered, trimmed, merged using the DADA2 pipeline, followed by taxonomy assignment using the PR2 reference database.

Our results demonstrated that both sample size and identification technique significantly influenced estimates of alpha and beta diversity. Nematode soup technique yielded the highest taxonomic richness but also greater variability across replicates. Larger soil input volumes generally increased richness while reducing variability, regardless of technique. This study serves as a guide for the selection of appropriate protocols in soil nematode metabarcoding studies.

Deep dive into nectar measurements

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Nectar, the sweet liquid plants produce primarily in flowers, is important for a plethora of insects in their (adult) life. It is one of the driving forces that shape pollination interactions and thus a valuable resource for plants. As nectar is highly attractive to many flower visitors, including non-pollinating ones, flowers have developed a vast range of shapes that restrict nectar consumers. Ensuring that spent energy is allocated to “beneficial” flower visitors. This range of adaptations, often morphological, also makes it hard for researchers to collect nectar in a standardized way. This becomes even more apparent, when comparing the few records of broader sets of nectar measurements. We set out to develop a nectar sampling protocol applicable across most plant families by testing and comparing different methods to collect nectar. We additionally tested if treatments, i.e. bagging, watering before the nectar extraction affect the measured volume and the sugar content of nectar.

All plants were collected on the university campus Weihenstephan to encompass a diverse set of native plants. We compared measurements of various plants to provide a set of guidelines. These will help to collect nectar from various plant families as standardized as possible and include newly developed, 3D printable, lab ware that assists in nectar extraction.

We aim for a set of protocols that will not only help to extract nectar for different applications in plant science, but also provide a broad dataset of samples collected, extracted, and measured in controlled and standardized conditions.

Changes in Cuticular Hydrocarbons (CHCs) in Alpine Bumblebees Along an Elevational Gradient

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Bumblebees are among the most important pollinators in mountain ecosystems and play a central role in the pollination of numerous plant species. However, climate change is increasingly putting cold-adapted species under pressure, as their thermal niches are shifting. Possible responses of bumblebees to rising temperatures include adjustments in the composition of cuticular hydrocarbons (CHCs), which are essential components of the insect cuticle. CHCs protect insects against desiccation and participate in chemical communication within and between species. The CHC composition is highly variable and can be shaped by both phenotypic plasticity and genetic adaptation. In this study, bumblebees were collected along an elevational gradient in the Alps to examine the extent to which CHC profiles of alpine bumblebees change with altitude. First, species of the collected bumblebee workers from the various elevation zones were identified, then their CHC profiles analyzed and compared both intra- and interspecifically. Our results show that CHC profiles are largely species-specific, but some elements of the CHCs, such as the proportion and chain length of saturated compounds, show a nuanced intra-specific trend along the elevational gradient. This study provides key insights into the adaptive capacity of chemical traits in alpine bumblebees in response to climatic change. If CHCs exhibit high plasticity along the elevational gradient, this could enhance the adaptability of alpine bumblebee species and reduce their vulnerability to climate change.

Cuticular hydrocarbons in mountain dwelling male bumblebees

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Bumblebees are vital pollinators in mountainous ecosystems. They are well suited to inhabit these environments, with their short active vegetation periods and cold temperatures, because they are cold adapted. This might be facilitated through certain traits, such as large body size, hairiness and cuticular hydrocarbons (CHCs). Here, we compared body size and the cuticular hydrocarbons between bumblebee males collected along an elevational gradient of 714m - 2032m a.s.l. in the Alps. We used males because they permanently leave the nest to search for potential mates and are therefore more exposed to the environment. Consequently, they should be well acclimatized to these conditions. Our results reveal that body size differed between the two species and slightly decreased with elevation. There was a species specific pattern for the cuticular hydrocarbon profiles and the proportion of saturated and unsaturated compound classes. The variation in classes only slightly decreased with elevation. This study provides key insights into the CHC profiles in male bumblebees. Given that the role of CHCs in social insects is two-fold, by protecting the insect from desiccation and by facilitating communication within species, the latter might be more important for male bumblebees and CHC responses to climate constrained.

Local adaptation to high elevation in East African honey bees (Apis mellifera)

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Species inhabit ecosystems and habitats where abiotic and biotic conditions meet their needs to ensure survival and reproduction. Individuals of the same species can exhibit different traits due to local adaptation, either by phenotypic plasticity and/or by fixed genetic changes. Elevation gradients at high mountains are interesting study sites, because they show rapid changes in temperature, humidity and solar radiation with increasing altitude. The Western honey bee (*Apis mellifera*) with its more than 30 subspecies is nearly globally present and occupies diverse ecosystems. To investigate local adaption connected to elevation, we collected honey bees from two different elevations at Mt. Kenya in East Africa: 1,100m ASL (dry savannah) and 1,900m ASL (montane forest). In bees from high and low elevation, we compared pigmentation and cuticular hydrocarbon (CHC) profiles. Looking for molecular correlates for adaptation to elevation, we investigated octopamine signaling in bees from different elevations. Octopamine is an important neurotransmitter involved in thermoregulation. Honey bees from high elevation were generally darker compared to those from low elevation. Although, the CHC profiles showed a complex pattern across elevations, a transfer experiment of hives indicates that CHC composition might change in response to environmental conditions. Intriguingly, bees at high elevation had higher octopamine titers in the brain and differed in their octopamine receptor mRNA expression from bees at low elevation. Our study suggests complex elevation-dependent differences in pigmentation, composition of CHCs and neurotransmitter signaling contributing to local adaptation in East African honey bees at elevation gradients. This makes them excellent models for studying adaptation and acclimatization to elevation.

Towards a One-Way Exit for Cavity-Nesting Hymenoptera in Nesting Observation Blocks: Prototypes and Challenges

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Despite their ecological importance for pollination of wild plants and crops and for natural pest control, long-term data on cavity-nesting wild bee and wasp populations remain limited.

Nesting observation blocks (NOBs) are wooden boards with cavities of various sizes that serve as nesting sites. They represent a widely used method to study diversity, abundance and phenology of overground cavity-nesting wild bees and wasps as well as their antagonists. Thus, they serve as a suitable method to be used in citizen science monitoring programs.

Due to the philopatric behaviour of many wild bee species, the females prefer to build their nests in the same cavity from which they emerged. This could cause an artificial increase in brood cell numbers within a NOB over time. To prevent the formation of artificial populations at monitoring sites, NOBs must be unavailable for recolonization after the emergence of overwintering bees. This also enables non-invasive sampling of residual materials such as faeces and pollen. These materials can provide high-resolution taxonomic data and insights into plant resource use through techniques like eDNA metabarcoding.

In most ecological studies, NOBs are emptied using lethal methods such as freezing, which is unsuitable for citizen science-based monitoring programs. We therefore developed a non-lethal approach to prevent recolonization while meeting key criteria: (1) maintaining a stable microclimate within the cavities, (2) accommodating all cavity-nesting insects, and (3) ensuring low cost and maintenance for scalability.

To meet these needs, we designed a fabric attachment for NOBs that is both water-repellent and breathable. Light is allowed to enter only through a single opening to leverage bees' natural phototactic behaviour. Over a three-year period, we tested and refined various exit designs. Here, we present our prototypes, share practical challenges, and highlight key findings from the development process.

Poster Session 42

Macroecology and modelling

Exploring Regional Insect Trends: A Macroecological Approach

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Biodiversity loss is a main driver of global change and “insect decline” one of its current hot topics. Despite numerous studies, we are still lacking a clear identification of the causes and their relative importance, as well as regional variation and the effect of habitat protection measures. While there are many studies on very large or very small areas facing these topics, few address actionable spatial units and long-term trends for various insect species.

Here, we will outline my doctoral project that will narrow this gap. Utilizing a long-term dataset (> 30 years) from a state-owned insect monitoring database I will employ spatially explicit occupancy modelling to (1) capture the regional variation of insect trends at the species level. Further, I will try to (2) explain these insect trends with habitat variables such as remote sensing-based land coverage, climate data, and management tools like protected areas.

By understanding the influence of these habitat variables, (3) future insect trends can be modelled, using existing land cover and climate models. The insights gained from this research not only advance the use of spatial occupancy models for biodiversity research methodologically but also provide crucial insights for practical conservation efforts at the regional level.

Estimating effects of microbial functional diversity on carbon cycling in marsh ecosystems

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Numerical ecosystem models intend to project carbon turnover and storage under different environmental conditions to investigate feedbacks between carbon cycling and climate. Microbial processes that govern soil organic carbon formation play a crucial role for understanding biogeochemical cycles within soil systems. However, the explicit representation of microbial processes as well as their complex community structure in ecosystem models is still in need of improvement. Here we focus on the role of microbial functional diversity for carbon fluxes in marsh ecosystems. Wetland ecosystems, such as the Elbe Estuary and its marsh soils, represent important carbon sinks. Estimating potential changes in microbial community composition with theoretical and process-based models is therefore useful for bridging the gap between biodiversity and ecosystem functioning. Incorporating functional diversity is well established in vegetation models and is the methodological basis for the project. Diversity is based on multiple microbial functional types that vary in their traits. The simulated microbial community develops population dynamics based on the environmental conditions, which leads to selection of certain functional types. This allows predictions of the abundances and potential shifts in the community structure. The parameter values are derived from empirical data and a specifically developed experimental approach that investigates microbial growth and uptake kinetics.

This process-based modelling approach aims to answer the research question on the role of functional diversity in relation to carbon dynamics in marsh soils of the Elbe estuary by comparing carbon dynamics in the model with and without explicitly modelled microbial functional diversity. The findings of the study are expected to enhance projections of soil organic carbon storage in wetland ecosystems as well as emphasizing the role of microbial functional diversity for ecosystem carbon dynamics.

Microbial physiological traits in complex environments: a crossroads for SOC fate projections?

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The quantitative understanding of microbial physiological roles in microbial-explicit soil organic carbon (SOC) models has been limited, primarily focusing on microbial carbon use efficiency (CUE) in relation to SOC storage. To improve this understanding, it is crucial to explore underlying processes such as microbial respiration and growth, which directly influence both SOC loss and sequestration. In this study, we synthesize global data on CUE, alongside microbial growth and respiration measurements via 18O-microbial DNA growth, revealing significant variations across biomes. CUE was found to be lowest in forests and highest in the temperate zone. Additionally, the ecosystem-specific nature of microbial respiration, growth, and CUE suggests that microbial growth and respiration are more strongly influenced by the amount of microbial biomass carbon and SOC, while CUE can be decoupled from or even negatively correlated with SOC quantity. The observed negative CUE-SOC relationship indicates that CUE is more strongly driven by the quality of soil organic matter. For example, biomes with wet-dry conditions support fast-cycling systems but exhibit lower CUE due to resource inefficiencies. Therefore, to refine our understanding of CUE's role in soil ecosystems, we define microbial CUE as the ratio of microbial growth to carbon uptake (growth plus respiration). This highlights that CUE is directly shaped by microbial growth and respiration, rather than solely by external factors. Shifting the focus, it is more insightful to explore how respiration and growth are co-regulated, rather than concentrating solely on external drivers of CUE.

The mangrove-saltmarsh ecotone: Explaining observed vegetation patterns with a new modelling approach considering plant-soil-water-feedback

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(Sub)tropical coastal wetlands often consist of mangrove and saltmarsh habitats, where mangroves are usually located in the lower, regularly flooded zones close to the sea, and saltmarsh plants in the upper, dryer and hypersaline zones. The transition between these two habitats, the so called "mangrove-saltmarsh ecotone", is characterised by multiple feedbacks between local abiotic factors and vegetation. We hypothesize that these feedbacks result in characteristic vegetation patterns that are reflected, for example, in the sharpness of transition between the two habitat types. While models exist to describe the dynamics of these two habitat types separately, an integrative approach that accounts for both mangroves and saltmarshes and their interactions with their biotic and abiotic environments does not exist. In the absence of an integrative model, we are missing a mechanistic understanding of ecotone vegetation patterns and their dynamics, including future variability under global change. To address this knowledge gap, we build on the hybrid process-based simulation tool pyMANGA that describes feedbacks between vegetation and subsurface hydrodynamics. This tool has already been successfully used to reproduce the typical zonation of mangrove forests. We extend the pyMANGA simulation to model potential saltmarsh habitat, which requires the description of both saltmarsh plants and the unsaturated soil conditions in which they are often found. Our final model describes the complex interactions between saltmarsh plants, mangrove shrubs, mangrove trees and soil water, simulating the entire mangrove-saltmarsh ecotone. It allows us to systematically investigate the emergence, persistence and temporal shift of different ecotone patterns under changing hydrological conditions. Here, we introduce the model concept and provide a proof of its suitability by presenting a case study of a mangrove-saltmarsh ecotone in Parà, Brazil.

MIGRAZE - An individual-based model of ungulate migration systems

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Understanding the dynamics of migratory systems under global change is essential for effective land use and conservation planning. MIGRAZE is an individual-based ecological model designed to simulate the interactions between ungulate migration and food availability in semi-arid regions. Here, focussing on the wildebeest. The model is based on the Serengeti–Masai Mara ecosystem, where approximately 1.3 million wildebeest migrate annually, following opposing gradients of grass biomass and nitrogen content. MIGRAZE integrates this behaviour by simulating herd-based movement using the stochastic movement simulator (Palmer et al. 2011) to make the step selection. The direction of the movement is chosen based on land cover type, grass biomass and grass nitrogen content in their perceptual range. Vegetation dynamics follow the framework of Fryxell et al. (2004), incorporating rainfall patterns and the accumulation of dry matter to simulate green grass growth during the rainy season. Population dynamics are modelled using a stage-structured approach. Additionally, MIGRAZE allows for the implementation of diverse land use and conservation scenarios, as well as varying population dynamics parameters. It offers a powerful tool for exploring how migratory systems of ungulates respond to climate and land-use change, with a case study focusing on the Serengeti–Masai Mara ecosystem.

Seasonal dynamics of detritus flows and decomposition across ecosystem boundaries

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Material fluxes are ubiquitous in nature within and across ecosystems, connecting habitats with vastly different characteristics like forests to rivers and lakes. While individual fluxes and their cascading effects are well known, very few studies address the intra-annual phenology of ecosystem processes, despite the pronounced seasonality of fluxes. Here, we empirically quantified and resolved fluxes of recalcitrant and labile types of leaf litter in temperate riparian forests and streams across a year, representing one of the most emblematic examples of seasonal systems. We quantified intra-annual variation in litter inputs from terrestrial plants to forest floors and streams and estimated aquatic and terrestrial decomposition rates across the year at 6-week intervals. Our data shows that the autumn pulse of leaf litter is complemented by smaller magnitude but more constant-through-the-year lateral flows to the stream ecosystems. Decomposition of labile litter fluctuated seasonally, on a different phenology, with generally higher rates in summer, but rates of recalcitrant litter decomposition remained largely constant. Microbial organisms were the main contributors to the decomposition process in both forests and streams. Overall, our work highlights the asynchronous and seasonally variable changes in decomposition rates between recalcitrant and labile detritus despite their initial synchronized availability and suggests that the dominating presence of recalcitrant litter buffers ecosystem responses to the concentrated temporal distribution of litter resources. Investigating such ecological processes both across ecosystem borders and at fine intra-annual resolutions is imperative to understand complex system responses in the context of species' shifts in phenologies and resource quality.

Changing phenology of zoonotic diseases under climate and land use change

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Tick-borne encephalitis (TBE) and West Nile virus (WNV) are zoonotic, vector-borne diseases of growing concern in Europe, marked by rising case numbers and new infection areas. Their transmission risk follows characteristic seasonal patterns, largely driven by the weather-dependent activity of their arthropod vectors. Consequently, climatic warming - particularly alongside land-use changes - may significantly alter the phenology and seasonal dynamics of TBE and WNV by shifting the geographic and temporal distribution of vectors and viruses. In this study, we aim to assess the impacts of climate and land-use changes on the seasonal transmission dynamics of TBE and WNV in Europe, both historically and under future scenarios. Specifically, we focus on phenological shifts in the intensity of infection risk and the length of the transmission season throughout the year.

To achieve this, we developed spatiotemporal species distribution models (SDMs) for both viruses and their primary vector species, generating monthly habitat suitability predictions across Europe for past and projected future conditions. For virus modelling, we employed a nested approach incorporating vector habitat suitability as an additional predictor, capturing the dependence of virus occurrence on vector presence.

Our analysis offers valuable insights into the changing phenology of TBE and WNV in response to environmental shifts. By identifying temporal shifts in infection risk and length of disease transmission periods, as well as their spatial manifestations through the emergence or intensification of suitability hotspots, our results contribute to a better understanding of how transmission patterns have evolved in the past. Importantly, our results also provide a basis for anticipating future spatiotemporal trends in infection risk, thereby supporting more effective disease risk management through informed early warning systems, targeted surveillance, and adaptive public health strategies.

Responses of saltmarsh vegetation to spatio-temporal ressource heterogeneity – insights from an individual-based model.

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Saltmarsh ecosystems in coastal landscapes are often characterized by a strong salinity gradient. These gradients can alter the cover and composition of saltmarsh species with various implications for ecosystem functions. To better understand the underlying mechanisms, we developed a new individual-based model to simulate the growth dynamics of (sub-)tropical saltmarsh vegetation under conditions of resource limitation and interspecific competition. In contrast to other approaches to modeling saltmarsh vegetation, our model captures plant-level processes and interactions within a spatially explicit environment. By integrating key ecological drivers such as solar radiation and porewater salinity, the model enables the emergence of complex vegetation dynamics from simple individual rules.

Using the model, we investigated (i) the extent to which interspecific competition influences the performance of individual plant functional types under both stressed and non-stressed conditions; (ii) the key drivers underlying shifts in functional type composition and dominance along a salinity gradient; and (iii) the effects of temporally variable salinity driven by the tidal regimes and the rainy season on the biovolume and community structure of plant functional types. The model effectively reproduced spatial and compositional patterns that align with empirical observations from natural saltmarsh ecosystems.

Thus, the principal strength of the model lies in its capacity to generate emergent patterns characteristic of tropical saltmarsh systems—suggesting that fundamental ecological processes, when modeled at the individual level, are sufficient to explain the large-scale vegetation structures observed in these ecosystems.

Beyond its explanatory power, the model represents a versatile and expandable platform for addressing a wide range of ecological questions related to pattern formation, ecosystem resilience, and responses to environmental changes, such as altered inundation regimes due to climate change. Because of its generalizable design, the framework also holds potential for applied contexts, including conservation planning, habitat restoration, and the adaptive management of coastal ecosystems under stress from climate change.

Burrowing facilitated the survival of mammals in harsh and fluctuating climates

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Species' ability to cope with climatic instability varies greatly, influenced by factors such as dispersal, physiological adaptations, and phylogenetic conservatism. Here, we investigate how burrowing behavior, a key component of species' endurance strategies and ecosystem functioning, shaped the contemporary patterns of species richness and range size as well as the diversification of mammalian lineages. Analyzing 4,407 terrestrial mammal species, excluding bats, combined with novel trait data on 3,096 species, we reveal contrasting responses to climatic factors between burrowing and non-burrowing species. Burrowing lineages are disproportionately species-rich at lower temperatures and productivity. Both range size and species richness steeply increase with climate seasonality in burrowing species as opposed to non-burrowing species. The proportion of burrowing species increases with latitude, with regions above 20°, especially those exhibiting greater Pleistocene temperature changes, being almost exclusively composed of burrowing species. Trait conservatism, higher net diversification rates, and Eocene peak diversification provide the evolutionary context for these contemporary patterns, underscoring the role of burrowing for mammalian radiations into temperate climates. Moreover, the lower extinction rate of burrowing species and peak diversification at the Cretaceous-Paleogene (K-Pg) boundary support the longstanding hypothesis that burrowing behavior promoted survival during the "impact winter" that marks the replacement of non-avian dinosaurs by mammals. Our study highlights the potential of readily available trait information for understanding the ecological and evolutionary processes that shape species distributions through space and time. The careful integration of divergent environmental constraints bears vast improvements for forecasts of species' responses to climatic changes and global models of biodiversity patterns.

Continental diversification of plant lineages in ecological and genomic space

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Some plant lineages contain much more species than others. Evolutionary ecologists tend to explain richness by ecological constraints affecting the fitness of individuals and the survival of populations: lineages occupying a large variance of niches may undergo frequent ecological speciation, but also frequent extinction in marginal environments. Evolutionary genomicists tend explain species richness by genomic instability: lineages of high variance in genomic characters (number or size of chromosomes, ploidy) may have undergone frequent genomic speciation but also frequent extinctions through genomic accidents.

We compiled a database of whole-genome characters for the whole of Europe (18 000 taxa) and used a recent database on ecological-niche positions of species along five environmental axes. We characterized families by the variance (standard deviation) in both genomic and ecological space, and we used these variances to explain species richness of families, accounting for phylogenetic non-independence.

In simple models, we found high species richness to increase with variance in temperature and moisture niches across all orders. Within the Asteranae and Rosaneae, species richness also increased with variation ploidy level. In more complex models, accounting for the possible interactions between variance in ecological and in genomic space, we found that variance in chromosome size appears to facilitates the effect of environmental variance on species richness (except in Asteraneae).

The results suggest that diversification in environmental space, reinforced by genomic incompatibilities between ecologically divergent species, is widespread across a continent.

Volatility of ecophysiologically relevant traits as a measure of short-term phenotypic plasticity and in relation to acclimatization potential and genetic adaptation

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The fitness of organisms results from their ability to utilise resources under certain regimes of environmental conditions. Physiological traits are relevant for this, which are, on the one hand, subject to natural selection of their genetic basis within populations and, on the other hand, affected by the acclimatisation of individuals to local conditions over their lifetime. Adaptation of organisms to environmental conditions therefore has an eco-evolutionary dimension, which corresponds to its actual, genetic meaning, and an ecophysiological component, which corresponds to acclimatisation as an expression of phenotypic plasticity. In this study, the importance of the strength of short-term, gradual adaptations that trace the path to the unfolding of the full acclimatization potential under certain environmental conditions is investigated. Using a model-based approach, the advantages and disadvantages of different strengths of short-term adaptability in combination with varying acclimatisation potentials and in comparison to adaptation through selection and inheritance of genetic traits are systematically addressed. For this, the term volatility is introduced and proposed as a measure to characterise this specific short-term component of phenotypic plasticity. It is so far unknown in the ecological community, but used in finance and statistics to describe the variability of a trait in time. This work adopts this approach and proposes a new approach for the complementary description of the adaptation of organisms. Also because climate change affects the environmental conditions of many organisms during their lifetime, such a characterisation is seen as very informative and demanded.

Gaining Knowledge in Ecological Modeling

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Computational experiments based on models can be used for either generating or testing hypotheses. Each case has epistemic implications for research practice. Based on subjective Bayesianism, this poster outlines paths of epistemic reasoning in ecological modeling, highlighting available tools for strengthening credence in the experimental outcomes, such as preregistration, quantifying prior beliefs, value transparency, and Bayesian hypothesis testing. Insights from philosophy of science hold potential to guide study designs and improve trust in ecological research.

Combining GBIF data with national atlases reduces spatial bias in climate niche modelling

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Investigating the climate niche properties of plant species has become increasingly important in the face of climate change, particularly for predicting future distributions and ecological responses. Accurate niche modelling requires both reliable climatic variables and comprehensive distribution data. While the Global Biodiversity Information Facility (GBIF) represents a widely used open-access resource for species occurrence data, its coverage exhibits substantial geographical bias, with robust representation in Western Europe but significant gaps in Central and Eastern European countries. This sampling bias potentially leads to truncated climate niche models and inaccurate characterization of niche properties.

Our study quantifies the impact of this geographical bias on climate niche modelling accuracy across numerous grassland species native to Central Europe but exhibiting diverse distribution patterns. We compare climate niches fitted using three distinct datasets: (i) raw GBIF occurrence data, (ii) digitized expert range maps encompassing complete species distributions, and (iii) GBIF data enriched with records from digitized national atlases from several Central European countries. We hypothesize that the enriched dataset will yield niche size estimates and optimum positions intermediate between those derived from raw GBIF data and expert range maps. Furthermore, we anticipate that discrepancies in niche properties between raw and enriched GBIF datasets will be more pronounced for continental species compared to those with oceanic or widespread distributions.

This research highlights the importance of critically evaluating GBIF data when modelling climate niches. Our findings demonstrate that strategic integration of complementary data sources can effectively address geographical sampling bias, leading to more accurate characterizations of species' climate niche properties—a critical consideration for robust ecological forecasting under climate change scenarios.

High-Resolution Snow Depth Mapping on the Zugspitzplatt (Bavaria) using UAV LiDAR Time Series for Ecological Applications

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Snowfall in the Alps has been declining over the last decades, negatively impacting alpine ecosystems. The resulting changes to small-scale water availability and snowpack characteristics are relevant for botanical and zoological research. Local terrain features, which impact wind redistribution of snow and melting rates, affect snow accumulation and thereby the habitats of alpine flora and fauna.

Such environmental changes can, for instance, be monitored with multispectral remote sensing data, which has been used to map fractional snow cover. However, satellite data products struggle to capture the effect of small-scale topography on snow accumulation and depth estimation. Therefore, recent studies have started using uncrewed aerial vehicles (UAVs) to map snow depth at centimeter resolution.

The aim of this study was to analyze how UAV data can be used to map snow depth in alpine terrain. Our data was collected on the Zugspitzplatt (Bavaria, Germany) in 2024-25 using a DJI Matrice 300 RTK with a Zenmuse L1 LiDAR sensor. Our dataset consists of multiple acquisitions in varying snow conditions to capture the different stages of the snow accumulation process. For each acquisition, the snow depth was mapped by subtracting a snow-free digital surface model (DSM) from a snow-on DSM. The accuracy of the resulting maps was validated using in situ snow depth measurements.

We compared two approaches for mapping snow depth, deriving DSMs from LiDAR point cloud data and photogrammetry. Preliminary results indicate that LiDAR data provides more accurate estimates of snow depth than photogrammetry-based approaches. We additionally analyzed the impact of various terrain properties, such as local slope or aspect, on the snow accumulation.

This study shows the potential of using UAV LiDAR data to perform high-resolution snow depth mapping in alpine terrain and detect variations in snow accumulation dependent on topography and timing of snow fall.

Poster Session 43

Plant and vegetation ecology

Effect of drought legacy on carbon and water dynamics in Sorbus torminalis and Fagus sylvatica

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We studied legacy effects of repeated soil drought on two contrasting Central European tree species: drought vulnerable beech (*Fagus sylvatica L.*) and potentially drought resisting chequers (*Sorbus torminals* (L.) Crantz) to understand dynamics in carbon and water cycles under repeated drying-wetting cycles as predicted under future climate conditions.

Two-year-old saplings of both species were planted in a loamy soil. Trees were grown under optimum water conditions for half a year before moving them to growth chambers where they were exposed to three different soil water content treatments: control (well-watered during the whole experimental period), drought 1 (drought stressed once to a soil water content (swc) inducing 50% reduction of transpiration) and drought 2 (drought stressed twice to a swc inducing 50% reduction of transpiration). During the experiment leaf water potential (pre-dawn and midday), transpiration, stomatal conductance, photosynthesis and stable carbon isotopes of leaves were frequently measured.

Transpiration and photosynthesis were reduced in both species during the first drought period and remained lower than in unstressed individuals even during recovery. Relative to controls, δ13C values increased in the leaf sugars, remaining higher even through the recovery phases. However, previously stressed plants were able to keep gas exchange rates at a constant level for longer time during the second drought period than plants that experienced drought for the first time, before showing a decline in transpiration and photosynthesis after prolonged drought. Ultimately, towards the end of the second drought period, single and double stressed saplings showed very similar water and carbon dynamics. The altered reactions to high-frequency drying-wetting cycles indicate fast acclimation strategies of the plant species. Our experiment emphasizes the importance of seasonal drying-wetting cycles for plant performance.

A quantitative model of chemodiversity: investigating the mechanisms assumed to underpin the diversity of natural products proposed by different theories by the outcomes they lead to.

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Plants produce a great diversity of specialised metabolites (SMs), which play an important role in inter-species interactions, and have great agricultural value. These SMs are produced in complex metabolic pathways. The question of which evolutionary processes brought about and maintain this chemodiversity has led to numerous verbal models, such as the interaction diversity hypothesis and the screening hypothesis. Many of these verbal models have been partially tested in lab and field studies, however, some of their assumptions are difficult to test in this manner. To close this gap, in this talk I present a general individual-based model which can be used to model a great many verbal hypotheses of chemodiversity, with a particular focus on metabolic pathways. I show how it can be used to compare multiple hypotheses by comparing the screening and interaction diversity hypotheses. We found that, when the basic assumptions of both hypotheses were satisfied, the high enzyme promiscuity and prevalence of 'useless' metabolites predicted by the screening hypothesis did not occur, while the high prevalence of beneficial metabolites of the interaction diversity hypothesis did. This result provides arguments to favour the interaction diversity hypothesis over the screening hypothesis, particularly in systems where results could previously be explained by either verbal model. I discuss how this model could be used for other hypotheses, and modified to reflect specific systems.

The Spread Dynamics of Mimosa diplotricha in Hainan Tropical Rainforest National Park and Strategies for Its Control

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Invasive species pose significant threats to global biodiversity, particularly impacting vulnerable tropical ecosystems. Among such species, Mimosa diplotricha, a highly invasive plant native to South America, presents severe ecological challenges in Asia, notably in China's biodiverse Hainan Tropical Rainforest National Park. This invasive species rapidly proliferates due to favorable climatic conditions, aggressive growth patterns, and lack of natural predators, severely disrupting native biodiversity and ecological functions.

The core objective of this research is to analyze the spread dynamics of Mimosa diplotricha within Hainan Tropical Rainforest National Park and formulate effective control strategies. This study addresses critical knowledge gaps, including insufficient understanding of dispersal mechanisms, ecological impacts, and specific management strategies tailored to the tropical rainforest context.

Employing a mixed-methods approach, the research integrates comprehensive field surveys, geographic information system (GIS) mapping, spatial modeling, and statistical analyses. Stratified random sampling within the park will gather primary data on species density, environmental variables such as soil moisture, canopy cover, and temperature—factors influencing M. diplotricha's spread. Secondary data from scientific literature, government reports, remote sensing imagery, and meteorological records will support primary findings, providing a robust analytical framework.

The methodological backbone includes Species Distribution Modeling (SDM) using Sjsdm to project potential distributions of M. diplotricha based on environmental variables. Additionally, spatial analyses facilitated by R will visualize invasion patterns and predict future spread dynamics.

Expected outcomes include comprehensive identification of key environmental and ecological factors influencing M. diplotricha spread, detailed spatial distribution maps highlighting invasion hotspots, and robust predictive models. Ultimately, this research will yield targeted, evidence-based management strategies designed to mitigate ecological impacts and support biodiversity conservation within Hainan Tropical Rainforest National Park. These insights will be applicable to similar tropical ecosystems globally, aiding in invasive species management and ecological restoration initiatives.

Frost resistance - a neglected driver of plant phenology and distribution?

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With ongoing climate change, many plants are responding to changes in CO2 levels and temperatures. It was shown that frost events may become more frequent even with a general rise in temperature. As plants shift their spring phenology to earlier dates and/or their range towards the poles and to higher elevations frost can be a potential risk for plant survival and performance and frost resistance might be an important driver of the ability of plant species to change their phenology and range.

However, this has not been studied yet. To close this gap, we measured frost resistance in mainly herbaceous plant species using the electrolyte leakage method. We assume that 1) a species' ability to shift their spring phenology to earlier dates is driven by their ability to tolerate late frost events, as shifts without high frost resistance will lead to frost damage. And 2) species' ability to shift their distributional range towards the poles and higher elevational sites is driven by their ability to tolerate late-frost events, as the likelihood of late-frost events increases with these shifts. We will present our first results at the GfÖ in September.

SEED-DarkDivNet – an empirical test how species belonging to the dark diversity can establish based on their traits and suitability for a given site

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SEED-DarkDivNet is an add-on in the DarkDivNet and started in February 2020. DarkDivNet is a global network across 119 regions that aims to better understand the mechanisms underlying the absence of species that could potentially occur at a given site, i.e. the dark diversity. SEED-DarkDivNet aims at empirically testing how species belonging to the dark diversity can establish based on their traits and co-occurrence with species locally present. Collaborating partners from 6 different countries (Czech Republic, Estonia, Germany, Italy, Spain and Portugal), working in 9 study regions are participating in this add-on and collected seed material of ~ 200 species from the regional species pool and belonging to the dark diversity. Collected species differed in their suitability for a given site. In autumn 2020, 50 seeds of 20 plant species were added to four permanent subplots in core sites within each study region. To quantify the effect of competition on establishment success, half of each subplot was disturbed. For each species, dispersal traits were measured. We also measured seedling traits of most of the sown species under controlled conditions in the lab. Seedlings were grown in the climate chamber under standardized conditions and the SLA, tissue C:N, and shoot and root biomass were measured when individuals had two fully emerged true leaves. We were able to get traits from at least 108 species/populations. Preliminary analyses show that, as expected, more species could establish at disturbed compared to undisturbed patches and species with higher suitability values could establish better compared with species with low suitability values. Further analyses will show how dispersal and seedling traits affect the establishment of dark diversity species in the field.

Diversity and ecology of saxicolous lichens in the Knersvlakte (South Africa)

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There is limited knowledge about the diversity of saxicolous (rock-inhabiting) lichens in the edaphically arid quartz fields of the Knersvlakte. Moreover, the factors influencing the composition and distribution of lichen vegetation in this unique environment remained largely unexplored. To address this gap, we conducted lichen vegetation surveys on quartz fields at the Moedverloren and Ratelgat sites within the Knersvlakte nature reserve, aiming to gain a deeper understanding of lichen diversity and its relationship with environmental drivers. Different elevation levels of west-facing (towards the coast & fog-exposed) and east-facing (towards the inland) slopes were studied. The study showed that the lichen vegetation of quartz fields is far more diverse than previously known. We found a total of fifty-five taxa that showed various adaptations to the arid climate and the unique fog conditions. Four types of lichen vegetation could be distinguished that are specific to different environmental conditions. Fog exposure appears to be an important environmental factor mainly on the west-facing upper slopes. However, the saxicolous lichen vegetation is also influenced by salinity as well as by habitat diversity. Our results showed that the quartz fields of the Knersvlakte are an arid diversity hotspot for lichens, driven by various factors beyond just fog.

Vegetation and Biodiversity Dynamics in Floodplain Forests under Reduced Flooding Regimes

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Temperate floodplain forests are among the most species-rich habitats in Europe, shaped by dynamic interactions between water, land, and vegetation. Alpine braided rivers as the Isar in South Bavaria formed particularly dynamic floodplains characterized by high flooding frequency, flow velocity and sediment transport. Centuries of forest- and water management have altered these landscapes by reducing flooding, increasing sole erosion and lowering groundwater levels, resulting in conversion of early successional vegetation to plantations and secondary high forests. In 2020, 2,300 hectares of the Isar floodplain have been designated as natural forest reserves without further management. However, this designation does not reverse flood and water regulation, as large-scale hydrological restoration is unlikely in such a densely populated region. A central question is how these secondary floodplain forests will evolve under current and future environmental conditions.

Flood events and fluctuations in groundwater levels play a key role in maintaining the ecological functions of floodplain habitats. Many plant and animal species, including ground-layer vegetation and epiphytic bryophytes growing on tree trunks, interact with regular inundation and high humidity. The absence of these flood pulses alters site conditions of typical floodplain communities. This research project examines how the reduced influence of natural hydrological processes affects vegetation development, biodiversity, and ecosystem function along the Isar between Munich and Landshut. The study will be based on a stratified sample with vegetation plots, insect traps and acoustic monitoring of songbirds. By focusing on ground vegetation, epiphytic mosses, and selected animal groups along the trophic chain, the study aims to derive practical knowledge for biodiversity-oriented management in anthropogenic floodplain landscapes.

Towards a standardized framework for identifying leaf herbivory damage types: Bridging a critical knowledge gap in Functional Insect Ecology

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Leaf herbivory by insects is a key ecological process with strong implications for plant performance, food webs, and ecosystem functioning. Insect damage left behind on leaves, ranging from holes and chewed margins to mines, galls, surface feeding and punctures, can reveal much about the interactions of insect herbivores with plants and the herbivore community structure. To characterize herbivore functional communities, damage on plants can be grouped into damage types as they reflect distinct functional feeding groups such as hole feeders, margin feeders, miners, gallers, surface feeders, and suckers and offer a promising proxy to characterize insect herbivore functional communities. Despite their potential, functional feeding groups and damage types remain severely understudied in modern ecological research, with most attention limited to external chewing damage. We therefore suggest that a systematic assessment and classification of damage types can complement or even substitute labor-intensive insect sampling, especially in regions or time periods with limited accessibility. Damage types are relatively easy to collect and can provide consistent, comparable data across sites and years. However, robust application is currently hindered by the lack of standardized guides and reference collections. Our goal is to close this methodological gap by building capacity to more reliably identify and interpret damage types in ecological field studies. This requires clearer definitions, reference material, and expert collaboration. We seek to engage with other scientists with field experience or damage type expertise to develop a guide with photographic examples of damage types across functional feeding groups, ecosystems, and environmental gradients. Such a resource would enable broader ecological applications, from biodiversity monitoring to studying climate change effects on herbivore-plant interactions.

Resurvey of vegetation across a network of Italian protected areas, The Ecological Dinamycs in Italian protected areas Network (ECODIPA-net) vegetation resurvey project

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Plant communities are threatened by habitat destruction, climate change, invasive species, pollution, and land-use changes. Protected areas (PAs) are considered essential in mitigating the impacts of such drivers, maintaining local biodiversity and natural processes by limiting direct anthropogenic impacts at the local scale. However, global and broad-scale drivers influence plant communities also in PAs, whose vegetation shifts may reveal long-term trends that distinguish between natural fluctuation and human-driven impacts. In this context, resurvey of vegetation, i.e., the repeated sampling of past vegetation surveys conducting relevés in the same sites and with comparable methods, is gaining increasing popularity as a cost-effective and powerful approach for the direct study of fine-scale vegetation changes over time.

In Italy resurvey studies have been carried out on a local scale investigating different ecosystems, without efforts towards a national harmonization and a lack of focus on PAs. to address this issue, we launched the collaborative network Ecological Dynamics of Italian Protected Areas (ECODIPA-net), to build a nationwide database of vegetation plot resurvey in Italian National and Regional Parks (NRP). The database includes 1376 resurvey plots across 29 Italian NRP with historical information dating as back as 1934 but is mostly concentrated during the 70s and 80s. The resurveys have been carried out during spring-summer 2024 and 2025 by the members of the network.

The preliminary results include community, habitats, and species trends in time and shows the vegetation dynamic trends in Italian PAs. Results indicate an increase in time in the overall species richness, particularly at high altitudes; moreover, alien species and red-list species increases and decreases, respectively. at the individual species level an increase of woody vegetation types and the increase of species connected to the ongoing climatic and land use changes is evident.

Faunal interactions with berry-like cones of Juniperus communis in Patagonia: implications for propagation

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Seed dispersal and predation are key processes influencing plant recruitment and biological invasions. In this study, we investigated the faunal interactions with *Juniperus communis* fruits in its introduced range in Patagonia (Argentina), where the species is expanding into natural ecosystems. Using camera traps, we recorded 231 interactions, the vast majority involving native rodents (96%), and only 4% involving thrushes (*Turdus falcklandii*). Rodents exhibited mainly in situ consumption and partial consumption behaviors, with limited evidence of fruit removal. These interactions were more frequent on the ground and during nighttime. Conversely, thrushes showed diurnal activity and interacted mostly with canopy fruits. Compared to the species' native range, where birds are supposed to be primary dispersers, our findings highlight a shift in dispersal agents, suggesting that mice could play a dual role as both seed predators and dispersers. Observed removal behaviors are consistent with scatter-hoarding, a mechanism that may promote germination by modifying the seed coat or relocating seeds to favorable microsites. Occasional observations of other birds and medium-sized mammals interacting with *J. communis* fruits suggest the existence of additional, understudied dispersal pathways. Our results demonstrate that *J. communis* engages in novel interactions in its introduced range, involving local fauna with distinct ecological roles. These interactions may facilitate its recruitment and contribute to its invasive potential in Patagonian ecosystems. Understanding both the behavioral mechanisms and the identity of the faunal partners involved with this incipient invader is crucial for anticipating invasion dynamics and informing conservation strategies in these temperate ecosystems.

Intraspecific plasticity of leaf Silicon and Calcium aligns with plant functional type elemental demand

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The chemical composition of plants is an important functional trait in plant ecology. Silicon (Si) and calcium (Ca) are prominent in the leaves of different functional groups, with grasses acting as Si accumulators and legumes as Ca accumulators. These two elements serve as defensive elements against herbivores and play a key role in determining the nutritional quality of forage for grazing animals. Plant Si accumulation can be passive or active, with most grasses possessing efficient Si transporters, while legumes accumulate less Si and more Ca. Regardless of strategy, soil Si and Ca availability strongly influence plant uptake. This study investigates whether intraspecific variation in leaf Si and Ca mirrors functional type-specific elemental demand across 45 grassland sites in the Biodiversity Exploratories. We hypothesized that grasses, with high Si demand, would show greater leaf Si plasticity in response to soil Si, while legumes would show stronger Ca responses. Our results revealed clear species-specific responses. Grasses showed a significant increase in leaf silicon concentrations with rising soil silicon availability, reflecting their high demand and active uptake mechanisms. In the case of calcium, although legumes consistently exhibited higher baseline leaf Ca levels, all species showed increased leaf Ca with greater soil Ca availability, likely due to the predominantly passive nature of Ca uptake. Forbs displayed variable patterns, with some aligning more closely with grasses and others resembling legumes in their elemental responses.

These findings highlight the role of elemental demand in mediating nutrient uptake strategies and plant economic strategies at the intraspecific level, linking soil resource gradients to plant functional adaptation.

Small-scale fen restoration brings back key species and ecosystem characteristics

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Fens play a crucial role in conservation and climate change mitigation by acting as carbon sinks and hotspots for specialized species. However, human actions degraded the majority of European fens. Degraded fens lose their special biodiversity and associated ecosystem services. Fen restoration can improve conditions for fen specialists and bring back key ecosystems services. Most restoration projects are of small-scale and limited by cost or socio-ecological factors. In this study, we analyzed the effects of small-scale restoration of fens on the vegetation composition and ecosystem characteristics, and explored the development of fen vegetation with increasing time since restoration. We compared fens drained for forestry and restored in the last 38 years, with near-natural and unrestored fens. We found that restoration efforts have successfully increased the similarity to near-natural fens with time since restoration, but there was a breakpoint after seven years. Restoration brought back key fen species, increased water availability and led to new peat formation without reaching near-natural conditions. Our study highlights the importance of restoring a variety of degraded fen types, even at small scales.

Vegetation-ecological differences between natural and anthropogenically influenced dunes on Spiekeroog

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In the face of rising sea levels due to climate change, future-oriented flood protection is becoming increasingly important. Recently, the potential for naturally designed protective dunes has gained attention, with natural dunes recognized as providers of the ecosystem service "flood protection." However, the geomorphological-ecological differences between engineered protective dunes and natural dunes and how these affect ecosystem services, remain insufficiently understood. We aim to investigate the functioning and importance of (natural) dune ecosystems in coastal protection and to identify how their protective capacity can be maintained or optimized while conserving their ecological value. We will extract information about historical coastal dune protections from arial pictures, historical maps and planning permissions from the NLWKN. Then we will survey engineered protective dunes and adjacent natural dunes differing in location, geomorphology, sediment balance and age to be able to compare the current state of both dune types. We will conduct vegetation surveys of vascular plants, mosses and lichens and take soil samples across transects spanning from embryonic dunes to brown dunes. We expect to obtain insights on the temporal development of abiotic and biotic factors of coastal protection dunes, which can then be used to assess the nature conservation and engineering status of natural dunes and coastal protection dunes and to find options for the future use of natural dynamics in coastal protection dunes. Preliminary results from Spiekeroog will be presented here.

Interacting effects of climate and land-use gradients on plant taxonomic and functional diversity in Central European Landscapes

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Land use change is recognized as a significant driver of biodiversity loss. Likewise, climate change negatively affects biodiversity due to slow adaptation or poor migration of many biological groups, leading to massive species losses and biotic homogenization. As the structural and functional basis of ecosystems and indicators of the local site conditions, plants help understand the performance of higher trophic levels. Therefore, functional and taxonomic diversity patterns in plants at local and landscape scales can be essential proxies for ecosystem functionality. To understand the role of climate and land use on different dimensions of plant diversity, we recorded plant species across 60 landscapes in Bavaria, comprising five climatic zones and three land uses common in Central Europe. This space-for-time approach aimed at disentangling the effects of the two biodiversity drivers. The analysis of interacting climate and land use demonstrates an overwhelming role of land use in plant diversity patterns, leading to the lowest species richness and homogenization of plant assemblages in agricultural sites, especially crop-dominated ones. At the same time, we found a high functional and taxonomic diversity in urban sites due to the heterogeneity in local habitats and large numbers of neophytes. Exploring these patterns underpins the need to assess various aspects of diversity and implement functional approaches in biodiversity monitoring for improved restoration and management planning in modified ecosystems.

Poster Session 44

Urban Systems

Oasis of diversity - Cemeteries as Biotopes and Stepping Stones for Urban Biodiversity: Recognizing, Enhancing and Communicating Biodiversity

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Can and should urban cemeteries be rewilded - and how? As green spaces within densely built environments, cemeteries are often perceived as valuable oases - not only for grieving and remembrance, but also as places of recreation and nature experience: They provide critical habitats for a variety of plants, animals and fungi.

Yet, cemeteries are under increasing pressure. Some are being closed, repurposed, built over, or maintained in ways that may not support biodiversity. What kind of maintenance supports ecological value? How should cemeteries evolve from a biological perspective? Should they be managed as natural oases - or be left to fallow - or be build over? And what other factors shape biodiversity in cemeteries - such as size, isolation, urban context, or human presence?

This doctoral project aims to assess the existing biodiversity of urban cemeteries and identify key parameters for enhancing it. It combines ecological field studies with citizen science approaches to monitor various animal taxa, including mammals (like squirrels), arthropods (like groundbeetles), and others. The ultimate goal is to highlight the ecological potential of cemeteries and provide actionable recommendations for their management. Promoting biodiversity in times of global biodiversity loss and climate change is more urgent than ever. Enhancing structural diversity and preserving cemeteries as habitats for animals, plants, and fungi is therefore essential for sustaining urban biodiversity.

Urban Plant Aesthetics and its implication for ecology, nature conservation and human well-being.

Gaia Micco[1], Gala Mona Louise Dädlow[1], Bertrand Fournier[1], Nicolas Mouquet[3,4], Marco Moretti[2]

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Urban areas and their associated plant communities are highly influenced by human activity. With more than half of the world population living in cities, Urban Green Spaces (UGS) offer vital ecosystem services and often represent the only accessible connection to nature for many urban residents. However, homogenization processes within urban environments, along with the top-down management of UGS, strongly filters the plant species that can enter the local city pool.

Flowering plants in particular provide important cultural ecosystem services, having both commercial and aesthetic value, in addition to the ecological one. Aesthetic experiences, such as noticing a flower while walking the city streets (and perhaps sharing a picture on Instagram, picking it, or seeking out a similar flower in a shop), represent an important aspect of our relation to non-human being and the environment. Understanding how our sense of beauty and preference influences our choices in managing UGS is essential, as it may limit or enhance their contribution to biodiversity and human well-being.

To explore these dynamics, we conducted a paired-image online survey representing 490 plant species recorded in urban Switzerland. By analyzing the aesthetic scores assigned to each image, alongside features extracted directly from the digital files (e.g., color, shape, symmetry), we investigated which visual, aesthetic-related plant traits most influence human preferences. We also examined how these preferences correlate with ecological metrics not directly tied to visual appearance, such as functional distinctiveness and IUCN conservation status.

The study advance the understanding of the role that aesthetic values play in shaping urban biodiversity. Our results align with psycho-ecological hypotheses suggesting that human preferences for certain plant traits are not arbitrary but may be rooted in evolved psychological responses to environmental cues. Recognizing these innate aesthetic inclinations can help urban planners design green spaces that are both ecologically functional, that can promote biodiversity and provide psychologically restorative environments that enhance overall human well-being.

Plant Aesthetic Traits and Their Role in Urban Community Assembly

Gala Mona Louise Dädlow[1], Gaia Micco[1], Marco Moretti[2], Nicolas Mouquet[3,4], Bertrand Fournier[1]

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Urban green spaces and their vegetation play a critical role in ecological functions and human well-being in cities. The species composition of urban plant communities is strongly influenced by anthropogenic factors, particularly decisions related to plant selection, such as purchasing, planting, and weeding. While the aesthetic appeal of plants may significantly affect these choices, its role in shaping urban plant community assembly and ecosystem functioning remains underexplored.

This study aims to (1) quantify human perceptions of plant aesthetics, (2) identify the key traits that contribute to aesthetic appeal, and (3) assess the role of these traits in urban community assembly within Swiss cities.

To achieve these goals, we conducted a paired-image online survey with 1279 images of 490 plant species found in Swiss urban environments to assess participants' aesthetic preferences. We identified the plant traits that drive these preferences and explored their correlation with ecological metrics relevant to biodiversity and ecosystem functioning, such as pollination strategies, drought resistance, and functional rarity.

Preliminary results suggest that blue radially symmetric flowers are aesthetically preferred by people. However, we found little evidence that these traits are positively filtered at the city scale. Instead, filtering patterns varied among different types of urban green spaces. For example, yellow-flowered species were selectively filtered in allotments and ruderal habitats, but not in other green space types. Additionally, traits associated with human aesthetic preferences were found to correlate with plant pollination strategies. These findings provide new insights into how human preferences can influence urban plant community composition and the ecosystem services delivered by urban green spaces.

The Role of Commercial Plant Species in Shaping Urban Species Pools in Switzerland

***Vivien Grothe*[1], *Gala Mona Louise Dädlow*[1], *Bertrand Fournier*[1], *Marco Moretti*[2], *Sebastian Richard Ruile*[2]**

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The composition of the species pool plays a foundational role in shaping biodiversity patterns and determining the range of ecological functions in urban environments. As the source from which local communities are assembled, the species pool constrains or enables the development of diverse and functionally rich urban floras. In cities, it is influenced by both naturally established species and those introduced through commercial horticulture. However, the functional contributions of commercially available species to urban species pools remain poorly understood. Identifying how these species differ in ecological traits is essential for assessing the functional potential of urban ecosystems and guiding biodiversity-informed planning. This study examines how commercial plant species shape the functional composition of urban species pools by comparing the traits of naturally established and commercially introduced species in Switzerland. We constructed a species pool that included both groups and analysed ecological, morphological, phenological and human-preference-related traits using Principal Component Analysis across herbs, shrubs and trees. Preliminary results show that commercial herbs occupy a narrower trait space within that of established herbs, while commercial trees display greater trait diversity than their established counterparts. Across all growth forms, commercial species are generally shorter, produce lighter seeds and flower earlier. Commercial herbs are also marked by ornamental traits, such as multi-coloured, bilaterally symmetrical flowers. By introducing novel trait combinations and increasing redundancy in specific regions of trait space, commercial species may affect community assembly and biodiversity dynamics, potentially altering biotic interactions. Characterizing their role deepens our understanding of urban biodiversity assembly and underscores the critical influence of human agency in urban ecosystems.

Mesocosm experiment on copper retention in sustainable urban drainage systems

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Sustainable urban drainage systems (SUDS) play a key role in urban green infrastructure by mitigating environmental pollution and managing stormwater. However, the impact of heavy metals, particularly copper remains poorly understood. Copper, commonly released from roofs, is a major pollutant in urban runoff and poses risks to plant health, ecosystem functionality, and human health. To ensure the long-term effectiveness of SUDS, these systems must be designed for hydrological efficiency and the resilience of their vegetation under stress conditions, including contamination by heavy metals. Understanding the tolerance and adaptive capacity of native plant communities under copper exposure is essential for informed species selection and substrate design.

This study addresses a critical knowledge gap by establishing a mesocosm experiment that simulates realistic scenarios of copper contamination. A pilot system was developed in which rainwater runoff from an existing copper roof is directed onto experimental plots planted with native plant communities derived from regional seed mixtures. These mesocosms allow for controlled yet ecologically meaningful assessment of how plant communities respond to copper-enriched inputs over time. To evaluate the role of substrate amendments in mitigating copper stress, zeolite – a natural aluminosilicate mineral with high cation exchange capacity and metal-binding properties – is incorporated in some of the mesocosm substrates.

The experimental design enables a comparative analysis of plant communities' resistance, resilience, and functional performance under chronic copper exposure. It also assesses the capacity of zeolite to immobilize copper and limit its accumulation in soil and plant tissues. By linking plant functional traits with targeted substrate interventions, this research provides valuable insights for designing more robust and sustainable SUDS capable of withstanding the increasing pressures of urban pollution.

How effective are flowering mixtures as a measure to promote native pollinator diversity in private gardens

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With the referendum “Save the Bees” protecting and promoting insects, as important providers of crucial ecosystem services like pollination, has gotten into the public focus. Companies recognized the public's growing interest in this topic and nowadays are presenting a wide selection of flowering mixtures especially made to promote insect diversity in private gardens. Yet, it remains unclear, how effective these mixtures really are and if they are really made to promote the organisms they are advertising with.

We examined the extent to which flowering mixtures have a positive effect on pollinator diversity and which pollinators actually benefit from them. We tested four “butterfly mixtures” and four “bee mixtures” to find out which seeds they actually contain and how many exotic plant species are included per mixture. In a second step, we created 30 2x2m flower patches (three to four patches per mixture), which were randomly distributed within two Bavarian villages. From June to September 2023, we recorded which pollinators (including bees, butterflies/moths and hoverflies) were seen at each flower patch.

We were able to identify 40,388 seeds to species level. Within the mixtures, we found seeds of 103 different plant species. The proportion of exotic seeds within mixtures varied between 19 – 66%. When recording the pollinators, a total of 1,237 individuals and 101 species (64 bee species, 23 butterfly/moth species, 14 hover fly species) were documented. There were significant differences in abundance and species richness between the different flower mixtures. While pollinator diversity generally benefited from the flowering mixtures (compared to “only lawn”- control patches), it was mainly common and generalist insects that used the flowering areas. In summary, flowering mixtures could further be developed by including more native plant species of different families, also considering larval food plants of butterflies and nectar sources for oligolectic species.

Changing the mowing regime is not enough: The effect of urban grassland management on vegetation, arthropods, and carabids.

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Urban grasslands offer great potential for enhancing biodiversity and serving multiple ecosystem services. Grassland management is crucial in maintaining grassland characteristics and conserving plant and fauna diversity. Two studies explore how different grassland management practices influence biodiversity in urban floodplain and dike grasslands in North Rhine-Westphalia, Germany. Across 16 sites, we evaluated the effects of reduced mowing, both with and without the addition of native species sowing. Results show that combining reduced mowing with native species sowing significantly increases species richness and alters community composition across plants, arthropods, and carabids. In contrast, reduced mowing alone led to gradual shifts in vegetation composition but showed limited effects on overall species richness, even after several years. Long-term data suggest that biodiversity improvements under reduced mowing alone may require decades to manifest. These findings highlight that while reducing mowing intensity supports ecological recovery, additional restoration measures such as sowing are essential for accelerating and maximizing biodiversity gains in urban grasslands.

Children's playgrounds as a potential habitat for wild bees in urban areas

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Urban green areas can provide important alternative habitats for wild bees, which are increasingly losing their natural habitats due to anthropogenic pressures. This study focused on evaluation of children's playgrounds as overlooked yet potentially valuable sites for solitary bee conservation within cities.

In July and August 2023, solitary bees were monitored at 41 playgrounds and 41 neighbouring control sites (grasslands) in Prague. We recorded local environmental variables for each site, and parameters of surrounding landscape (land cover categories) were assessed within 200 m and 500 m radius around sampling sites. A total of 1030 wild bee individuals were collected and identified to the species level.

Generalized linear mixed models with a Poisson distribution showed that vegetation, nectar availability, paved surface, and surrounding green areas (500 m) significantly affected species richness and abundance of wild bees. More bees were found in areas with higher nectar availability and vegetation, while a higher share of impervious surfaces reduced their numbers. Canonical correspondence analysis confirmed nectar availability, shading, and paved areas as key drivers of community composition.

A total of 72 species were recorded, with 47 species found at playgrounds and 65 species at control sites. In general, the control sites were significantly more species rich and hosted higher bee abundances than playgrounds. Five species recorded in the study are listed in the Czech Red List: *Megachile lagopoda* (EN), *Anthophora quadrimaculata* (EN), *Rhophitoides canus* (VU)*, Megachile pacifica* (NT)*, and Melitta leporina* (NT). The most abundant species was Halictus tumulorum. In total, 14 % of the bee species recorded in the Czech Republic were documented in this study, emphasizing the ecological importance of urban environments.

Floral resources and pollination services in rural villages

Mona Trabold[1], Taia Schrøder[1], Fabienne Maihoff[1], Andrea Holzschuh[1], Ingolf Steffan-Dewenter[1]

[1]Julius-Maximilians-Universität, Würzburg, DE

Villages in rural environments hold the potential to serve as valuable habitats for wild pollinators, yet they remain largely overlooked in ecological research. Public green spaces and private gardens offer a mosaic of flowering plants that could support diverse pollinator communities. However, the increasing use of ornamental species with low nectar or pollen values, intensive lawn management, and the expansion of sealed surfaces raise important questions about how much of this potential is actually being realized.

This study extends previous research on pollinator richness and abundance by additionally investigating floral resources and the realized pollination success in village habitats, focusing on wild bees and hoverflies as key pollinator groups. We measure the quantity and quality of nectar and pollen provided by a variety of native and non-native plant species commonly found in village settings, to assess whether pollinator visitation rates are influenced by the availability of different nectar and pollen resources. Further, pollination success is studied by using two model species, *Fragaria × ananassa* and *Scabiosa columbaria*, to evaluate pollination both as an ecosystem service and as a key ecological function supporting wild plant reproduction. In doing so, we address the question of whether village habitats are affected by pollination limitation.

Our aim is to generate actionable insights that can guide pollinator-friendly planting and management in rural village contexts. By making the ecological role of these overlooked habitats more visible, this study contributes to broader conservation efforts and offers a transferable framework for supporting pollinators across similar cultural landscapes.

Effects of urban stressors on plant-pollinator interactions in urban community gardens

***Alexandra Zink*[1], *Sara Leonhardt*[1], *Monika Egerer*[1]**
[1]***Technische Universität München, Freising, DE***

Insect pollinators are facing global declines, with potential implications for both agriculture and wild plant communities. The factors driving these declines are diverse, including habitat loss, agricultural intensification, and climate change. Urbanization creates a unique combination of stressors such as habitat fragmentation, pollution, and increased temperatures, with influences that are potentially positive for pollinator communities, such as increased plant diversity and heterogeneity due to intensive and highly variable management by people. Observed effects of urbanization are highly variable between functional or taxonomic groups, and may be offset by local habitat factors. Plant-pollinator networks and the services provided by pollinators may be impacted by urban stressors, however these relationships are even less understood. Urban gardens provide a framework to study pollinator communities and their interactions across a gradient of urbanization and varying local habitat. We sampled plants, pollinators, and their interactions, 4 times between April and October, in each of 33 community gardens across Munich and Berlin, Germany. Each sampling, we measured flying insect abundance and diversity using pan traps and hand-netting, and observed all flower-visiting insects along transect walks centered in each garden. We measured plant diversity and cover in eight 1-square-meter plots randomly placed throughout each garden. To quantify urban stressors across our sites, we measured the proportion of impervious surface at various radii around each garden and used environmental data loggers to monitor temperature and humidity throughout the year. Here we present results on how urban imperviousness and temperature influence the abundance and diversity of insect pollinators and the structure of their interactions with plants in urban gardens.

Monitoring and evaluation of urban reptile conservation measures in Prague using ACOs.

Adam Votava[1]

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Reptiles are experiencing alarming levels of worldwide decline and are considered as highly endangered in the Czech Republic. The main threats are habitat destruction, landscape fragmentation, invasive species and negative human activities. Conservation efforts aim to reverse the loss of biodiversity, but implementing measures in urban environments is particularly challenging. Nevertheless, the City of Prague has supported reptile populations through the construction of hibernacula and stone walls. This study focuses on creating a database of 37 such measures in Prague, their monitoring and suggestions for improvement.

Monitoring was carried out at 26 sites in 2023 using artificial cover objects (ACOs), which provide reptiles with safe basking sites. Temperature data loggers were also installed at selected sites. The results show that ACOs are highly effective for monitoring legless reptiles, especially slow worms (*Anguis fragilis*), which accounted for 98% of all individuals recorded. Grass snakes (*Natrix natrix*) were also frequently observed (90% of records under ACOs), while lizards were rarely found. In terms of type of structure, 60% of reptiles were recorded on hibernacula and only 8% on walls.

Material tests showed that rubber sheeting (pond liner) provided the greatest temperature difference from the environment (+5°C on average), followed by carpet (+2°C). Warmer materials were clearly preferred by the reptiles. Based on these findings, adjustments to existing conservation structures were suggested. The study provides data on the thermal ecology of selected reptiles of central Europe and valuable insight for future management of reptile habitats in urban environments.

The relative habitat potential for wild bees in Frankfurt am Main

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The decline in insect diversity has been a major issue for several years now. Possible causes include the intensification of agriculture, the loss of semi-natural habitats, the use of pesticides, the fragmentation of habitats, the effects of climate change and invasive species. Against this backdrop, urban areas are becoming increasingly important for the conservation of insect diversity. Although cities are often considered hostile to many animal and plant species, their heterogeneous structures, such as parks, gardens, fallow land and green roofs, can provide valuable substitute habitats for insects, especially Hymenopterans.

This study examines the relative habitat potential of urban areas for solitary wild bees with a flight radius of 200 m using the example of Frankfurt am Main. With the help of the detailed biotope mapping and additional structures, we calculated the relative habitat potential of wild bees in Frankfurt am Main. Overall, Frankfurt offers a rather low habitat potential for wild bees, although we could also identify distinct hotspot areas. Additional scenarios such as the upgrading of gardens by creating suitable nesting habitats or the conversion of flat roofs into green roofs throughout the city can provide indications for improving the habitat potential and can be used to develop recommendations for action.

Buzzing Villages: Where Community Action Meets Ecological Research

Taia Schrøder[1], Mona Trabold[1], Fabienne Maihoff[1], Anne Krügl[1], Nikki Sauer[1], Andrea Holzschuh[1], Ingolf Steffan-Dewenter[1]

[1]University of Würzburg, Department of Animal Ecology and Tropical Biology, Wuerzburg, DE

Wild pollinator diversity has been extensively studied in agricultural landscapes and, increasingly, in urban environments. However, the role of rural village habitats in supporting insect populations - especially in the context of alarming global insect declines - remains largely understudied. Public green spaces and private gardens in villages may serve as important refuges from agricultural intensification and habitat loss. Private gardens and community green areas hold considerable potential to support a wide variety of flowering plants that provide essential food resources for wild pollinators. Additionally, traditional structures such as old barns, dry stone walls, and sparsely vegetated soil patches can offer valuable nesting sites. However, closely mown lawns, aesthetic preferences for ornamental plants with low nectar and/or pollen values, and increasing land sealing (e.g., through paving or construction), raise concerns about the actual potential of villages to support pollinators.

The project *"Summende Dörfer" (Buzzing Villages)* explores pollinator communities in rural villages through a participatory approach. In collaboration with local residents and municipal staff, the project aims to create ecologically improved habitats and assess how these changes influence pollinator diversity and the ecosystem services they provide. Of the 40 participating villages, 20 are currently undergoing ecological enhancement following a baseline assessment conducted in the first project phase (2020) and will be compared to the remaining 20 control villages.

To motivate private garden owners to contribute, the project includes public outreach activities and a recognition program that rewards pollinator-friendly gardening practices. *Buzzing Villages* brings science, community engagement, and conservation together in a shared effort to strengthen biodiversity in rural landscapes.

Urban Tree biomass estimation: Integrating terrestrial and airborne laser scanning

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[4]Technische Universität Braunschweig, Braunschweig, DE

Estimating the biomass of urban trees is common in ecosystem service studies and there are several approaches. The most common approach relies on measuring the diameter at breast height (DBH) for a sample of trees, applying allometric equations to estimate individual tree biomass, and extrapolating these results to the entire urban area. The inherent uncertainty of this method can be reduced by combining DBH-based estimates with remote sensing imagery and/or land-use data. However, considerable uncertainty remains due to the lack of allometric equations specifically developed for urban environments and for commonly planted urban species; most existing equations were developed for commercially relevant forest trees.

In recent years, terrestrial laser scanning (TLS) has produced highly accurate results on street and small neighborhood level, but city-wide implementation remains infeasible due to logistical, data processing, and other constraints. Here, we present a method that combines TLS-based biomass estimation for a representative subset of urban trees with city-wide crown measurements derived from airborne laser scanning (ALS). We compare the resulting biomass estimates with those produced by conventional methods and discuss the potential of this approach for high-resolution carbon sequestration monitoring in urban landscapes.

Urban lawns and grasslands throughout the year – the influence of urbanization and management on plant communities and structural vegetation parameters

Karla Wenner [1]
Nadja K. Simons [1]

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Urban lawns and grasslands account for a large proportion of open green spaces in cities. They are used for a variety of purposes, including recreation, sports facilities, environmental education, and nature conservation. Lawns and grasslands also provide important ecosystem functions such as providing habitat and food resources for animals, biomass production and water retention.

Plant community shifts along urbanization and management gradients are relatively well documented, but little is known about changes in plant communities and structural vegetation parameters of urban grasslands and lawns throughout the year. As management events and other human-induced disturbances can strongly alter habitat conditions, plant species with varying traits may be favored at different times. Changes in plant traits have been shown for agricultural grasslands of different management intensity. However, management of urban grasslands can be even more intense and occur at different times compared to agricultural management.

This contribution aims to investigate plant communities of urban lawns and grasslands throughout the year and to examine whether community composition changes throughout the year and especially after management events. We selected 39 sites within the city of Würzburg, Germany. The sites were categorized according to their management intensity (semi-natural grassland / extensively managed lawns / intensively managed lawns). To account for direct management effects, vegetation surveys were carried out in May and July 2024. In addition, structural vegetation parameters were assessed monthly from May to September 2024 and in February 2025. The degree of urbanization was measured by mapping the land cover within a 600 m radius of the sites.

By including sites with different management techniques and intensities as well as our winter assessments of structural vegetation parameters, we aim to review current management practices and to recommend possible adjustments.

Playing in Nature: Exploring Social-Ecological Networks in Urban Parks and Children's Interactions with Biodiversity

***Zoe Davis*[1]**

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Play in natural environments is widely recognised for having a critical role in enhancing children's cognitive development, motor coordination, and connection to the natural world. While many studies have focused on how play varies across different kinds of natural landscapes, less is known about how local, nearby nature supports children's play and interaction with biodiversity. In this study, we use social-ecological networks (SENs) to examine how children interact with fine-scale biodiversity in six urban parks in Melbourne, Australia. For each park, we conducted detailed plant surveys and recorded a range of plant functional traits to characterise ecological richness in a globally comparable way. We then used behavioural mapping methods to record children's play activities and interactions with the environment. Through SENs, we map the relationships between biodiversity levels, park design, and observed play types. Our study reveals how ecological richness can support a variety of play types. By exploring children's interactions with nature through SENs, this study offers valuable insights for designing more inclusive, ecologically meaningful urban spaces that support both child development and urban biodiversity goals.

Program

Sunday 31.08

09:00 - 13:00 | Second floor | Room 2.006 | 2.007
Workshop W1 EU Nature Restoration Law

- 17:00 | Second floor | Room 2.002
Workshop W2 Acoustic monitoring

Monday 01.09 09:00 - 16:30

09:00 - 13:00 | Groundfloor | Foyer
Registration and IT Desk Room 1.002

10:30 - 13:00 | Second floor | Room 2.003
Workshop W4 Transdisciplinary Research

13:00 - 14:00 | Groundfloor | Room 0.004
Opening of the meeting

14:00 - 16:00 | Groundfloor | Room 0.001
18 Dynamics in insect ecology

- 16:00 | Groundfloor | Room 0.002
35 Biodiversity patterns across scales, taxa and systems

- 16:00 | Groundfloor | Room 0.004
06 Climate change effects on biodiversity

- 16:00 | First floor | Room 1.012
14 Forest structure, dynamics and diversity

- 16:00 | First floor | Room 1.013
30 Soil ecology

- 16:00 | Second floor | Room 2.002
17 Landscapes and habitat features for biodiversity conservation

- 16:00 | Second floor | Room 2.006
29 Plant population biology and seed ecology

- 16:00 | Second floor | Room 2.007
25 Pollinators

16:00 - 16:30 | Foyer
Coffee break

Monday 01.09 16:30 - End

16:30 - 18:30 | Groundfloor | Room 0.001
07 Conservation, management and restoration

- 17:00 | Groundfloor | Room 0.002
35 Biodiversity patterns across scales, taxa and systems

- 18:30 | Groundfloor | Room 0.004
06 Climate change effects on biodiversity

- 18:30 | First floor | Room 1.012
14 Forest structure, dynamics and diversity

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- 17:00 | Second floor | Room 2.002
17 Landscapes and habitat features for biodiversity conservation

- 18:30 | Second floor | Room 2.006
03 Behavioural and movement ecology

- 18:30 | Second floor | Room 2.007
25 Pollinators

17:00 - 18:30 | Groundfloor | Room 0.002
05 Biodiversity trends

- 18:30 | Second floor | Room 2.002
34 Urban ecology

18:30 - 21:30 | Groundfloor | Room 0.004
Ice breaker "Climate and Wilderness Show"
by Jan Haft and the Orchestras of Change

Tuesday 02.09 09:00 - 15:00

09:00 - 10:00 | Groundfloor | Room 0.004
Keynote 1 Flavours of iNEXT *Anne Chao & Pia Bradler*

10:00 - 10:30 | Foyer
Coffee break

10:30 - 11:00 | First floor | Room 1.013
06 Climate change effects on biodiversity

- 12:30 | Groundfloor | Room 0.001
02 Arthropod communities under global change

- 12:30 | Groundfloor | Room 0.002
34 Urban ecology

- 12:30 | Groundfloor | Room 0.004
04 Biodiversity and ecosystem functioning across scales

- 12:30 | First floor | Room 1.012
13 Forest biodiversity: effects of structure and management

- 12:30 | Second floor | Room 2.002
20 Management and restoration in agricultural landscapes

- 12:30 | Second floor | Room 2.006
11 Ecological theory, modelling and statistical analyses

- 12:30 | Second floor | Room 2.007
26 Pollution

11:00 - 12:30 | First floor | Room 1.013
24 Plant traits

12:30 - 14:00 | Foyer
Lunch

- 14:00 | Second floor | Room 2.013
Workshop W5 GFBio's VAT

14:00 - 15:00 | Groundfloor | Room 0.004
Keynote 2 From Rio92 to COP30 *Jos Barlow*

Tuesday 02.09 15:00 - 16:30

15:00 - 16:00 | Groundfloor | Room 0.001
02 Arthropod communities under global change

16:00 | Groundfloor | Room 0.002
15 Forest dynamics under pressure: from ecosystem processes to species responses

- 16:00 | Groundfloor | Room 0.004
04 Biodiversity and ecosystem functioning across scales

- 16:00 | First floor | Room 1.012
23 Plant phenology

16:00 | First floor | Room 1.013
24 Plant traits

- 15:30 | Second floor | Room 2.002
20 Management and restoration in agricultural landscapes

16:00 | Second floor | Room 2.006
11 Ecological theory, modelling and statistical analyses

16:00 | Second floor | Room 2.007
26 Pollution

15:30 - 16:00 | Second floor | Room 2.002
08 Designing agricultural systems for sustainable insect pest management

16:00 - 16:30 | Foyer
Coffee break

16:30 - 17:30 | Groundfloor | Room 0.001
02 Arthropod communities under global change

-17:30 | Groundfloor | Room 0.002
15 Forest dynamics under pressure: from ecosystem processes to species responses

- 17:30 | Groundfloor | Room 0.004
04 Biodiversity and ecosystem functioning across scales

- 17:30 | First floor | Room 1.012
33 Tree traits, stress, and biodiversity

- 17:30 | First floor | Room 1.013
28 Resilient forests under climate change: integrating perspectives of ecologists, modelers, and stakeholders

Tuesday 02.09 16:30 - End

16:30 - 17:30 | Second floor | Room 2.002
08 Designing agricultural systems for sustainable insect pest management

-17:30 | Second floor | Room 2.006
11 Ecological theory, modelling and statistical analyses

- 17:30 | Second floor | Room 2.007
09 Diversity below species level

17:30 - 19:30 | Rooms 1.004 | 1.005 | 2.011 | 2.012 | 2.013
Poster Session

19:30 - 21:00 | Groundfloor | Room 0.004
Film screening and artist talk "I don't hear bugs in the city"

19:30 - 20:30 | Rooms 1.012 | 1.013 | 2.002 | 2.003 | 2.004 | 2.006 | 2.007
GfÖ working group meetings

Wednesday 03.09 09:00 - 14:00

09:00 - 10:00 | Groundfloor | Room 0.004
Keynote 3 Living on the edge *Jean-Philippe Lessard*

10:00 - 10:30 | Foyer
Coffee break

10:30 - 12:30 | Groundfloor | Room 0.004
GfÖ Award Session & Award Keynote

12:30 - 14:00 | Foyer
Lunch

- 14:00 | First floor | Room 1.013
Meeting of BAAE and AK spokespersons

- 14:00 | Second floor | 2.002
Workshop (discussion): Women in Science - Challenges, Solidarity, and Solutions

14:00 - 16:00 | Groundfloor | Room 0.001
28 Resilient forests under climate change: integrating perspectives of ecologists, modelers, and stakeholders

- 16:00 | Groundfloor | Room 0.002
16 Grasslands: conservation, management, restoration

- 16:00 | Groundfloor | Room 0.004
19 Macroecology and biogeography

Wednesday 03.09 14:00 - End

14:00 - 16:00 | First floor | Room 1.012
22 Multi-trophic interactions under stress

- 16:00 | First floor | Room 1.013
08 Designing agricultural systems for sustainable insect pest management

- 16:00 | Second floor | Room 2.006
10 Ecological communities in forests: deadwood and decomposition

- 16:00 | Second floor | Room 2.007
33 Tree traits, stress, and biodiversity

16:00 - 16:30 | Foyer
Coffee break

16:30 - 19:00 | Groundfloor | Room 0.001
GfÖ general meeting

19:30 - Midnight | staatlicher Hofkeller | Residenzplatz 3, 97070 Würzburg
Winetasting in the historical Hofkeller "World heritage site"

Thursday 04.09 09:00 - 10:30

09:00 - 10:00 | Groundfloor | Room 0.004
Keynote 4 *Listening to nature* Zuzana Buřivalová

10:00 - 10:30 | Foyer
Coffee break

10:30 - 12:30 | Groundfloor | Room 0.001
36 Ecological communities: change, variation and human impacts

- 12:30 | Groundfloor | Room 0.002
16 Grasslands: conservation, management, restoration

- 12:30 | Groundfloor | Room 0.004
01 Accelerating farming system transition through agroecology

- 12:30 | First floor | Room 1.012
32 Traits and functional diversity

- 12:30 | First floor | Room 1.013
19 Macroecology and biogeography

Thursday 04.09 10:30 - 15:00

10:30 - 12:30 | Second floor | Room 2.002
27 Reconciling forest protection, forest conservation and forest management in the climate crisis

- 12:30 | Second floor | Room 2.006
12 Experimental plant ecology

- 12:30 | Second floor | Room 2.007
31 Species interactions and interaction networks

11:00 - 12:30 | First floor | Room 1.013
21 Novel methods in monitoring

12:30 - 14:00 | Foyer
Lunch

- 14:00 | Groundfloor | Foyer
Active break: Biodiversity walk

12:30 - 14:00 | Groundfloor | Room 0.001
45 How to get published in in Ecology?

14:00 - 15:00 | Groundfloor | Room 0.004
Keynote 5 Agroecology in a changing world *Lorenzo Marini*

15:00 - 16:00 | Groundfloor | Room 0.001
36 Ecological communities: change, variation and human impacts

- 16:00 | Groundfloor | Room 0.004
01 Accelerating farming system transition through agroecology

- 16:00 | First floor | Room 1.012
32 Traits and functional diversity

- 16:00 | First floor | Room 1.013
21 Novel methods in monitoring

- 15:30 | Second floor | Room 2.002
27 Reconciling forest protection, forest conservation and forest management in the climate crisis

- 16:00 | Second floor | Room 2.006
12 Experimental plant ecology

Thursday 04.09 15:00 - End

15:00 - 16:00 | Second floor | Room 2.007
31 Species interactions and interaction networks

16:00 - 16:30 | Foyer
Coffee break

16:30 - 18:30 | Rooms 1.004 | 1.005 | 2.011 | 2.012 | 2.013
Poster Session

18:30 - 19:30 | Room 0.004
Closing ceremony

20:00 - 02:00 | Odeon | Augustinerstraße 18, 97070 Würzburg
GfÖ Club Night

Friday 05.09

09:00 - 17:00 | outside | Main train station Würzburg
Excursion 1 Volkacher Main loop, quince nature trail, vineyards, dry grasslands and pollinators

- 17:00 | outside | Main train station Würzburg
Excursion 2 Nutrient-poor grassland and coppice with standards forests of Bad Windsheim– sun-drenched habitats

- 17:00 | outside | Main train station Würzburg
Excursion 3 The University Forest Sailershausen – high diversity in tree species and research projects

- 17:00 | outside | Main train station Würzburg
Excursion 4 Grainberg-Kalbenstein and Saupurzel nature reserve (Main-Franconian dry grassland between Karlstadt and Gambach)

09:30 - 12:30 | outside | Franconia fountain in front of the Würzburg Residence
Excursion 5 The Würzburg residence and historical city centre

Public transport within Würzburg

From main train station (Hauptbahnhof) to conference location
Line 14 Hauptbahnhof to Gerbrunn
Line 114 Hauptbahnhof to Universität Sportzentrum

From City to conference location
Line 10 Sanderring to Hubland Nord/Sprachzentrum
Line 34 crossing Heidingsfeld/Sanderau/Frauenland/Uni Hubland/Gerbrunn/Lengfeld

Conference location

Gebäude Z6 Hubland Süd
(Zentrales Hörsaal- u. Seminargebäude)

JMU Würzburg
Am Hubland
97074 Würzburg

Imprint

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Host of this years conference **Julius-Maximilians-Universität Würzburg**

Local Scientific Comittee

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Christian Hof & Malte Jochum (Department of Global Change Ecology)
Ingolf Steffan-Dewenter & Thomas Schmitt (Department of Animal Ecology and Tropical Biology)
Stefan Dech (Department of Remote Sensing)

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