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Abstract book

Contents

Plenary Sessions

The perceived trade-off between climate mitigation and biodiversity in boreal forests

Bengt-Gunnar Jonsson, Mid Sweden University

We face two parallel crises, climate change and biodiversity loss. Both threaten our society and ecosystem functioning. The boreal forests in the Nordic countries harbor unique natural values and at the same time may play a role for climate mitigation. A current narrative is that we need to choose whether to use these forests to provide biomass for substitution of fossil sources or to protect them for biodiversity conservation. That is, that there is a clear trade-off to consider and where the arguments talk in favor for increased management intensity and harvest levels to move from a fossil-based economy to a bioeconomy. I will challenge this perceived trade-off as the potential carbon sequestration in Nordic boreal forests outperform the benefits from substitution for the critical coming decades. Lower harvest rate would provide significant climate benefit and at the same time allow options for improving biodiversity status. This window of opportunity should be used to identify means for improving the green-infrastructure through landscape level planning as well as time for developing alternative management that support forest landscape multifunctionality.

From pattern to process in community ecology: challenges and prospects

Nerea Abrego, University of Jyväskylä

A central aim of community ecology is to gain mechanistic understanding about how different processes jointly create variation in natural communities and to use such understanding for making predictions about how the ongoing global change will impact biodiversity. However, as I argue in this talk, community ecology currently lacks a general, quantitative synthesis of the relative contributions of the processes structuring communities, hindering the transformation of community ecology into a predictive science. One important reason for this is that most empirical studies are based on non-manipulative observational data, whereas manipulative experimental data would be needed to yield undisputable causal inference on the underlying processes. Furthermore, while theoretical metacommunity frameworks assume discrete local communities linked by dispersal, there is high disparity among empirical studies in how (and if) the boundaries of local communities are defined. This mismatch between theoretical and empirical research hampers the possibilities to synthesize and compare the results from empirical studies, especially given that the relative effects of different assembly processes vary across spatial scales. In my talk, I derive on case studies to illustrate the current mismatch between theory and data, and suggest a framework for how these two could be more effectively linked in the future.

The need and processing of information for nature solutions

Aino Juslén, Director of Nature Solutions Unit, Syke

The spread of open data and open science principles and the development of digital systems have allowed enormous opportunities in the sharing and research of different types of nature data. In Finland, especially, the collection and sharing of species information is advanced. Currently, integration of species information data from Finnish Biodiversity Information Facility (FinBIF) with habitat type and remote sensing data from Finnish Ecosystem Observatory (FEO) is being developed. In addition to the diversity of data types and technical challenges, the readiness of different parties to use information in the practical work against nature loss needs to be developed. In my presentation, I describe the flow of observation data from field to research, land use planning and decision-making in Finland and at the EU level, both in the present moment and in future visions.

Beyond genome scans: The “what”, “why” and “how” behind a large-effect locus linked with Atlantic salmon age at maturity

Craig Primmer, University of Helsinki

A common aim in biological research, linking genotype with phenotype, has seen dramatic taxonomic diversification in recent years as new technologies have enabled genomic approaches collectively known as ‘genome scans’ to be applied in almost any species. However, such diversification is not as apparent when it comes to understanding the biological processes behind identified associations, especially considering loci associated with life-history traits. Age-at-maturity is closely linked to fitness in many species, with the timing of maturation often involving trade-offs. For example, delayed maturation can lead to larger body size, higher fecundity and/or increased offspring survival, but longer generation times can carry an increased mortality risk prior to reproduction by prolonging pre-maturity life stages. Genome-wide association studies (GWAS) in Atlantic salmon earlier identified a single locus that associates strongly with age-at-maturity (sea-age), and a single nucleotide polymorphism (SNP) located near the gene vgll3 explained 39 % of the phenotypic variation in maturation age. The relatively simple genetic architecture of this trait combined with the features of Atlantic salmon as a model system offer a good opportunity to better understand the ecological drivers and molecular mechanisms underlying this locally adapted life history trait. In this talk, I will summarize the group’s recent research investigating what phenotypes are influenced by vgll3, why those differences affect maturation age, how these changes are induced at the molecular level and how this information can be used in salmon conservation and management.

Oral presentations

Parallel session 1: Anthropogenic effects #1

The responses of an aquatic keystone detritivore to chemical pollution

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Many environmental stressors experienced by natural populations are caused by anthropogenic change, such as chemical pollution. These stressors can cause strong natural selection, modify ecological interactions between different organisms, and manifest as direct and indirect effects. Here, we assessed the effects of fungicides on the freshwater isopod *Asellus aquaticus*, a keystone detritivore. Fungi play an important role for the diet of isopods as they break down complex cell walls of the plant material that the isopods feed on, and also act as a protein source. Host associated fungi (e.g. on the body and gut) could also be important symbionts of *A. aquaticus*. Hence, fungicides could affect *A. aquaticus* in two ways: directly via toxicity or indirectly by modifying dietary quality. To test direct and indirect effects of the fungicide Tebuconazole, a fully factorial laboratory experiment was conducted on juvenile *A. aquaticus*, which were reared over 4 weeks at different concentrations of tebuconazole and fed leaf (*Alnus glutinosa*) discs inoculated at different levels of the fungicide. The responses were measured as growth rates, changes in pigmentation, feeding rates, and survival.

Endocrine Disrupting chemicals in Finnish breeding female eiders and their eggs

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Human and wildlife populations are exposed to multiple contaminants worldwide. Endocrine disrupting chemicals (EDCs) cause adverse effects on behavior, fecundity, growth, survival and disease resistance. The DISRUPT project (sites.utu.fi/disrupt/) investigates EDC exposure and their biological effects in breeding female waterbirds and their offspring. We particularly focus on the Common Eider *Somateria mollissima*. During the past decades the Baltic breeding population of common eider has largely declined. A parallel increase in adult male sex ratio bias has been observed. In addition, increasing breeding failure have been observed at the egg/hatchling stage. We have established that Finnish breeding female ducks are contaminated by a mixture of EDCs including per- and polyfluoroalkyl substances (PFASs), some of emerging concern, phthalates, benzophenones, and lead (Pb). We also show a transfer of EDCs from the females to their eggs.

Molecular screening reveals that wind turbine presence causes lower apparent survival in white-tailed eagles

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The expansion of wind power is a common measure of climate action worldwide. In Finland, there are plans to construct multiple new turbines over the next years. However, wind turbines may negatively impact wild animals. A difficulty in assessing how turbines influence populations is the difficulty in estimating their effect on different demographic parameters. While the white-tailed eagle *Haliaeetus albicilla* is a success story of conservation in Finland, it is at threat of colliding with the rotor blades and estimates of demographic effects of wind power construction are needed. The White-tailed Eagle work group has been collecting adult feathers from nests for long-term genetic identification. By using 14 nuclear microsatellites, we have identified individuals at the same nests between years, but also movement between nests, and relate this to the presence of turbines. Our preliminary results indicate that the presence of turbines negatively affects white-tailed eagles by leading to ~7% lower apparent survival rates. Future analyses will help us disentangle mortality from displacement and allow us to make predictions about the large-scale impact on the population in Finland.

The presence of wind turbines repels bats in boreal forests

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Impacts of wind power on bats are usually evidenced by fatalities. However, wind turbines may affect use of the surrounding habitats by bats. Little is known about such impact, especially in the European boreal region. We studied the consequences of operating wind turbines on the presence of bats. Using passive recorders at 84 sampling sites placed between 0 to 1000 metres from turbines, we monitored bat activity over four months at 7 Finnish wind farms located in forests. Our results show higher presence at 600 m and further from turbines for *Eptesicus nilssonii*, and higher presence at 800 m and further for *Myotis spp*. This indicates a potential loss in habitat quality around wind turbines, e.g., a greater number of open areas in forests, which are unfavourable to Myotis species. This lower presence could also be an indication for active avoidance of the wind turbines from the bats. These results show undeniable impacts of wind power on bats in Finland, and enforce the requirement for better consideration of bats during the development of such projects in Finland. We also call for investigation on the causative mechanisms of the observed effect, to better facilitate mitigation.

Glow-worm reproduction under light pollution: the effect of artificial light color on mate attraction success

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Light pollution, or artificial light at night, is an environmental problem that threatens many nocturnal organisms worldwide. In the European common glow-worm (*Lampyris noctiluca*), reproduction relies on darkness, as sedentary females use bioluminescence to attract flying males. Previous studies show that broad-spectrum white artificial light disrupts glow-worm mate attraction, but little is known about the effects different light colors. In this study, we experimentally investigated the effect of artificial light color on the mate attraction success of imitation females in the field. Imitation females were illuminated from above by either blue, white, yellow, or red artificial light, or no artificial light (dark control). Mate attraction success depended on the color (wavelength spectrum) of artificial light, with short wavelength (blue and white) light decreasing it more than long wavelength (yellow and red) light. Thus, spectral tuning of artificial lights can be an effective measure for mitigating the ecological effects of light pollution.

Parallel session 2: Movement, migration & mobility

The effects of land-use on dispersal dynamics of alien fish species

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Numerous species worldwide have been intentionally introduced to reinforce local fisheries. Despite the intense harvest, by dispersing frequently to new environments, they set a global threat to ecosystem functioning and biodiversity. A better understanding of species and environment dependent dispersal strategies let us to predict potential distribution of alien species, and hence optimise management practises. We used electrofishing data from the past three decades from Kemijoki headwaters to model the dispersal dynamics of introduced brook trout and local brown trout. We used a spatial stream network modelling approach to estimate the effects of land-use, habitat preferences, and past species abundance and occupancy in the fish communities. We also tested if the dispersal of brook trout among the tributaries was intra- or interspecific density dependent. Obtained dispersal strategy can be species specific, where alien species with broader niche requirements can utilise habitats that are less occupied, unfavourable, or unsuitable for native species, and there produce a sustainable population. Strong native populations may inhibit the dispersal success of the alien species.

Functional groups shape the size and function of spores across the fungal kingdom

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Theory predicts that spore size influences the success of fungi in dispersing and establishing in new habitats, yet a synthesis of empirical data testing this prediction across the fungal kingdom has not been done. Here we performed such a synthesis by first assembling a database of fungal offspring morphology covering over 25,000 species. We found that spore size varies by over eight orders of magnitude in the kingdom. Using this data, we then tested: a) whether spore size of symbiotic fungi have a distinct size compared to free-living fungi reflecting differences colonizing a living host vs dead organic matter; b) whether spore size influences the worldwide distribution of species depending on symbiotic status. We found that symbiotic fungi indeed have distinct sizes to free-living fungi particularly in the Ascomycota compared to the Basidiomycota. We also found smaller spore sizes led too broader global distribution of fungi but only among free-living fungi. Our findings suggest that evolutionary shifts have influenced spore size and its function differently according to functional lifestyles.

Natal dispersal behaviour of the white-tailed eagle revealed by molecular genotyping

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Natal dispersal refers to the distance between the site of birth and the site of first breeding. Drivers of natal dispersal in species with high adult site-fidelity are important to understand as they shape spatial trends and can cause shifts in the range of species. The Finnish population of the white-tailed eagle (*Haliaeetus albicilla*, WTE) has recovered from near extinction to over 600 pairs. We study natal dispersal in this population to reveal processes behind its growth and to get insights on how the population might expand in the future. We have identified nesting WTE based on resightings, and genotypes obtained from DNA extracted from feathers. Nestlings were sampled during ringing and feathers shed by adults were collected from nest sites. Natal dispersal is determined by matching nestling genotypes to adult genotypes. Our results reveal that WTE often return to their natal area for nesting, but that females disperse further than males. Furthermore, high population density reduces dispersal distance, likely because WTE can use social information to identify good nesting areas. Future analyses will reveal by which habitat characteristics WTE choose their breeding site.

Who moves? Assortative mating and fitness benefits of exploratory behaviour at the range front

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Although dispersal propensity was once thought random, we now know that exploratory and aggressive individuals can be more likely than others to move. This has implications for how range front populations deal with novel resources and threats, and their continued movement into new areas. However, whether spatial sorting of behavioural phenotypes persists beyond the colonizing generation will depend in part on assortative mating. To test this hypothesis we first developed a field-ready standardized method to assay behaviour (exploration, social response) of a population of reed warblers (*Acrocephalus scirpaceus*) breeding at their northern range edge in Finland. We then used latent factor analysis to derive repeatable variables (N = 337 birds), before comparing 81 pairs where both the male and female had been caught at the nest. Here we will report whether there is evidence for assortative mating, and whether more exploratory or aggressive individuals, or pairs, have greater reproductive success, and discuss the implications for future population changes and range expansions.

The response of bat activity to prevailing weather conditions depends on latitude

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Bats are among the least monitored vertebrate groups in Finland despite their diversity, numbers and impact on food webs. The first long term monitoring project for bats in Finland was established in 2015 and, as a result, the large scale spatio-temporal patterns of bat activity have subsequently been described. In this follow-up study, we aim to explain daily variations in bat activity with prevailing weather conditions and latitude using the existing dataset. We predict that weather has greater impact on bat activity at southern latitudes compared to the north where bats have to make the most out of the short season and limited hours of darkness. Our study provides insight into behavioural ecology of the most common bat taxa, and also helps in understanding consequences of climate change to bat diversity in Finland.

Parallel session 3: Methodological advances #1

Who eats bladderwrack? A citizen science study with an iconic Baltic Sea species

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Citizen science (i.e. engaging citizens in scientific research) often allows studying processes on large geographic scales. It has a long tradition e.g. in ornithology but it still rarely used in marine ecological research. In this study, citizen scientists collected information on bladderwrack (*Fucus vesiculosus*) associated invertebrate fauna along the Finnish Baltic Sea coast in 2020-2021. We used the data to assess geographic and temporal patterns in invertebrates along the coastal eutrophication gradient. We also compared the data collected with citizen science and traditional scientific methods. The data collected by the citizen scientists were generally of high quality. Abundances of Harris mud crab, amphipods, gastropods, and blue mussel varied along the eutrophication gradient, with the highest total abundances found in the areas with the lowest eutrophication status. Abundances of isopods varied between the study years. The results indicate that citizen science can be an efficient method even in marine research, especially when studying larger taxa.

Integrated modelling of carbon processes and biodiversity targets in Finland

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We have carried out modelling of both anthropogenic emissions and forestry measures in Finland and identified forested areas important for biodiversity protection based on spatial prioritization. Scenarios until 2050 based on mitigation measures of the national climate and energy strategy, forestry policies and predicted climate change have been used. We evaluate how implementation of these scenarios would affect greenhouse gas fluxes, carbon storages, and the possibility to reach the Finnish carbon neutrality target. Potential new forested areas for biodiversity protection according to the EU 10% target would provide a significant carbon storage (426-452 TgC) and sequestration potential (12 to 17.5 TgCO2eq a-1) by 2050, indicating complementarity of emission mitigation and conservation measures. Our results can be utilized for integrating climate and biodiversity policies, accounting of ecosystem services for climate regulation, and delimitation of areas for conservation.

Evaluation of empirical tree growth model for continuous cover forestry & climate change scenarios

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Forest growth models employed in Fennoscandia were generally targeted at rotation forestry (RF) stands, using age as key predictor. Uneven aged and irregular stands (i.e. continuous cover forestry, CCF) are becoming of increasing importance especially for biodiversity reasons. New models suited for both RT and CCF (i.e. age-independent) have been developed. However, the ongoing climate crisis will strongly affect boreal regions and their forest growth. Our research aimed at 1) calibrating a new age-independent model with more inclusion of climatic variables; 2) independently validate it together with other age-independent published models; 3) investigating their responses under different climate change scenarios. Results showed both new and existing models performed well in both RF and CCF forest structures. The predicted climate change scenarios increased forest growth in all models, although with implausible high growth in some cases for the highest warming scenario. Concluding, age-independent models can be used both in RF & CCF for long-term simulations comparing growth and biodiversity values. Adequate response to climate change must be included in the model structures.

Biotic and abiotic controls of key ecosystem processes in the tundra

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Greenhouse gas (GHG) exchange between the biosphere and atmosphere is a critical ecosystem process, controlling also global climate feedbacks. These GHG fluxes play an increasingly important role in the Arctic, where the rapid climate change might accelerate the release of GHG emissions to the atmosphere. However, the magnitudes and drivers of the three main GHG fluxes of carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are poorly understood and rarely studied together. Here, we explore the spatial patterns and drivers of GHG fluxes during the peak growing season (July) in sub-Arctic Finland. Our results show that this region was on average a net GHG sink. This sink was driven by plant CO2 uptake, however widespread CH4 uptake in drier upland vegetation types (86 % of the region) was also evident. Average N2O fluxes were negligible. CO2 fluxes were controlled primarily by annual average soil temperature, vegetation type, CH4 fluxes by soil moisture and vegetation type, and N2O fluxes by soil C/N. Our results thus show that the key ecosystem processes in the Arctic are driven by various abiotic and biotic conditions.

Parallel session 4: Responses to environmental change

Seed limitation interacts with biotic and abiotic causes to constrain novel species' impact on community biomass and richness

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Seed limitation can narrow down the number of coexisting plant species and limit plant community productivity. It is also likely to constrain community responses to changing environmental and biotic conditions. In a 10-year full-factorial experiment of seed addition, fertilisation, warming and herbivore exclusion, we tested how seed addition alters a tundra grassland community richness and biomass, and how its effects depend on seed origin and biotic and abiotic context. We found that seed addition increased richness in all treatments, and increased plant community biomass depending on nutrient addition and warming. Novel species, originally absent from the communities, increased biomass the most, especially in fertilised plots and in the absence of herbivores, while adding seeds of local species did not affect biomass. Our results show that dispersal limitation can constrain the establishment of novel species and their effects on community biomass, and demonstrate that these relationships are contingent on trophic interactions and environmental conditions.

Recent range shifts of moths, butterflies, and birds are driven by the breadth of their climatic niche

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Species are altering their ranges as a response to climate change, but the magnitude and direction of observed range shifts vary among species. The ability to persist in current areas and colonize new areas plays a crucial role in determining which species will thrive and which decline as climate change progresses. As long-term selection to past climates have shaped species' tolerance ranges, metrics describing species' contemporary climatic niches may provide a means for understanding responses to climate change. We provide a first-filter test of the effect of climatic niche dimensions on shifts in the leading range edges in three relatively well-dispersing species groups. Based on the realized changes in the northern range edges of 383 moth, butterfly, and bird species over c. 20 years, we show that moths and birds occupying a narrower thermal niche and butterflies occupying a broader moisture niche show stronger shifts towards the north. Our results indicate that past evolutionary processes that have formed a continuum of species that differ in their climatic tolerance, may currently dictate how species respond to rapid anthropogenic climate change.

Climate change reshuffles northern species within their niches

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Climate change is a pervasive threat to biodiversity. While range shifts are a known consequence of climate warming contributing to regional community change, less is known about how species' positions shift within their climatic niches. Furthermore, whether the relative importance of different climatic variables prompting such shifts varies with changing climate remains unclear. Here we analysed four decades of data for 1,478 species of birds, mammals, butterflies, moths, plants and phytoplankton along a 1,200 km high latitudinal gradient. The relative importance of climatic drivers varied non-uniformly with progressing climate change. While species turnover among decades was limited, the relative position of species within their climatic niche shifted substantially. A greater proportion of species responded to climatic change at higher latitudes, where changes were stronger. These diverging climate imprints restructure a full biome, making it difficult to generalize biodiversity responses and raising concerns about ecosystem integrity in the face of accelerating climate change.

The potential for evolutionary rescue in an arctic seashore plant maladapted to altered climatic conditions

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Climate change forces natural populations that cannot track suitable conditions by dispersal to adjust through plastic responses and/or to adapt evolutionarily. Here, we study southern and northern varieties of an arctic seashore plant, *Primula nutans ssp. finmarchica*, which is confined to seashores at its northern range edge, and already shows signs of maladaptation to altered climatic conditions. We evaluate the potential for these primrose populations to evolve through time to facilitate survival in the novel conditions (i.e. the potential for evolutionary rescue) utilizing manual crossing experiments and quantitative-genetic analyses. Our data indicate five times higher evolvability in vegetative than floral traits, and that floral and vegetative traits can evolve independently. Although possibly rapid evolutionary responses in growth may somewhat alleviate the documented climate maladaptation, the reduced evolutionary potential of flowers may slow down evolution in response to potentially rapid climate-induced changes in pollinator communities, compromising reproductive fitness and reducing the likelihood of evolutionary rescue in these threatened primrose populations.

The duality of climate and habitat change drives moth communities' changes in Finland

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Global changes are widely affecting species and communities across multiple taxa and at different scales. Despite extensive studies on the subject, evaluating the impact of climate and habitat changes is still complex. Life history traits, species distribution, and habitat characteristics are key components to understanding how species can overcome environmental changes as they are interconnected to species' ability to disperse. Using the Finnish moth long-term monitoring dataset, we evaluated how both climatic and habitat information drive moth communities' responses. We used the Hmsc framework and applied recently developed conditional variance partitioning (Shulz et al., 2021) to evaluate the relative importance and uncertainty of environmental drivers across sampling sites and species traits. We showed that site characteristics (habitat disturbance), as well as species-host plant affinities (tree and shrubs), explain both moth occurrences and community diversity current changes as well as potential community responses under future environmental scenarios.

Parallel session 5: Biodiversity and conservation

The effect of forest integrity on wildlife abundance in Finland

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Human disturbance alters the structure, composition and function of forests reducing their integrity worldwide. For the first time, we tested the effectiveness of the global Forest Landscape Integrity Index (FLII) to understand the relationship between variation in the ecological integrity of Finnish forests and differences in the occurrence and abundance of large mammal species recorded in nation-wide winter track surveys. Results using 236,332 tracks from 3897 transects indicate that species native to the boreal forests have a greater abundance in higher-integrity forests (e.g., mountain hare, lynx, moose, and wolverine) while invasive species were more common in lower–integrity forests, indicating a greater adaptive capacity of these species in areas with higher human impact. Our results have broad implications as they are the first to link the global FLII to biotic data and thus, are an important step in validating FLII for use in conservation. Linking FLII with native species abundance will make it possible to identify threshold values to set clear conservation goals for forest management, the conservation of native species and slowing the spread of invasive species.

The effects of peatland drainage and restoration on tardigrade abundance and diversity

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Boreal peatlands are ecologically unique, endangered, moss rich ecosystems. Tardigrades are common moss-living micrometazoans. Yet, nothing is known about the effects of drainage and subsequent restoration on peatland tardigrade ecology. We collected 139 moss samples from 7 bogs in Central Finland: 3 pristine, 2 drained, 2 restored 11 years ago. We found 433 tardigrades belonging to 11 genera. Compared to pristine bogs, tardigrade abundance and number of genera was higher in drained (abundance 20x, genera 2x) and restored (abundance 9x, genera 1.4x) bogs. Moreover, the most common genus differed between pristine and the other two types of bog. We conclude that peatland drainage shifted tardigrade abundance and community composition closer to what is found in forests. The latter appear to match the patterns seen in peatland vegetation, especially in bryophyte, across management regimes. Thus, pristine bogs may host specialized tardigrade taxa that were lost due to drainage and did not recover 11 years post restoration. More systematic studies on this poorly known phylum in endangered peatland habitats are needed.

The iratebirds citizen science -project: a dataset of birds' visual aesthetic attractiveness to humans

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Amidst a global biodiversity crisis, shedding light on the factors that make humans like one species or another can inform conservation actions, e.g. by leveraging flagship potential, and help identify threats. A part of how humans perceive other species is due to their aesthetic attractiveness, or lack thereof, to us. We created the iratebirds -citizen science project to understand which bird species are visually more aesthetically attractive to humans. The data are from an internet browser-based questionnaire (iratebirds.app), where people were asked to evaluate their reaction to the appearance of a bird on a linear scale of 1-10 (with hearts as symbols on the scale). The ratings were based on the best-quality photographs from the Cornell Lab of Ornithology's Macaulay Library database which hosts user-submitted photographs of the world's bird species. The final data set covers the raw data as well as modeled visual aesthetic attractiveness scores for 11 319 bird species and subspecies globally, based on 6 212 respondents from tens of home countries. This is the first such attempt to quantify the overall visual aesthetic attractiveness of all the bird species to humans.

High stumps as breeding and nesting sites for birds in boreal forests

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Artificial high stumps are increasingly made by forestry companies to compensate the deficit of dead wood in intensively managed boreal forests. However, their significance for birds benefiting from decaying wood is poorly known in Finland. We studied the use of birds of 69 artificial and 78 natural high stumps in Central Finland. The stumps were of the Norway spruce or birch, and they situated in old or recent logging areas or in thinned forests. We found from stumps 297 feeding holes and 47 nesting holes that were mainly made by woodpeckers. The number of feeding and nesting holes were higher when the stump was higher and thicker. Furthermore, feeding and nesting holes situated higher above ground when the stump was higher. Stumps with less bark and situating close to forest edge had more feeding holes. Effects of the tree species, stump type or logging type on the number of feeding or nesting holes were not significant. Our results show that birds use both artificial and natural high stumps. However, most signs were of common species. For the benefit of birds, forest managers should make higher artificial stumps of thicker trees close to forest edge in logging areas.

Freshwater fish conservation in insular ecosystems: the first study of the Critically Endangered European eel in Madeira

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Despite efforts to recover the European eel (*Anguilla anguilla*), the species' stocks continue to dwindle throughout its range. Surprisingly, there is still a critical knowledge gap for the Macaronesia islands where the species represents the only native freshwater fish. In this multi-approach study, we characterise the eel population and investigate its status in Madeira Archipelago. Historical records were gathered from biodiversity databases, natural history museums and literature. Past records were than compared with the species' current spatial distribution. For that, we conducted a questionnaire survey directed to local citizens, complemented with electrofishing in 10 streams of Madeira Island. Historical information confirms the existence of resident individuals since 1825 and contributes with cues about their adaptation to local conditions. While the eel is still widely distributed across Madeira Island, its population is found mainly downstream, possibly due to human-imposed conditions. The results of this study contribute crucial baseline information for the species' insular preservation and to a broader view of challenges faced by this Critically Endangered species.

Parallel session 6: Community ecology #1

Macrosystem community change in lake phytoplankton and its implications for diversity and function

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The combined effects of eutrophication, land-use and climate change are major threats to aquatic ecosystems, their biodiversity and integrity in sustaining ecosystem functions. Disentangling the mechanisms by which environmental change contributes to community assembly processes and species niches remains challenging, especially at macro-ecological scales. We leverage phytoplankton community data from 853 lakes along a 1200 km latitudinal gradient, monitored over four decades, to quantify the spatio-temporal and scale-dependent environmental impacts on species niches and assembly processes while accounting for species traits and phylogenetic constraints. Our results demonstrate the emergence of novel and widespread community composition clusters in previously more uniform communities, with cluster-specific community trait profiles indicating functional differences. A robust phylogenetic signal of species responses to the environment indicates strong niche conservatism and low taxonomic dispersion. Our findings imply profound spatio-temporal structuring of species co-occurrence patterns and highlight emerging functional differences of lake phytoplankton communities.

Year-round changes in fish community structure in boreal, humic lake

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Seasonal changes in temperature, light and oxygen are pronounced in boreal lakes. Large boreal lakes are inhabited by various fish species with different thermal, light and oxygen optimums, but we know little about year-round activity and habitat selection. We asked how the catch proportion of different fish species varies throughout the year, how the catch per unit effort (CPUE), size and condition factor change and what are the underlying variables behind putative changes? Fish were sampled with gillnets from three main lake habitats. Water quality measurements were also taken. Roach (*Rutilus rutilus*) was the most abundant fish, followed by perch (*Perca fluviatilis*). Roach dominated biomass catch, followed by pikeperch (*Sander lucioperca*). Generally, CPUE was the lowest during winter and the highest in summer. Condition of fish peaked in summer. Caught fish were mainly larger in winter and smaller in summer. Variables explaining CPUE changes were condition factor, temperature, nitrogen concentration and pH. August has been the prime month of fish research, but our study shows that it might not provide optimal view of species composition, CPUE, size and habitat selection of fish.

Drainage-induced browning causes loss and change of benthic biodiversity and reduction of biofilm nutritional quality in headwater streams

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Increased concentrations of terrestrial-derived dissolved organic carbon (DOC) are causing freshwater browning. In forestry-intensive regions, browning is greatly accelerated by peatland drainage. In a stream mesocosm experiment, we explored the effects of browning on the biomass and nutritional quality (polyunsaturated fatty acid (PUFA) content) of the periphytic biofilm. Browning reduced algal biomass and availability of essential PUFAs but increased the availability of long-chain saturated fatty acids. A field survey of 45 streams repeated the same pattern: biofilm quality decreased significantly with increasing DOC. We also explored the impacts of browning on benthic biodiversity along a wide gradient of DOC concentrations (3.6 to 27 mg L-1) in 63 streams impacted by drainage or peat production. DOC was a prime determinant of invertebrate diversity, with the strongest negative response in algal scrapers. We also detected an abrupt invertebrate community shift at 12-13 mg DOC L-1. Browning thus induces both a change in benthic biodiversity and a dramatic reduction in the nutritional quality of the stream biofilm, likely reducing trophic transfer efficiency in stream food webs.

Microbial rarity in stream networks: different assembly processes in the rare vs. common biosphere

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Microbial communities are typically dominated by rare species that represent the majority of biodiversity and perform vital ecological functions. We explored this 'rare biosphere' using data on bacterioplankton communities at 13 sites of a boreal stream network across three years, with five temporal replicates each year. Using the relative mean abundance of 0.01 as the rarity cutoff, we observed 565 abundant and 10 657 rare taxa. Bacterial communities consisted mainly of permanently (35 %) or transiently (60%) rare species. Conditionally rare (mostly rare, occasionally abundant) taxa only consisted 3% of all bacterial taxa. Both common and rare taxa exhibited a reduction in species richness along the flow path, but significantly so only for rare taxa. Both rare and abundant subcommunities differed strongly between the upmost headwaters and downstream sites. Rare taxa were mainly assembled by homogenizing selection whereas the common biosphere was driven by dispersal-related stochasticity or undominated processes. Our data show that the rare and common bacterial biosphere in streams display similar spatial and temporal patterns but are controlled by different ecological processes.

Assessment of agro-ecological community characteristics through food webs

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Understanding the interactions in ecological communities allows assessment, and even prediction, of how communities respond to natural and anthropomorphic impacts. The trophic interrelationships of invertebrates within a community often form an extensive feeding web composed of several trophic levels. Food webs can be constructed directly from empirical field studies or, alternatively, by using literature records to map all the trophic interrelationships in natural and agro-ecosystems. For terrestrial communities, this includes the plants, herbivores and natural enemies associated with these herbivores. The food webs that we recently constructed for coconut and date palm agro-ecosystems infer large-scale community ecology consequences of shared and non-shared natural enemies, such as the relative importance of direct and apparent competition. The plant-insect community characteristics of these agro-ecosystems are explained with emphasis on alternative pest management strategies against *Opisina arenosella* and *Batrachedra amydraula* respectively. We also discuss the utility of the less labour-intensive literature-based approach as an alternative to field-based studies.

Parallel session 7: Methodological advances #2

Can we infer spatial and temporal scales of interspecific interactions from co-occurrence data?

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Spatiotemporal variation in species communities is generated by the assembly processes environmental filtering, biotic interactions and dispersal. Inferring assembly processes from co-occurrence data is a much-debated challenge in community ecology. Recent methodological studies have focused on identifying assembly processes from co-occurrence data using bipartite graphs or joint species distribution models. However, the spatial and temporal scales of abiotic and biotic interactions have received less attention. In our study we simulated competitive metacommunities with an agent-space model operating in continuous time and space using processes that are directly linked to the metacommunity paradigms. We applied a virtual ecologist approach to sample spatiotemporal co-occurrence data from simulations and used the joint species distribution model HMSC to investigate to what extent spatial and temporal scales of abiotic and biotic interactions are identifiable. Our results have implications on theoretical and empirical studies showing how the spatiotemporal scales of interactions are linked to the metacommunity theory and what can ideally be inferred from empirical co-occurrence data.

Deep-rooted challenges in monitoring wildlife populations: the very ecology of a species complicates the collection and analysis of population data

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Monitoring programs often target to detect changes in population sizes, utilizing diverse census technique and study design types to do so. Study design details should be chosen based on the ecology of species monitored and on the study questions aimed to answer. Yet such considerations are often infeasible either because not enough ecological information exists, or since monitoring targets many species and questions jointly. My presentation is on how ecological processes such as habitat-selection or home-range establishment complicate typical types of monitoring data, and if not taken into account, the perceived population changes can be biased. For this, I present two studies that illustrate and tackle such phenomena: firstly, with an extensive modeling study, I show that some species- and census technique type combinations are likely to under- or over-estimate population change. Secondly, by analyzing the Finnish bird monitoring data, I show how different habitat preferences of individual species may lead into confusion when their population trends are analyzed, if the sampling is not properly environmentally balanced. Finally, I discuss potential remedies for such issues.

Integrated model framework to utilize different monitoring programs for mapping species distributions

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Monitoring of biological communities provides us with essential understanding about species geographical distributions and communities. Still, many species globally and nationally lack sufficient monitoring programs for estimating their geographic ranges which compromises assessments of species vulnerability status and may bias estimates of the benefits of areal species conservation. I will present methods to alleviate the problem of data deficiency for modeling species geographical ranges by using data from different monitoring schemes in an integrated species distribution model (SDM). As an example, I integrate observations from citizen-science efforts and a structured monitoring scheme to predict the geographical ranges of South American hummingbirds and locate the hot spots of their diversity. The novelty of the work lies at integrating data sets from different survey designs while addressing their distinctive sampling processes and examining the benefit of the approach for continental scale biodiversity research. Last, I will look into possibilities for the usage of integrated SDMs with new types of data that can inform us about species ranges.

Not just data collection secondary school students use diverse skills and provide reliable data in ecological citizen science project

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Ecological citizen science is often criticized in including citizens only during data collection phase and calling what is essentially crowd-sourcing as science. We studied secondary school students' participation in Helsinki Urban Rat Project and collected data on rat occurrence in their own near-environment by using track plates. In total, over 3 000 students have participated, 778 students have answered questionnaire, 29 students were interviewed and 9 student groups were video and audio recorded during their participation. We compared students' assessment of rat track abundance in the plates to expert scientists' assessment and found that students provide largely reliable data. Students valued experientiality, involvement, meaningfulness, and freedom to choose in the project, suggesting that data collection in itself can be participatory. Students also describe a wide range of factual, conceptual, procedural, and metacognitive knowledge that they acquired during their participation. Our results suggest that even quite straightforward participation in authentic research can provide meaningful experiences for the participants.

A field-based method for assessing local-scale geodiversity for biodiversity research and management

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Global environmental change calls for complementary approaches for biodiversity conservation. Consideration of geodiversity (the diversity of Earth's abiotic features) could provide new insights, as it offers the "stage" for organisms to flourish. However, the methods to map and quantify geodiversity at local scale have remained limited to date. Here, we introduce a field method for observing local scale geodiversity and pilot the method in Arctic-alpine tundra environment in northern Finland and Norway. The field method is based on observation of geofeatures (elements of geology, geomorphology and hydrology) from a given area (here, 5, 10 and 25 m radii circle). In addition, we test, whether the richness of geofeatures (i.e., geodiversity) is positively related to vascular plant species richness of the same sites (n=76). The results show that the method sufficiently captured the abiotic variation of the studied sites. Species richness of the sites was positively correlated with geodiversity, especially in habitats characterized by deciduous shrubs. Thus, the method has potential to be used in complementing other environmental data in biodiversity conservation and management.

Domain-specific neural networks improve automated bird sound recognition already with small amount of local data

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An automatic bird sound recognition system is a useful tool for collecting data of different bird species for ecological analysis. Together with autonomous recording units, such a system provides a possibility to collect bird observations on a scale that no human observer could ever match. With annotated bird sound data, the recognition models can be adjusted to perform well with specific type of data. In our recent article, we demonstrate the workflow for building a global identification model and adjusting it to perform well on the data of autonomous recorders from a specific region. We trained a convolutional neural network with a global data set to obtain a base model. The base model was then fine-tuned with local data from Southern Finland in order to adapt it to the sound environment of a specific location. Our results suggest that fine-tuning with local data significantly improves the network performance. Data augmentation enables training with a limited number of training data and even with few local data samples significant improvement over the base model can be achieved. Our model outperforms the current state-of-the-art tool for automatic bird sound classification.

Probabilistic taxonomic classifier PROTAX: past, present, and future

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DNA based taxonomic identification is an important step when measuring biodiversity. We have developed a probabilistic taxonomic placement method PROTAX that explicitly takes into account various uncertainties involved when determining the taxon membership of a DNA sequence. When calculating taxon probabilities, our method takes into account that 1) some taxa may not have any reference sequences, 2) some taxa may be completely missing from the taxonomy, and 3) some reference sequences may be mislabelled to belong to wrong taxa. We have successfully applied PROTAX to fungal, mammalian, insect, and bacterial data. The software is freely available and for COI based Finnish insect identification there is also a web based user interface available. The latest development of PROTAX is expanding it to cover the entire animal kingdom of the world. For that application, we have built PROTAX to identify species based on over 7 million reference sequences of BOLD database. In this presentation, we describe how to train and use PROTAX and demonstrate its usefulness in several applications that have been conducted over last five years.

Parallel session 8: Sustainability #1

Honeybees' functions through DNA in honey

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To assess a species' impact in an environment, we need to know the functions of a species. Honeybees are important pollinators, but they likely have other impacts as well. Here we use the DNA contents of honey to assess honeybees' functions comprehensively. Based on data from metagenomics and DNA metabarcoding of honey samples from North-Europe, we identify the taxa from which the DNA originates and assign the taxa to ecological groups. Most of the DNA sequences are from gut microbes of honeybees, showing honeybees host microbes that are both beneficial and detrimental to themselves. The second most abundant group are plants, showing North-European honeybees feed on and pollinate mostly cultivated plants. Based on the very high frequency of occurrence of pathogens associated with plants, bees and other animals, honeybees appear to be spread them, but also microbes protective of those pathogens. The occurrence and abundance of different microbes and plants vary across the season, but largely also according to the sites of the hives, both locally and regionally. With these, honey-borne DNA describes honeybees' functions and guides us to look at relevant associations.

Polyculture farming shapes arthropod communities in agroecosystems: The effects of cover crop diversity and functional traits

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Concern for decline of insect-mediated ecosystem services (pollination and biological pest control) have increased incentives to sustainable agriculture. The effects of introducing 1–8 cover crop species (polyculture treatments) to barley monocultures was studied in a 3-year field experiment. Arthropods were sampled with suction sampling, counting individuals from barley stalks and pitfall trapping. The effects of polyculture farming or cover crop properties (functional traits and species richness) were analysed with separate linear (mixed) models. Polyculture farming increased the biomass of several arthropod taxa compared to barley monocultures but did not increase aphid or thrips pressure on barley. Aphids were positively affected by the proportion of nitrogen-fixing or deep-rooting cover crops, while opposite effects were found for beetles. Diptera and Hymenoptera responded positively to diversity gradient within polyculture plots, underlining the importance of small-scale habitat diversity for these important pollinators. Growing cover crops alongside the main crop can increase the arthropod abundances, which could promote biodiversity and ecosystem services on crop lands.

Managing problematic plants in Reykjavík, Iceland

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Invasive and alien plants, such as Nootka lupine (*Lupinus nootkatensis*), cow parsley (*Anthriscus sylvestris*), and sweet cicely (*Myrrhis odorata*), can threaten urban biodiversity and negatively impact urban ecosystems. Developing management strategies to monitor and control the spread of these species is essential. These strategies can include mapping distribution, public outreach, and actively controlling these problematic plants. Several management actions were implemented during the summers of 2021 and 2022, which included mapping the distribution of Nootka lupine in protected areas and launching an outreach campaign about sweet cicely and cow parsley in Reykjavík. Our management efforts, public events and social media presence were a collaboration with multiple stakeholders. We generated detailed distribution data of Nootka lupine for two protected green spaces. Outreach events focused on learning to recognize and manage cow parsley and sweet cicely, as well as using them for cooking, fostering public awareness and action in a fun and interactive way. These efforts will be used to further develop local and Nordic management strategies for alien and invasive plants in cities.

Effects of organic farming and semi-natural grasslands on within- and between-year pollination success of an insect-pollinated crop

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Organic farming and semi-natural grasslands are important for pollinating insects in agricultural landscapes, but their relative effects on crop pollination remain understudied, in particular regarding their relative importance for pollination variability between years. We studied the individual and combined effects of organic versus conventional farming and increasing proportions of semi-natural grasslands in the surrounding agricultural landscapes on the pollination success of the field bean (*Vicia faba*) in southern Sweden, during three consecutive study years. We found no effects of organic versus conventional farming on plant-level or average farm-level pod set or seed set. However, we found indications that variation in farm-level seed set was lower amongst organic farms compared to conventional ones. Increasing proportions of semi-natural grasslands was significantly positively related to plant-level seed set, although it was unrelated to farm-level pollination success metrics. We conclude semi-natural grasslands contribute to increasing seed set, thereby providing synergies between ecosystem service provisioning and biodiversity conservation.

Bioenergy crops on marginal land - trade-offs and synergies for biodiversity

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Agricultural biomass is a cornerstone in strategies to mitigate climate change. However, despite the mitigation potential of bioenergy crops, they are associated with indirect land-use changes and negative environmental impacts. Hence, utilization of marginal land or non-managed land have been suggested as alternative sites for cultivation. Based on a spatial analysis of Swedish marginal land, we conclude that a large share of land being abandoned in Sweden are pastures. To get a better understanding of the ecological value of marginal land, we have used a space for time substitution approach in a mixed farm-forest landscape in South Sweden to analyze two bioenergy scenarios for marginal land. We sampled plant diversity in abandoned pastures, pastures converted to spruce plantations or ley fields, and active pastures. Our preliminary findings show that pasture abandonment slightly decreases the plant species richness. When comparing the two bioenergy scenarios, young spruce plantations maintain most of the plant species richness for the early stage of the forest, but as the canopy closes, most of this plant diversity is lost, which is also the case for sown ley fields.

Exploring pollinator tools: The usability and the utility of pollinator tools in agriculture landscapes

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Widespread declines of insect pollinators are both a conservation concern and threaten the pollination of wild plants and crops. A plethora of tools have been created to help predict and/or facilitate management decisions aiming to benefit pollinators in agricultural landscapes. However, to date there has not been any assessment of these tools, in particular concerning how user-friendly and applicable they are. Therefore, a systematic map was undertaken to explore "the usability and utility of tools that have been developed to predict, and/or facilitate management decisions relating to insect pollinators and pollination in agricultural landscapes". We searched for, collated, and assessed the usability (the degree of which a tool is easy to use) and utility (how fit it is for purpose) of pollinator assessment tools relevant for agricultural landscapes. We searched a bibliographic database, grey literature, and asked experts in the field. We summarise the current existing pollinator tools, their usability, their utility, and highlight knowledge gaps.

Time lags in the response of plants to the conversion to organic farming

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Management interventions aiming at improving habitat quality do not systematically lead to an immediate increase in species richness and densities. Such time lags between habitat improvements and biodiversity benefits have been observed for some agri-environments schemes such as organic farming. Previous empirical for plant communities failed to consider differences in species traits linked to dispersal capacities, sensitivity to agricultural disturbances and the effect of source habitats. Here, we designed a space-for-time substitution study to fill this knowledge gap. In 90 fields along gradients of time since transition to organic farming (TST) and landscape complexity, we found an increase in plant species richness with increasing TST. Organic fields started to have a higher plant species richness than conventional ones 10 years after conversion. This increase depended on species dependance to animal pollination. Some traits such as herbicide sensitivity showed a more rapid change after conversion. Our results have important implications for the assessment of expected benefits of organic farming, and for understanding the conditions leading to efficient conservation efforts.

Parallel session 9: Life history and sensory ecology

Melanin-based plumage coloration is associated with risk-taking in tawny owls under stressful conditions

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Intraspecific colour variation is often associated with camouflage or protection, but melanin-based colour variation is also linked to behavioural and physiological aspects including risk-taking behaviour. In the melanin-based plumage colour polymorphic tawny owl (*Strix aluco*), the grey morph is known to be more cryptic than the brown morph. Using 19 captive tawny owls, we tested if these two colour morphs that differ in crypsis tend to differently expose themselves in a familiar environment and an open field test, as well as whether their response to predation risk and mobbing cues differs. The two colour morphs did not differ in their exposure under low-stress conditions, but brown tawny owls were more likely to perch in the outer, exposed part of the aviary than grey tawny owls after release in an experimental aviary. The two morphs responded the same way to mobbing and predation risk. Our findings show that the two colour morphs expose themselves similarly under low-stress conditions. However, under stressful conditions, the less cryptic morph, brown, exposes itself, whereas the more cryptic morph, grey, uses camouflage.

Colour morph specific variation in survival and reproduction across Europe in the tawny owl *Strix aluco*

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Changes in environmental conditions are predicted to lead to microevolutionary adaptations. We expect large scale spatial variation in such adaptations and attempts to tackle this question with individual-based data are scarce. Organisms with genetically based colour polymorphism are excellent candidates to study microevolutionary responses to environmental variation based on phenotypes. In tawny owls, which come in two melanin-based colour morphs, grey and brown, morph-specific fitness has been strongly associated with variation in climate and life history decisions. However, little is known about the geographical variation in the fitness of the colour morphs. Here, we propose a wide geographical-scale comparison of survival and reproduction of the colour morphs in five different populations across the distribution range. We found a large variation in LRS between the study populations and between morphs. We present data and discuss how LRS is linked with survival differences between morphs in these populations. These results suggest that the fitness of morphs vary on a large spatial scale, which is likely to affect the large-scale patterns of colour polymorphism in this species.

Genetics and energetics of life-history variation in Atlantic salmon

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Life-history variation is produced by trade-offs in energy allocation, but the physiological processes that modulate energy use and shape life-history evolution are not well known. The Atlantic salmon (*Salmo salar*) exhibits strong variation in age-at-maturity with strong genetic control via two genomic regions, vgll3 and six6. This enables implementing genomic prediction of age-at-maturity to test potential genetic correlations and co-evolution, between age-at-maturity and energetic traits. We have shown that there is no covariation between standard metabolic rate and the genomic regions, but late maturation genotype via vgll3 also decreases the maximum metabolic rate of juvenile salmon in epistatic interaction with six6. Here, we measured activities of lactate dehydrogenase and citrate synthase enzymes as proxies for anaerobic and aerobic capacities, respectively, from four tissues to understand how tissue-specific signatures of energy allocation can shape these effects. The results provide insights to the mechanistic basis of life-history variation as well as to potential metabolic constraints on life-history evolution.

Body size and sex differences affect cancer across species in lemurs

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Oncogenic mutations during cell divisions make organisms susceptible to cancer. Yet, although larger size typically requires more cell divisions, larger species are not more cancer-prone than smaller ones. Selection to suppress cancer until ages with low reproductive value can explain this pattern and predicts stronger cancer defences in larger species. Here, we test this by taking advantage of a high-resolution cancer dataset. We conceptualize cancer defences as the number and rate of mutations that result in cancer, which we estimate by fitting a multistage cancer model to age-specific cancer data with a maximum likelihood approach. We build 10 models that differ in how defences relate to body size, species differences and sex differences, and select the best-performing ones with an information-theoretic approach. Our results suggest stronger cancer suppression in larger species, allowing them to evolve longer cancer-free lifespans. Moreover, we find higher rate of oncogenesis in female lemurs than males. Our study supports the hypothesis that selection matches cancer defences to species life history, explaining the lack of correlation between species size and cancer incidence.

Extended phenotypes as mediators of transfer of relational concepts between species

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Conceptualization requires cognitive abilities because it enables extrapolating previous experiences into new situations, and it has long been considered to be a privilege of primate brains. However, recent evidence shows that many animal species (e.g., rats, pigeons, and bees) are capable of conceptualization, but the extent of species and situations where conceptualization is displayed is not yet fully understood. We tested whether pied flycatchers can form relational concepts (smaller/bigger rule) when using experimentally manipulated (clutch size) information that is based on extended phenotype from great tits. First flycatchers observed a tit demonstrator that apparently had preferred either large or small symbol when choosing a nest box and were then enforced to choose between two empty nest boxes with symbols of different shape and size but preserved the relational rule (smaller/bigger). The results suggest that the interaction of the great tit females' physical size and clutch size (high/low) has a significant effect on the symbol size choice of pied flycatcher.

Pollen removal changes floral scent in buzz-pollinated flowers

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Floral scent influences the recruitment, learning, and behaviour of pollinators. By varying scent emission, flowers can transmit information about reward availability or whether a flower has been recently visited by pollinators. This may be particularly important in species which visually conceal floral rewards, as in the c.20,000 species of plants which release pollen via small openings at the apex of tubular anthers: poricidal plants. Here, the anther structure encloses and visually conceals pollen, appearing visually similar regardless of pollen quantity within. We investigated whether the volume and composition of floral scent emission varied upon pollen removal in seven taxa of poricidal *Solanum* (Solanaceae). We found that pollen removal reduced overall scent emission. Moreover, in *S. lumholtzianum*, the emission of specific compounds (linalool and farnesol) decreased upon pollen removal. Our findings suggest that scent could act as a signal of pollen availability used by visitors to poricidal flowers to inform foraging decisions.

Can you see me? Sexual signalling in an artificially lit world

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Artificial light at night (ALAN) is a rapidly spreading environmental problem that threatens many nocturnal organisms. Here, we investigate the effects of ALAN on mate attraction in the common glow-worm (*Lampyris noctiluca*), a charismatic beetle whose flightless females glow in the dark to attract flying males. Through a series of experiments in the laboratory and in the field, we found ALAN to negatively affect both male mate finding and female glow behaviour. Furthermore, both the intensity, colour and duration of ALAN affected mate attraction success. These results indicate a lack of adaptive behavioural responses to ALAN in this species. In the long term, these effects have the potential to not only affect reproduction negatively, but also the population. Nevertheless, based on our results, using less intense lights with longer wavelengths for shorter periods of time seem promising solutions for limiting the adverse effects of ALAN on sexual signalling in this species. As adaptation to rapid environmental change often is challenging, and genetic adaptation alone often is too slow, these results add to the much-needed information on appropriate mitigation measures.

Parallel session 10: Sustainability #2

Future supply of boreal forest ecosystem services is driven by management rather than by climate change

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Boreal forests provide a wide variety of ecosystem services (ES) and are experiencing the highest rates of warming on the planet. To foresee how to adapt forests to global change, we need a better understanding of the relative importance of forest management and climate change on the supply of ES. We assessed the potential supply of a wide range of ES (timber, wildberries, mushrooms, carbon, scenic beauty, species habitat availability and deadwood) given seven management regimes and four climate change scenarios. We used SIMO simulator to project forest dynamics in Finland into the future. Then, we tested the relative importance of management and climate as drivers of the supply of these services using generalized linear mixed models. We found that the effects of management on the supply of these ESs were, on average, eleven times higher than the effects of climate change. Notably, the importance of these drivers substantially differed among biogeographical zones within the boreal biome. We conclude that new guidelines for adapting forests to global change should account for regional differences and the variation in the effects of climate change and management on different services.

Long-term effects of nature-based forest management on dead wood: lessons from Evo experiment

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In managed Fennoscandian forests, prescribed burning and leaving retention trees are used as nature-based solutions. However, their long-term effects on biodiversity are not yet well understood. The Evo restoration experiment was established in 2001 in mature Norway spruce forests in Southern Finland. It includes partial cuttings with standing retention of 50 m3 ha-1 with or without prescribed burning and three levels of downed retention: 5, 30 and 60 m3 ha-1, as well as controls in both upland and paludified biotopes, with three replicates each. In this sub-study, we inventoried dead wood by size, tree species, decay class and position before, one and 16 years after the treatments. Both volume and diversity of dead wood 1) increased with the level of downed retention, 2) were higher in burnt than in unburnt forest stands, and 3) were higher in upland than in paludified biotopes. Relative importance of different dead wood parameters for wood-inhabiting communities and threatened species will be analyzed. Our findings highlight the long-term importance of prescribed burning, standing and downed retention as nature-based forest management methods for maintaining dead wood diversity.

Efficiency of the Triad management approach to provide multifunctionality in Finnish forest landscapes

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Land-use policies strive to enhance sustainable use of natural resources. To balance the social, ecological, and economic demands of forested landscapes, the Triad approach have been suggested. The core idea is to allocate landscape zones with specific management priorities to enhance multifunctionality: production (intensive management), multiple use (extensive management), and conservation (forest reserve). We aimed at testing the efficiency of the Triad approach and to define the respective proportion of these zones to enhance multifunctionality in Finnish forest landscapes. Through a simulation and optimization framework we explored a range of permutations of the three zones and evaluated how the definition of these zones impacted a various biodiversity and ecosystem service indicators. Our results highlight the potential of Triad in promoting forest multifunctionality and strong trade-off between economic value and multifunctionality. We conclude that restricting forest management into intensive, extensive, and reserve zones does not implicitly contribute to a positive overall forest multifunctionality, however management still requires clear landscape objectives.

Boreal forests and restorative health benefits to humans: management recommendations, synergies and trade-offs

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There are increasing demands from forests to provide a broader range of ecosystem services while simultaneously improving forest habitats to preserve biodiversity. Despite the broad acknowledgement of the restorative benefits of forests for human health, this dimension is seldom accounted for, partly due to the lack of tools to quantify it. Here we present the relative contribution of different management practices to the restorative value of forests, and inspect trade-offs and synergies between health, other ecosystem services and biodiversity. A novel framework accounting for the different perceived sensory dimensions allows us to link forest structure to restorative benefits for humans. We simulated growth of a commercial forest landscape in central Finland 100 years into the future for a broad representation of management regimes. We used multiobjective optimization to find the best combination of managements and trade-offs among health, ecosystem services and biodiversity. Continuous cover forestry has the largest contribution to the restorative value of forests, followed by set-asides and rotation forest management practices. This links to multiple synergies and trade-offs.

Is restoration effective? A large-scale and long-term study of vegetation in boreal peatlands

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Ecological restoration of degraded ecosystems is used to counteract the loss of biodiversity and secure ecological functions, and restoration efforts will increase substantially in the near future. This concerns also boreal peatlands which have been degraded widely: in Finland alone, over half of the original peatland area has been drained. Yet, our knowledge of the effects of restoration is hindered due to small spatial and temporal scales often used in restoration studies. We studied the effect of restoration on moss and vascular plant species communities in a controlled experimental set-up of 150 Finnish forestry-drained peatlands. The sites represent six peatland types, 700 km of latitudinal extent, and follow the effect of restoration for 10 years. In general, restoration decreased abundance of common forest species and increased abundance of typical peatland species, yielding in overall community composition change towards pristine sites. Yet, the change in some peatland types (high productive pine mires and fens) was greater than in others (spruce mires, low productive pine mires and fens). Thus, to be most effective restoration could be targeted to specific peatland types.

Snag fall in Fennoscandian boreal forests

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Longevity of standing dead trees (snags) is an important determinant for their role for biodiversity, and a dead tree fall greatly influences the rates of carbon release. How fast snags fall varies widely among species and regions and is further influenced by a variety of stand- and tree-level factors, but our understanding of this variation is fragmentary at best. We combined snag observations in the Finnish, Norwegian, and Swedish National Forest Inventories, accrued since the mid-1990s. Using ca. 50 000 harmonized observations, we modeled the probability of snags of the main boreal tree species falling during a 5-year re-measurement period, as a function of tree- and stand-level variables. We found probabilities to differ among species and climatic conditions, but also consistent effects of tree size, decay stage, forest management interventions and site type type. This type of understanding and model development are a requirement for incorporating snags into forest management.

Microclimates in a boreal forest landscape in southern Finland

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Forest management in Finland has changed recently when uneven-aged management has become an alternative to traditional even-aged forestry. Management affects the forest structure, which is expected to modify microclimates under the canopies. We studied the microclimate in 20 uneven-aged and even-aged forest plots in Vesijako-Kailankulma Research Forest by the Natural Resources Institute Finland. We used terrestrial laser scanning to quantify structural characteristics of the different forests, and 80 temperature loggers to measure microclimatic variables soil and air temperature in 2021-2022. We demonstrate that the management types caused differences in the vertical layering and horizontal heterogeneity of vegetation. Our preliminary results show a small but visible difference in microclimate temperatures between stands of different ages, most apparent in summer and winter. At our study sites, the total amount of plant material was a strong modifier of air temperatures. We expect our results to clarify how forest management contributes to shaping microclimates experienced by organisms, which has potential consequences on biodiversity.

How do functional traits, species properties and climate influence tree mortality across Europe?

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Tree mortality occurs sporadically due to disturbances and continuously as background mortality that is largely due to tree-tree competition. Both mortality types are increasing in Europe, partially due to climate change that alters disturbance regimes and increases competition by increasing stand densities. We used forest inventory data to study how functional traits, species properties and climate influence tree mortality probabilities across Europe. We used Bayesian inference to model disturbance mortality and a frequentist approach to model competition mortality. The probability of disturbance mortality varied depending on tree characteristics and disturbance type. E.g., increasing tree size decreased sensitivity to fire, but increased sensitivity to wind. Species with a high height to DBH ratio, low wood density and low root depth were sensitive to storms, while species with thick leaves, low wood density and low stomatal conductance were sensitive to fire. The probability of competition mortality peaked in monospecific stands and increased with decreasing shade tolerance. Our results help in enhancing resilience and safeguarding ecosystem functionality in European forests.

Forest management influences species richness of wood-inhabiting fungi affecting landscape structure and configuration in the boreal production forest

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The local patterns of biodiversity dependent on deadwood are driven by the structure and configuration of the forest landscape. The value of the landscape structure for biodiversity depends on the proportion of forest stands with high deadwood, while the value of its configuration on the proportion of connected suitable patches. Both these landscape features are affected by management oriented towards either economic or ecological values. We evaluate how a gradient of forestry intensification affects deadwood amount and configuration and consequently the species richness of wood-inhabiting fungi. To do so we simulate a boreal production forest and jointly maximize its timber and deadwood value with and without spatial aggregation constraints. Our results demonstrate that the structure of the landscape for biodiversity can be improved with limited economic losses. Improving landscape configuration requires larger losses, but the ecological benefits are larger both for common and red-listed species. The aggregation of stands with high deadwood not only creates areas of high biodiversity value but improves the matrix quality decreasing intensive harvesting and energy wood collection.

Long-term effects of retention forestry on epiphytic lichen diversity on living and dead *Pinus sylvestris*

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Retention forestry is the primary method of promoting old-growth structures in managed forests, but long-term monitoring on its effects is still missing. We surveyed epiphytic lichens, a key group among threatened forest species, on living and dead *Pinus sylvestris* in unharvested control sites and in logged retention sites 21 years after logging. The lichen assemblages on living trees were similar in retention sites and unharvested sites, although lower retention levels may be unable to support rare species. The amount of deadwood was much higher in retention sites, but lichen diversity on deadwood was higher in unharvested sites when the number of sampled trees was accounted for. Species composition was altered in retention sites on standing dead trees, but not on fallen trees. Very old standing dead trees (kelo trees) were found only in unharvested sites. They hosted several species which were not found elsewhere. We conclude that tree retention can maintain the lichen assemblages on living *Pinus sylvestris*, but not on deadwood. Lichen diversity on deadwood seems to be dependent on heterogeneous and long-lasting standing deadwood, which was not found in retention sites.

Parallel session 11: Evolutionary biology

Bateman gradients from first principles

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In 1948, Angus Bateman presented experiments and concepts that remain influential and debated in sexual selection. The Bateman gradient relates reproductive success to mate number, and this relationship was presented as the cause of intra-masculine selection. A deeper causal level was subsequently asserted: that the ultimate cause of sex differences in Bateman gradients is the sex difference in gamete numbers (e.g. fewer eggs than sperm), an argument that remains controversial and without mathematical backup. I will present models showing how asymmetry in gamete numbers alone can generate steeper Bateman gradients in males. This conclusion remains when the further asymmetry of internal fertilisation is added to the model and fertilisation is efficient. Strong gamete limitation can push Bateman gradients towards equality under external fertilisation and reverse them under internal fertilisation. Thus, I provide a mathematical formalisation of Bateman's brief verbal claim, while demonstrating that the link between gamete number and Bateman gradients is not inevitable nor trivial.

Quasi-social parasitoid sex ratios under multi-foundress local mate competition with reproductive dominance

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Social *Sclerodermus* parasitoids in the aculeate family Bethylidae form female multi-foundress groups on large, paralysed hosts and then cooperatively care for large broods of offspring throughout their development. The sex ratios of offspring produced by multi-foundress groups are more female biased than predicted by standard Local Mate Competition (LMC) theory. Using microsatellite markers to identify maternity shows that nearly every foundress produces offspring and overall reproductive skew is mild. However, males are more often the progeny of the largest or earliest-ovipositing foundress, and many foundresses do not produce any male offspring at all. Skew in male production suggests that larger females are able to dominate the production, or the survival, of males. We incorporate reproductive dominance and/or the infanticide of developing males into LMC theory, predicting both the sex ratios of individual foundresses and those of foundress groups. The predicted group sex ratios broadly match empirical observations and thus provide feasible explanation for the extremely female-biased sex ratios produced by multi-foundress groups and more generally expand the scope of LMC theory.

Conservation management tool: A reduced SNP panel for non-invasive genetic assessment of a genetically impoverished species, the European bison

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The European bison was saved from the brink of extinction due to considerable conservation efforts since the early 20th century. The current global population descends from 12 captive individuals, which represents a severe bottleneck event. Although the population size increased to more than 9,500 individuals worldwide by successful ex situ-breeding and reintroductions into the wild, the species is still threatened by a low level of genetic variability. Due to the low allelic diversity, traditional molecular toolsets, such as microsatellites, fail to provide sufficient resolution for accurate genetic assessments in ex situ-breeding management as well as non-invasive population monitoring. Here, I present a reduced SNP panel for microfluidic genotyping of low-quality and degraded samples from European bison. The panel accommodates 96 markers allowing for sex determination, individualisation, parental assignment, breeding line discrimination, assessment of genetic diversity and cross-species detection. Due to the low costs, high marker resolution and the suitability for various sample types the new SNP assay will allow to tackle crucial tasks in bison conservation management.

Conserved genetic diversity and weak founder effects after a rapid range expansion of a long-distance migrant (*Acrocephalus scirpaceus*)

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Many species are currently experiencing range shifts, largely reflecting ongoing climate change. However, colonizing new areas can have serious genetic consequences for the shifting population. Repeated founder events are expected to erode genetic variation and reduce adaptive potential, possibly slowing or even halting the expansion. This is especially known to affect less mobile species with low gene flow, but whether highly mobile species are experiencing similar bottlenecks during range shifts is less clear. Here, we investigated the origin and genetic effects of a recent, northward range expansion of the Eurasian reed warbler (*Acrocephalus scirpaceus*). We compared evidence from historical observations, ringing data from range edge (Finland), and genomic RAD-seq data covering the European breeding range. All evidence supported a southwestern expansion origin. Nucleotide diversity was conserved along the expansion axis, but allele frequency clines revealed a weak founder effect. The results suggest that even philopatric species with high enough dispersal capability can escape the genetic costs of rapid range expansions, retaining adaptive potential in newly colonized areas.

Signs of local adaptation to parasitism in a cuckoo-host coevolutionary mosaic

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Predicting future ranges of species has become an important tool for conservation under climate change and biodiversity loss. However, it is yet unknown how future distributions are affected by changes in species interactions and their genomic consequences. Here I utilize landscape genomic tools in one of the favorite hosts of the common cuckoo in Europe, the reed warbler, to study a) the impacts of both abiotic and biotic factors on reed warbler's range and b) genomic consequences of local adaptation and range expansion. Reed warblers are among the rare winners under the current climate warming and changes in land use. Understanding the genomic and behavioural mechanisms underlying their success can thus hopefully give us new insights compared to studies of threatened species, which are often the focus of future predictions. As the work is ongoing, here I will present the most recent results from genomic analyses on reed warbler RAD data across their breeding range in Europe.

Regional variation in climate change alters the distribution of colour polymorphism in tawny owls

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According to Gloger's rule animal colouration is expected to be darker in wetter and warmer climates and on lower latitudes. Such environmental clines are predicted to occur in colour polymorphic species and to be shaped by selection if colour morphs represent adaptations to different environments. We studied, if the distribution of the colour polymorphic tawny owl morphs (brown and grey) follow the predictions of Gloger's rule and if there is a temporal change in the geographical patterns corresponding to regional variations in climate change in Europe. We used data on tawny owl museum skin specimens collected 1900-2016. We investigated spatiotemporal variation in the probability of observing the colour morphs in different climate zones, and studied if the probability of observing the morphs was associated with the regional weather conditions in the preceding years. We provide novel insights in how the geographic distribution of pheomelanin-based colour polymorphism is changing over time. Our results further support previous studies of temporal and spatial clines in coloration in owls and differential climatic sensitivity of pheomelanin-based colour polymorphism.

Molecular insights on tawny's owl color phenotypes: is it brown the stronger colour?

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Identifying the genetic basis of evolutionary responses is critical to link frequency shifts of fitness-related traits to climate-driven selective pressures. Tawny owls (*Strix aluco*) are nocturnal birds of prey with melanin-based plumage coloration varying between two phenotypes: the warm- and wet-adapted brown and the cold- and dry-adapted grey. With the objective of identifying the molecular basis of coloration, we performed long-read whole-genome sequencing of two specimens (one grey and one brown) and RADseq 385 others, representative of a Finnish population with familiar relationships recorded over the last decade. Here we present the first two assemblies of tawny owl genome (70x; NG50=91.5Mb, size=1.2Gb) which was utilized as a reference for mapping RADseq's short reads. Genome-wide association analyses identified two loci strongly associated with colour and suggested an epistatic effect based on allelic combinations of both. Candidate loci were found to be located in intronic regions of feather keratin and collagen, suggesting a structural basis for pigmentation and supporting observations of different resistance to feather-degrading bacteria between colour morphs.

Genomic divergence and a lack of introgression between commercial and wild bumblebees, *Bombus terrestris*

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The movement of non-native commercial bumblebees used for pollination services can affect local pollinator populations via introgressive hybridization. The extent of genomic introgression and evolutionary divergence between wild and commercial bumblebee species has yet to be fully explored. Wild populations could be faced with the potential disruption of locally adapted genes through introgression of maladapted alleles originating from escaped commercial bumblebees. Thus, affecting the wild population's ability to adapt and withstand future environmental change. We compared whole genome sequencing data from wild (WB) and commercial (CB) *Bombus terrestris* from sites in southern Sweden with long-term exposure to imported *B. terrestris* and sites without such exposure. We examined evidence of introgression, dispersal and genome-wide selection signatures, between the two groups. We found no evidence of genomic introgression among WB and CB, which suggests suggests that the use of CB does not pose a genetic threat to local *B. terrestris* populations. We identified a divergent region on chromosome 11 in CB suggesting differential evolutionary processes operating in WB and CB *B. terrestris*.

Expansion of rDNA and pericentromere satellite repeats in bank voles exposed to environmental radionuclides

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Copy number variations in repetitive, heterochromatic regions of the genome such as the ribosomal RNA loci (rDNA) correlate with genomic stability, ageing and diseases, and may help protect the genome against external stressors. We measured copy number of 18S rDNA and pericentromeric satellite Msat-160 in a natural population of bank voles exposed to radionuclides in the Chernobyl Exclusion Zone (CEZ). We found significant increase in copy number of both markers in animals inhabiting contaminated locations compared to uncontaminated locations within the CEZ. Further, 18S rDNA and Msat-160 copy numbers were positively correlated in uncontaminated, but not in contaminated locations. These results show capacity in genomic architecture for local-scale geographic variation and highlight copy number variations in repetitive regions as a potential marker for environmental stress. Also, disruption to various cellular processes appear to be a common effect in bank voles exposed to radionuclides.

Monitoring of adaptive genetic loci informs conservation and management of Baltic salmon

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Fishing has the potential to influence the diversity of life-history traits of exploited populations. However, our understanding of how fisheries can induce evolutionary (i.e. genetic) changes remains incomplete. The discovery of large-effect loci linked with ecologically important life-history traits, such as age-at-maturity in Atlantic salmon (*Salmo salar*), provides an opportunity to study the impacts of temporally varying fishing pressures on these traits. An Atlantic salmon scale archive spanning 92 years allowed us to monitor adaptive genetic diversity linked with age-at-maturity of wild salmon populations from the northern Baltic Sea region. Using a genotyping-by-sequencing approach, we discovered strong temporal allele frequency changes at these loci within fishing seasons. Most notably, early season fishing targeted a genetic variant linked with late maturation. Therefore, selective pressures of fishing may vary depending on the timing of harvesting and may cause evolutionary changes in key life-history traits and their diversity. This knowledge can be used to guide management to reduce the potential effects of fishing practices on salmon populations.

Parallel session 12: Species interactions

Common cuckoos choose Common redstart hosts based on availability and location, rather than parental quality

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Brood parasites, such as the Common cuckoo (*Cuculus canorus*), rely on host species to care for their offspring. Therefore, theory predicts that mothers should select high-quality foster parents to enhance their reproductive success. However, evidence for this hypothesis remains mixed, potentially because studies rarely consider the outcomes of host-choice for the cuckoo nestling. Using long-term monitoring of nest boxes occupied by Common redstarts, the regular cuckoo host in Finland, we first tested if host quality (larger clutch size) predicts parasitism probability. Then, with a cross-fostering experiment we investigated whether cuckoo chicks grow best in the foster nest chosen by the cuckoo. We found no evidence that cuckoo females selected hosts based on quality, and cuckoo chicks grew at similar rates in naturally- and artificially-parasitised nests. Instead, laying date and spatial location had the largest effects with nests built later in the season being more likely to be parasitised and produce lighter and smaller cuckoo chicks. These results suggest that cuckoos select nests depending on availability and local conditions rather than host quality.

Are behavioural defences lost during a range expansion away from enemies? A field test with reed warblers

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The ranges of many species are changing rapidly, exposing them to both new enemies and competitors or allowing them to escape past threats, and predicting what happens next for these changing ecological communities is a major goal in understanding how species interactions influence biodiversity. Geographic Mosaic Theory of Coevolution predicts that hosts should lose their defences when in allopatry, making them vulnerable to reinvasion when parasites 'catch up'. The majority of work testing this theory has focussed on plants and insects, or on morphological and physiological defence traits. But what happens to behavioural defences, which are typically highly plastic and considered to be the 'first line of defence' of many organisms against environmental change? Are behaviours lost (as the theory predicts) or retained, or do hosts lose sensitivity to cues about local parasitism risk? Here I will share ongoing work in reed beds around Finland where we are finding that reed warblers, a favourite host of brood parasitic cuckoos elsewhere in Europe, may be losing defences (or plasticity) after 100 years in allopatry.

Food-web interactions of five passerine birds and their numerous arthropod prey

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Changing conditions are constantly testing the adaptive abilities of organisms. The anthropogenic influences of habitat loss and, increasingly, climate change are affecting species in boreal forests in highly variable ways, leading to shifts in phenology as well as species' distributions. While the impacts of these environmental changes on many individual species are presently already unclear, the impacts on whole ecosystems are far more complex still. In this study, we use DNA metabarcoding to unravel the interconnected food-webs of five widespread passerines and their hundreds of different arthropod prey over multiple breeding seasons. With these data, we look into interspecific and interannual differences in the diets of these birds, and whether they can help explain the present Red-Listed status of two of the bird species. Our results display the foraging flexibility of the focal insectivores, and simultaneously demonstrate the strengths of the metabarcoding methodology in classifying numerous invertebrates to detailed taxonomic levels.

Moth grouse interactions in the changing North

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The population declines of grouse species have been extensively studied, yet no consensus has been reached on the consequences of either climate change or habitat loss for these birds, as there are contradicting results even within Fennoscandia. The grouse species are uniquely dependent on insect food for a very short time span in their lives, making them especially susceptible to phenological mismatches with their lepidopteran prey. We assess the effects of environmental change on species interactions between moths and grouse species in Northern Finland using long term monitoring datasets. We infer trophic interactions based on moth species' larval traits affecting palatability, preferred strata in the landscape or temporal availability during the season. Specifically, we explore the effects of environmental change on these different functional groups of moths as well as their importance to the upper trophic level, relative to other factors affecting grouse population size or reproductive output. We find that the availability of palatable moth groups improves chick recruitment, while not maintaining higher overall grouse populations.

Could changes in autumn phenology of fruiting and bird migration increase the dispersal of alien plants from urban areas?

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Alien plants introduced into cities can spread, potentially becoming harmful invasives. Seed dispersers like frugivorous birds play a role in this spread, but it is unclear how they interact with alien and native plants within cities. At higher latitudes, the risk of aliens escaping into the wild is imminent due to warmer climates and extended autumn bird migrations. Here we use Helsinki as a case study to investigate whether urban gardens provide birds with a fruit resource (in terms of abundance and plant origin) that differs from forest fragments, whether birds preferentially consume fruits of particular origin, and which seeds are likely to be dispersed. We find alien plants are present in forests, fruits are more abundant in gardens and native fruits are more abundant than alien fruits. More birds were detected in gardens and, despite the high number of alien plants in gardens, birds consumed more native fruits. In faecal samples, we find that contrary to our expectations, there is no difference in the origin of the seeds dispersed, and fewer seeds are dispersed during the end of the season. Indicating that the risk of alien plants spreading through birds is quite poor.

Urban environments alter the gut bacterial and fungal microbiota in a wild rodent

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Urban development presents a major change in land use that can impact biodiversity and ecosystem function, and potentially wildlife health. The animal gut harbours complex communities of microorganisms (the microbiota) that, for example, deliver key metabolites to the host and affect the host's immune response. Impacts of human-altered landscapes on the gut microbiota of wild animals remain largely unexplored. Using marker gene sequencing we quantify how inhabiting an urban environment impacts the bacterial and fungal components of the gut microbiota of a small rodent (bank voles), compared with inhabiting other forest types (such as national parks and managed forests). Our data indicate a strong signature of inhabiting an urban environment on both bacterial and fungal gut microbiota, with a notably sharp decline in the diversity of fungal gut microbiota in urban habitats.

Host species and environment mediating pathogen microbiota dynamics

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Using plant-associated microbiota to enhance plant growth and resistance has great potential in plant protection. However, there is rare knowledge on how microbiota varies across environment, host species and disease status in wild. To characterize variation in microbiota, we collected leaves with and without downy mildew *Peronospora sparsa* symptoms from *Rubus arcticus*, *R. chamaemorus* and *R. saxatilis* from 11 locations across Finland. By sequencing the fungal and bacterial microbiota, we found that the environmental variation was the strongest driver of microbiota composition and that the effect of symptom status on microbiota differed by location. We identified a set of core microbes that were significantly enriched or depleted in the infected plants. To test how microbiota from different host species will affect *P. sparsa* infection development, we performed a reciprocal laboratory inoculation trial using field collected microbiota and in-vitro grown plants of the three Rubus species. Increased pathogen growth was observed in *R. chamaemorus* microbiota inoculated hosts of all three species suggesting that the outcome of pathogen infection is mediated by co-occurring microbiota.

Specific root-associated fungal communities facilitate plant growth at high altitudes

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To predict how species communities change along environmental gradients, we need to understand both the direct responses of species to their abiotic environment and how these responses are indirectly affected by their biotic interactions. Using plant-fungal symbiotic networks, we studied the changes in root-associated fungal (RAF) community composition along altitudinal gradients to see whether they facilitate plant growth. To test this, we set up a translocation experiment between high and low altitude populations of *Bistorta vivipara* in Finnish Lapland. To disentangle the effect of a changing RAF community from changing abiotic conditions, a water and nutrient-permeable root barrier was used to either exclude or allow new RAF colonizations. Our main hypothesis was that RAF communities from high altitudes improve growth rates of translocated plants compared to plants excluded from new RAF associations. Preliminary results reveal that plants have greater growth at high altitude if they associate with high altitude RAF. Our findings indicate that RAF communities improve plant growth under stress and that abiotic conditions influence how plants and fungi select their mutual partners.

How important is host diversity for disease?

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Pathogens are prevalent across all ecosystems and exert negative effects on their hosts. Hence, there is a pressing need to understand risks of infection and how these evolve. Traditionally, host-pathogen interactions have been largely viewed within the 'one host-one parasite' framework although in reality the same host may be attacked by a myriad of pathogenic microbes. However, remarkably little is known about the factors that determine which pathogens co-occur within the same host individual and how they interact. The relative roles of pathogen-pathogen interactions, host attributes and the environment have been notoriously difficult to tease apart. In my talk I will consider how both intra- end interspecific host diversity affect disease dynamics and the assembly of complex pathogen communities.

Soil-mediated effects of agrochemical use on plant hormone regulation and microbe-mediated plant resistance to insects

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Glyphosate is the active ingredient in most widely used herbicides causing an agrochemical pollution in habitats across the globe. Glyphosate disrupts the shikimate pathway, which is the basis for several metabolite groups produced by plants and a majority of microbes. We studied the effect of soil with a history of glyphosate-based herbicide use on a grass-mutualistic fungus and on hormone levels of different plants and showed that shikimate-deriving phytohormones were inhibited in oat together with a decrease in plant damage by insect herbivores, whereas in potato leaves the levels of several stress-related hormones were induced. Further, our results demonstrate a reduction of fungal-conferred plant defense when growing in soil with a glyphosate history, which caused an increase in natural herbivore infestation. We conclude, that herbicide residues have multifaceted consequences by modulating the hormonal equilibrium of plants and reducing microbe-mediated plant protection with cascading effects on trophic interactions. Thus, glyphosate residues may interfere with trophic interactions affecting the ecology and evolution of species in agricultural environments.

Parallel session 13: Community ecology #2

Shining a light on species coexistence: visual traits drive bumblebee communities

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Local coexistence of bees has been explained by resource partitioning, but coexisting bumblebee species often have strongly overlapping diets. We investigated if light microhabitat niche separation, underpinned by visual traits, could serve as an alternative mechanism underlying local coexistence of bumblebee species. To this end, we focused on a homogeneous flower resource bilberry in a heterogeneous light environment hemiboreal forests. We found that the bumblebee community segregated along a gradient of light intensity. In general, species with higher eye parameter (indicating larger investment in light sensitivity) foraged in dimmer light than those with a lower eye parameter (indicating a higher investment in visual resolution). We suggest microhabitat niche partitioning to be a potential mechanism underpinning bumblebee species coexistence. This study highlights the importance of considering sensory traits when studying pollinator habitat use and their ability to cope with changing environments.

Boreal moth biomass is either stable or increasing in time depending on key life-history traits

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Dramatic insect declines and their consequences for ecosystems globally have received considerable attention recently. Yet, it remains poorly known which traits explain declines and whether the decline in insects expands to high latitudes. We adopted a trait- and biomass-based approach to estimate temporal changes in moth communities in Finland in 1993-2019. We analysed spatial and spatiotemporal variation in moth functional groups' abundances with Joint Dynamic Species Distribution Models and accounted for environmental conditions. We did not detect any declining trends in the biomass of moth functional groups, but most groups were stable over time. Moreover, the biomasses of species using coniferous trees, lichens, and mushrooms as hosts, multivoltine species, as well as monophagous and oligophagous species feeding on trees have increased. We found that growing season and winter climatic conditions as well as habitat structures partially explained variation in moth biomass. Although the boreal moth communities are rapidly changing, in terms of total moth biomass they seem to perform better than expected on

the grounds of global trends across several key functional groups.

Trait-based selection and diversity changes along successional gradient in boreal forest understory

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Predicting how communities respond to changes in land use and environment is a key task in ecology. Trait-based frameworks have increasingly been used to infer community assembly processes, but their reliable detection remains a challenge. Here we propose an alternative approach, which focuses on ecological selection. We applied this predictive framework to over 3500 vascular plant communities in boreal forest understory across Finland. By assessing changes in the community trait niches along modelled forest density, fertility, and temperature gradients, we detected ecological selection types, potential underlying mechanisms and focal traits driving community assembly. We found that directional, stabilizing, and divergent selection simultaneously shape community trait niches along environmental gradients. Generally, reduction in community trait niches was associated with decreasing species richness. This framework links trait selection to diversity changes of communities and identifies key traits under selection, which can aid us in inferring the underlying processes of community assembly.

Long-term biotic homogenization of oligotrophic tundra vegetation across northern Fennoscandia

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Biodiversity loss is considered to greatly affect the structure and functions of the tundra biome. One scenario is increasing compositional similarity, i.e., biotic homogenization. However, empirical evidence of long-term diversity changes has remained relatively limited because of the lack of temporal data. Here, we study how the composition of common oligotrophic mountain heath and tundra plant communities have changed in northern Fennoscandia over several decades. We resurveyed old vegetation data in 2013-2020 that dates back to 1960's and includes over 300 vegetation plots with percentage covers of vascular plants, bryophytes and lichens. We found that Fennoscandian tundra communities have become compositionally more similar over decades and that this trend is similar throughout the study area. The observed homogenization is strongly linked to pronounced increase in the abundance of crowberry (*Empetrum nigrum ssp. hermaphroditum*) and decrease in the abundance of bilberry (*Vaccinium myrtillus*) and lichens in general. Our results can be used directly in habitat state assessments and highlight the importance of long-term monitoring also in common habitat types.

Species richness and composition of wood-inhabiting fungi in high stumps of logging areas and advanced thinning forests

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Forest management decreases the amount of dead wood in forests and disrupts dead wood continuity, which are important causes for endangerment of many forest species. High stumps (living trees cut at 2-6m height) are increasingly produced in forest logging and thinning to ease the cap in dead wood continuity. We studied the fungal diversity in high stumps and natural snags of birch and spruce situated in spruce dominated fresh or old logging areas as well as advanced thinning forests in Central Finland. We recorded all non-lichenized fungal species by visual mapping as well as by DNA based methods from 65 high stumps, and 78 natural snags. With using generalized linear mixed modelling on species richness and nonmetric multidimensional scaling on community composition we addressed the relationship between the diversity patterns and different attributes of site and dead wood quality. We discuss the results in relation to benefits for endangered fungal species and guidance for high stump production in forestry.

Parallel session 14: Anthropogenic effects #2

The combined effects of forest management and climate change on the future range size of Finnish boreal birds

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Biodiversity must cope with ongoing climate change and changes in forest ecosystems. Hence, how biodiversity responds simultaneously to these pressures remains largely unknown. In this study, we reviewed how the range sizes of 60 Finnish boreal birds are likely to be influenced by changes in suitable habitats due to climate change combined with anthropogenic disturbances. Forest changes in stand composition and age structures over the next century were simulated with a forest landscape model. Then, we modelled the dependency of species occurrence probabilities on climatic conditions and forest structure with HMSC. The results show that range sizes change between 2010-2100 and that the variation is explained both by climate change and forest management. However, the effects seem to be larger with the increasing effects of climate change and with decreasing intensity of forest management. Climate change is the main driver of species range centroid shifts. Thus, the combined effects of management and climate change will affect future bird species ranges, and this should be considered when developing adaptive management strategies for biodiversity conservation.

Impact of agricultural land-use on farmland birds in Northern Europe

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Agriculture is one of the main drivers of climate disruption and biodiversity erosion due to a multitude of factors. Those include the loss of natural and semi-natural habitats, their fragmentation and overall landscape homogenization thereof, or pollution through agro-chemicals. Farmland bird populations have shown to be particularly vulnerable to agricultural intensification with steep declines during the past decades. Northern Europe is no exception to this downward trend, even if farmland landscapes and management differ from continental Europe. We here focused on the effects of agricultural land-use on farmland birds in Northern Europe by first conducting a literature review and second analyze Finnish farmland bird monitoring time-series data in relation to land-use practices and landscape factors. Based on our findings we show which species and farmland practices are more often studied and for which ones we lack comprehensive scientific knowledge. Furthermore, the Finnish data will help to further understand farmland bird species responses to agricultural management at local and landscape scales.

Bird species' tolerances to anthropogenic disturbance in Europe

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Species can prefer or completely avoid human-dominated environments or be able to survive in both the presence and absence of human influence. However, estimates of species' tolerances to anthropogenic disturbances are scarce at large spatial and taxonomic scales. To fill this gap, we quantify European bird species' tolerances to anthropogenic disturbances and publish the tolerances openly to facilitate their use in research and conservation. We use data of filtered binary observations from eBird and of human footprint, model species' occurrences as a function of human footprint, and predict how likely each species is to occur under different levels of anthropogenic disturbance. Then, we calculate species' maximum tolerances as the level of human footprint where predicted occurrence probability is 10% of the maximum predicted occurrence probability. Preliminary results show that most bird species tolerate high levels of anthropogenic disturbances in Europe. The estimated maximum tolerances are proxies of species' adaptation potential to intensifying disturbances and can thereby guide future conservation efforts.

Fencing of the Finnish-Norwegian border in the 1950s and year-round reindeer grazing lead to a rapid loss of lichen cover in Finland

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A border fence between Finland and Norway was built during 1950-1957. Since then, the studied area in Finland has been used as a spring-summer pasture whereas the Norwegian side of the area has been used as winter pasture. We studied how the different herding practices affected lichen cover and temporal trends in it. We conducted detailed vegetation inventories on both sides of the border in two different locations in Enonteki and Kautokeino. We also reconstructed a lichen cover time series from 1961 to 2020 by using satellite images, and locally back to 1944 by using aerial images. The oldest aerial images showed no clear difference in lichen cover between the adjacent areas of Finland and Norway. However, only four years after the border fence was completed the outline of Finland could be seen from space. At present there is plenty of lichen in the Norwegian winter pastures, but little lichen in the Finnish spring-summer pastures. It is implausible that the reindeer could have eaten the lichen away as reindeer use lichen as a food source especially during winter. We suggest that the reindeer's impact on lichen cover on the Finnish side results from trampling during summer.

Bird feeding and the practices of bird and rat-proofing as a potential solution to human-wildlife conflict

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In Finland, many people want to feed birds, seeing it as a rewarding way of helping wildlife in urban and rural areas. Nevertheless, people often want to feed only some species (e.g., not pigeons or mammals such as rats). In Helsinki, bird feeding often attracts urban rats, which has resulted in human-rat and human-to-human conflicts and bird-feeding prohibitions in different public and private spaces. In places where feeding is allowed, bird feeders often try to make their feeders and feeding sites rat and bird-proofed, meaning they try to prevent unwanted species from accessing the sites and the food meant for birds. By looking into survey material and historical sources, we ask how people rat and bird-proof their feeding sites and devices and against what species. In many countries, rat-proofing has been historically used alongside culling. We suggest rat and bird-proofing practices can lessen wildlife conflicts and make cohabitation more sustainable.

Parallel session 15: Sustainability #3

Factors promoting sustainable use of natural resources in a co-management system: moose harvest by finnish hunting groups

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Managing natural resources sustainably is an enduring challenge to human society. Especially natural resources that belong to the commons risk unsustainable use possibly leading to overexploitation. Co-management is viewed as one approach to avoid overexploitation of natural resources. Here we study which factors in a co-management system promote long-term sustainable resource exploitation. In Finland, moose *Alces alces* are a common natural resource harvested by hunting groups within a co-management governance system that decides moose hunting licenses. We used data covering all Finnish moose hunting groups and their harvest from 14 years (2007-2020). We extracted information describing aspects of registered hunting groups starting more than a century ago. We computed the long-term change in moose harvest for more than 3000 hunting groups harvesting the majority (84%) of moose nationwide. Our findings show that allowing between-group cooperation and encouraging rapid establishment of groups with dynamic leadership roles improves stable benefits in natural resource use to groups of users in a co-management system.

Fish muscle mercury content and bioaccumulation have year-round changes - insights from the whole fish community of a boreal lake

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Boreal lakes demonstrate pronounced seasonality, where the warm open-water season and subsequent cold and ice-covered season dominate natural cycles. While fish muscle mercury content is well documented in open-water summer months, there is limited knowledge on the ice-covered winter mercury dynamics in fish. A year-round study was conducted to test how seasonality influences total mercury content (THg) and bioaccumulation of the fish community in Lake Pääjärvi, southern Finland. The whole fish community was sampled and tested for THg in the dorsal muscle of each species during all seasons in this humic boreal lake. Fish THg was the highest in the winter and spring, likely due to starvation and subsequent condensing, as well as spawning effort. The lowest THg was in summer and autumn during recovery from reproduction and after the somatic growing season. Bioaccumulation regression slopes between THg and fish length were steepest after spawning (spring-summer) and the shallowest during autumn and winter. Seasonal variation found in THg and bioaccumulation slopes supports the need for a standardized monitoring programme to include both winter and summer sampling in boreal lakes.

The effects of drainage and forest structure on grouse brood size

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Grouse (family Tetraonidae) are a group of birds that has suffered from human land use for a long time. Landscapes fragmented by forestry as well as heavily drained bogs and forests are not ideal habitats for grouses, yet they have become dominant features in many parts of Finland. I researched which environmental variables had the greatest effect on grouse brood size, i.e., which elements of the habitat were most critical in terms of chick survival. I used grouse location data from the Finnish wildlife triangle census and combined it with the data on the presence and abundance of ditches/drainage, forest structure from the multisource NFI, and mire habitats. I used generalised linear mixed models to explain the variation in brood size for study species (capercaillie, black-, willow-, and hazel grouse). The results showed that drainage had a negative effect on capercaillie brood size, deciduous trees were important for hazel- and black grouse, and the presence of pine mire was also important to black grouse. The willow grouse broods fared the best on open areas. My results provide guidelines how to restore managed forests to improve the offspring production of these boreal birds.

Are geese dining at their reserved table? Foraging habitat selection in barnacle geese staging in Eastern Finland

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In areas with high human activities such as agriculture or tourism, strong population recoveries of protected species can lead to serious human-animal conflicts. Over the last decades, the Russia/Germany & Netherlands population of Barnacle geese (*Branta leucopsis*) experienced a dramatic increase. During migration, they recently begun to stage in Eastern Finland, an area with high density of dairy farming and corresponding fields. The damage that barnacle geese can cause to these fields is substantial. Efficient management is needed to find efficient repelling strategies and to allocate accommodation areas for these protected birds. We tagged 70 individual barnacle geese with GPS collars in 2021 to study foraging habitat choice in general and specifically accommodation field use and habitat choice after a repelling event. Using hidden Markov models and integrated step-selection analysis, we found that geese generally do not select for accommodation fields during spring and autumn staging. Specifically, after a repelling event, geese avoid selecting repelling fields again compared to other fields. Our results will help to improve mitigation efforts and reduce agricultural damage.

Is it possible to have fun while following the rules? Social and ecological sustainability in Finnish moose hunting

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Sustainable management of shared natural resources, such as wildlife, is a continuous challenge due to the risk of overexploitation. A multidisciplinary Social-Ecological Systems (SES) framework aims to include all relevant working parts to analyze social and ecological sustainability of natural resource systems. In our study, we apply the SES framework for the first time in our knowledge - to moose management in Finland, concentrating on hunting groups. In Finland, moose hunting is top-down controlled. However, hunters have some power in deciding the use of licenses and whether to follow hunting recommendations. We carried out an electronic survey for moose hunters in Finland to find out to what extent regulations alone are enough or what kind of role the social side of group management plays in sustainable moose management. In addition, we investigate how differences in hunters, cooperation between them, and attributes of hunting groups promote socially and ecologically sustainable moose management. We collected 4736 responses (4% of all deer hunters) covering Finland. We find that local resource management offers valuable insight when implementing wider management strategies.

Poster presentations

1. Geodiversity in safeguarding biodiversity and human health
Janne Alahuhta, University of Oulu

2. Network topology can determine local community variability in metacommunities, an experimental approach using protists
Paulina Arancibia, University of Jyväskylä

3. Areas of high conservation value support specialist forest birds
Tristan Bakx, Lund University

4. Effects of island isolation on the benthic biodiversity of Åland
Jean-François Blanc, Åbo Akademi University

5. Causes and impacts of water browning in Finnish forest wetlands
Clarisse Blanchet, University of Helsinki

6. Unravelling the link between population fluctuations with changes in genetic diversity in Finnish butterflies
Audrey Bras, University of Helsinki

7. Short-lived species move uphill faster under climate change
Joséphine Couet, Finnish Museum of Natural History Luomus

8. The role of seasonal wetlands as biodiversity hotspots and nature-based solution to water quality decline in the Finnish boreal forest ecosystems
Aurélie Davranche, University of Helsinki

9. Educating future sustainability experts
Katja Enberg, University of Bergen

10. Effects of Habitat Fragmentation per se on the Genetic Diversity of the Glanville Fritillary Butterfly
Lola Fernández Multigner, University of Helsinki

11. Ecology meets wood material science: Drivers of kelo wood formation in forest ecosystems

Mariina Günther, University of Eastern Finland

12. Nest predation and clutch size in two subpopulations of the common eider

Ida Hermansson, Åbo Akademi University

13. The Finnish national biodiversity offset register

Joel Jalkanen, Finnish Museum of Natural History Luomus

14. Flower abundance in herbaceous high-latitude plant communities exposed to NPK-fertilization and grazing exclusion treatments

Nicolina Johanson, University of Oulu

15. Which conservation measures are most beneficial to bird response to climate warming?

Leonie Jonas, University of Turku

16. Blue food, green food, and the nature crisis

Christian Jørgensen, University of Bergen

17. Ecological and evolutionary consequences of selective interspecific information use

Mira Kajanus, University of Jyväskylä

18. Species Distribution Modeling with Expert Elicitation and Bayesian Calibration

Karel Kaurila, University of Helsinki

19. Microclimate relationships of intraspecific trait variation in sub-Arctic plants

Julia Kemppinen, University of Oulu

20. Sex-specific spatial wintertime distribution and hoarding behaviour of an avian predator

Elina Koivisto, University of Turku

21. Plants in the cross pressures of climate change and land use: variation of traits and thermal plasticity in European *Hypericum* populations

Susanna Koivusaari, University of Oulu

22. Snowbed vegetation and its mesotopographic variation in subcontinental mountains of NE Finland

Inka Kuusisto, University of Turku

23. Associations between metal pollution and early-life microbiota in three passerine species

Lyydia Leino, University of Turku

24. Exploring the phyllosphere microbial communities across three *Rubus* species and their effects on plant growth

Sara Leino, University of Helsinki

25. Using eye temperature to assess stress level in working reindeer

Océane Liehrmann, University of Turku

26. Making sense of spatial and temporal aspects of beta diversity

Marja Lindholm, University of Oulu

27. The periodic geospatial superbiome: How seasonality and geography correlate with great tit (*Parus major*) gut microbiome

Martta Liukkonen, University of Jyväskylä

28. Temperature sensitivity of breeding phenology and fitness of common redstarts

Ilaria Lonero, University of Edinburgh

29. Projected loss of brown macroalgae and seagrasses with global environmental change

Federica Manca, University of Helsinki

30. The effects of glyphosate-based herbicides on foraging behavior of pollinators

Kimmo Kaakinen, University of Turku

31. Automatic animal detection from camera trap images

Tommi Mononen, University of Helsinki

32. Patterns of aging are trait- and sex-specific in the long-lived Alpine swift
Héloïse Moullec, University of Turku

33. Up- and downregulating plant defences of *Ficus* and *Macaranga* species, and effects on herbivores and predators
Elina Mäntylä, University of Turku

34. Ecological assembly processes: a predictive framework for fungal and lichen metacommunities
Domenica Naranjo, University of Jyväskylä

35. Urban evolution of seasonal plasticity of life history and color in Lepidoptera
Matthew Nielsen, University of Oulu

36. LIFEPLAN: A planetary inventory of life – a new synthesis built on big data combined with novel statistical methods
Otso Ovaskainen, University of Jyväskylä

37. Remote sensing in mapping environmental preferences of epiphytic lichen communities on European aspen
Ida Palmroos, Finnish Environment Institute Syke

38. Remote sensing promotes the management of peatland resources and monitors the condition of ecosystems
Yuwen Pang, University of Helsinki

39. Disentangling processes behind occurrence and abundance of whitefish larvae distribution using fisheries and larvae sampling data
Ilaria Pia, University of Helsinki

40. Thermal plasticity of seed germination traits in European plant species
Laura Pietikäinen, Finnish Museum of Natural History Luomus

41. The benefits of polyandry in the bushcricket *Kawanaphila nartee*
Varpu Pärssinen, University of Gothenburg

42. Impacts of metal pollution on early-life microbial environment of wild birds
Miia Rainio, University of Turku

43. Micro-scale patterns and drivers of bird visitation on street fig trees in an Indian megacity

Prakhar Rawal, University of Turku

44. How does landscape structure affect butterfly diversity in agricultural environments?

Ulla Riihimäki, University of Helsinki

45. Variability of a cooperative defense behavior in social pine sawflies

Raphael Ritter, University of Helsinki

46. How picky are large herbivores? Modeling habitat selection of three semi-feral herbivore species in a Danish rewilding project

Roberto Ruggiero, Aarhus University

47. The effect of population size on adaptation to fluctuating temperatures

Emmi Räsänen, University of Jyväskylä

48. Spring habitats – their overall state in Finland and the impact of the Finnish Forest Act on their conservation status

Veera Saari, University of Jyväskylä

49. Spectral properties of dominant *Sphagnum* moss species in different boreal peatland ecosystems

Sini-Selina Salko, Aalto University

50. Dynamics of kelo trees in boreal forest landscapes

Pemelyn Santos, University of Eastern Finland

51. How are local communities defined? A mismatch between metacommunity theory and empirical studies

Lluís Serra, University of Jyväskylä

52. Local and regional effects of temporal fragmentation on biodiversity in drying river networks

Henna Snåre, Finnish Environment Institute Syke, Nature Solutions

53. High stumps as nesting sites for bees and wasps in boreal forests
Suvi Sutinen, University of Helsinki

54. Eavesdropping on conspecific alarm calls across territory borders: wild birds form population-wide information webs
Jakub Szymkowiak, Adam Mickiewicz University

55. Local or regional factors influencing historical forest fires in Fennoscandia
Gargi Tariyal, University of Eastern Finland

56. Including geodiversity in biodiversity research and conservation
Maija Toivanen, University of Oulu

57. Plasticity of host defences against cuckoos is not density dependent
Deryk Tolman, University of Helsinki

58. Does converting urban lawns into meadows improve biodiversity and carbon sequestration in the boreal region?
Justine Trémeau, Finnish Meteorological Institute

59. Big species specific differences in bats' responses to artificial light
Valeria Valanne, Finnish Museum of Natural History Luomus

60. Carry-over effects of developmental heat stress
Nadja Verspagen, University of Helsinki

61. Parental effects in a filamentous fungus: phenotype, fitness, and mechanism
Mariana Villalba, University of Jyväskylä

62. Effects of low-frequency vibrations on anhydrobiotic survival of tardigrades
Tommi Vuori, University of Jyväskylä

63. Genome evolution diverts stress tolerance in a grass species *Phragmites australis*
Cui Wang, University of Helsinki

64. Comparing functional diversity and ecosystem services provided by arthropods between agricultural and natural areas
Veikko Yrjölä, University of Helsinki