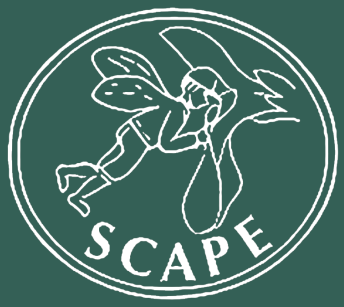

SCAPE 2021

35th Annual Meeting of the Scandinavian Association for Pollination Ecology

21 October
University of Warsaw Botanic Garden, Warsaw, Poland

22–24 October
European Centre for Geological Education, University of Warsaw, Chęciny, Poland

CONFERENCE PROGRAMME

Organizing Committee:
Marcin Zych, Katarzyna Roguz, Justyna Ryniewicz, Barbara Płaskonka, Marcin Mazurkiewicz – University of Warsaw Botanic Garden

Logistic partner: WhyNotTravel

Thursday, 21 Oct	
16.00 – 19.00	Registration
17.30 – 19.00	Supper / Organizers Welcome
19.15	Bus to Chęciny Station (from the Gardens courtyard)

Friday, 22 Oct		
7.00 – 8.30	Breakfast / Sauna	
8.30 – 10.25 / 1nd session (chair 1: Marcin Zych) / ECOLOGY		
8.30 – 9.15	Nectar neurobiology: facts and hipotheses / Massimo Nepi	
9.15 – 9.20	Short break	
9.20 – 9.35	Plant niche width and dominance influence structure of pollinator spectra of generalist plants	Zdeněk Janovský
9.35 – 9.50	Differentiation in diurnal pollen presentation schedule as a mechanism for minimising plant competition for pollinators?	Jakub Štenc **S**
9.50 –10.05	Resin for bees: an underrated resource?	Sara Diana Leonhardt
10.05 – 10.10	Pollination ecology of the African cycad Encephalartos ghellinckii	Terence Suinyuy
10.10 – 10.15	Time of Day Affects Abundance of Various Pollinator Taxa in Oilseed Rape Fields	Arrian Karbassioon **S**
10.15 – 10.20	Evidences of neuroactive octopamine in the floral nectar of *Echium vulgare L.*	Marta Barberis **S**
10.20 – 10.25	Nectar robbing induces assymetric competition between invasive and native bumble bees in Patagonia	Nick Rosenberger **S**
10.25 – 10.45	Coffee break	
10.45 – 12.00 / 2nd session (chair 2: Nina Sletvold) / ECOLOGY		
10.45 – 11.00	A comparison of the identification and quantification success of insect-dispersed pollen with novel pollen identification methods	Elena Motivans Švara **S**
11.00 – 11.15	Filtering approaches of pollen DNA metabarcoding data: strategies and ecological consequences	Paolo Biella
11.15 – 11.30	What do bees really need? – Comparing bee-plant visitation and pollen DNA based networks	Susanne Butschkau **S**
11.30 – 11.45	BRASILICO. A country-wide monitoring of bees	Samuel Boff
11.45 – 11.50	Relatively high outcrossing rates despite frequent within-plant pollinator movement in self-compatible Arabidopsis lyrata	Marc Stift
11.50 – 11.55	The effect of elevated developmental temperature on mortality and morphology of butterflies	Zahra Moradinour **S**
11.55 – 12.00	Evolution of floral rewards in the newly circumscribed Maxillaria sensu lato	Małgorzata Stpiczyńska
12.00 –13.00	Lunch	

S – student

13.00 – 14.20 / 3rd session (chair 3: Jane Stout) / EVOLUTION		
13.00 – 13.15	Components of local adaptation and divergence in pollination efficacy in a coevolving species interaction	Magne Friberg
13.15 – 13.30	Spatiotemporal variations in seed set and pollen limitation in populations of the rare generalist species *Polemonium caeruleum* in Poland	Justyna Ryniewicz **S**
13.30 – 13.45	Intraspecific variation in floral longevity: a meta-analysis	Marcos Mendez
13.45 – 14.00	Climate, pollinators, and flower colour polymorphism in *Anemone coronaria*	Yuval Sapir
14.00 – 14.15	Individual flowering schedules and floral display size in monkeyflower: a common garden study	Wendy Semski
14.15 – 14.20	Just showy or simply honest? Signaling of the floral reward in yellow iris (*Iris pseudacorus L.*)	Marcin Mazurkiewicz **S**
14.20 – 14.30	Comfort break	
14.30 – 16.00	Poster-session with coffee and cake / Yuval Sapir	
16.00 – 17.30 / 4th session (chair 4: Marcos Mendez) / EVOLUTION		
16.00 – 16.15	Pollinator-mediated selection on three deceptive *Dactylorhiza* Marsh orchids.	Cristina Rodríguez Otero **S**
16.15 – 16.30	Flower colour evolution in sexually deceptive *Ophrys* flowers	Casper van der Kooi
16.45 – 17.00	Pollinator-mediated floral divergence in *Castilleja:* long corolla tubes may reflect adaptation to novel hawkmoth pollinators	Katie Wenzell
17.00 – 17.15	Adaptive generalization: the neglected side of floral adaptation to biotic interactions	Kazuharu Ohashi
17.15 – 17.30	Sexual selection in hermaphroditic flowering plants: an experimental test of Bateman's principles	Jeff Karron
17.30 – 17.40	Comfort break	
17.40 – 19.10 / 5th session (chair 5: Paolo Biella) / SCENT		
17.40 – 17.55	The repeatability of floral scent across a geographic mosaic of coevolution in *Oenothera cespitosa* ssp. *marginata*	Katherine Eisen
17.55 – 18.10	Adding compound-specific information in chemodiversity measurements to understand the ecology and evolution of floral scents	Hampus Petrén
18.10 – 18.25	Measuring, comparing, and interpreting phenotypic selection on floral scent	Øystein Opedal
18.25 – 18.40	The evolution of floral scent rewards	Laura Hildesheim **S**
18.40 – 18.55	Does increasing water stress and elevated nitrogen influences phenotypic plasticity of floral scent in three *Brassicaceae* species?	Rebecca Höfer **S**
18.55 – 19.10	The Chemical Landscape of *Arabis alpina*	Hanna Thosteman **S**
19.10 – 21.00	Supper	
19.50 – late	Networking / Socialising / Sauna	

S – student

Saturday, 23 Oct		
7.00 – 8.30	Breakfast / Sauna	
8.30 – 10.05 / 6th session (chair 6: Casper van der Kooi) / CONSERVATION		
8.30 – 8.45	Are plant centred restoration efforts successful in restoring plant-pollinator interactions?	Demetra Rakosy
8.45 – 9.00	Wild bee flower visitation patterns along a land use and plant diversity gradient in agricultural land	Alejandra Parreno
9.00 – 9.15	Potential consequences of pollinator decline for plant population recovery and extinction risk	James Rodger
9.15 – 9.30	Clover rich leys as a potential complementary food resource for pollinating insects in semi-natural grasslands	Julia K. M. Weber
9.30 – 9.45	Global research in plant-pollinator communities in the Mediterranean biome	Afroditi Kantsa
9.45 – 10.00	treet food for pollinators: how urban landscape shapes the nutritional featus of bumblebees diet	Emiliano Pioltelli **S**
10.00 – 10.05	Pollination in the city center. Small and isolated patches of urban greenery are attractive for pollinators	Barbara Płaskonka **S**
10.05 – 10.30	Coffee break	
10.30 – 12.00 / 7th session (chair 7: Renate Wesselingh) / POLLINATORS		
10.30 – 10.45	Floral preferences of mountain bumble bees are constrained by trait matching but flexible through elevation and season	Douglas Sponsler
10.45 – 11.00	Pollinator foraging behaviour in diseased plant patches	Klára Koupilová **S**
11.00 – 11.15	Are bees at risk of exposure to herbicides?	Linzi Thompson **S**
11.15 – 11.30	Impact of landscape configuration and composition on pollinator communities across different European biogeographic regions	Irene Bottero **S**
11.30 – 11.45	Differential equation model for central-place foragers with memory: Implications for bumble bee crop pollination	Pau Aragones **S**
11.45 – 12.00	How many animals are pollinators?	Sissi Lozada Gobilard
12.00 – 13.00	Lunch	
13.00 –15.00	Excursion	
16.15 – 17.25 / 8th session (chair 8: Sara Leonhardt) / POLLINATORS		
15.00 – 15.45	The role of floral traits in pollination and pollinator disease transmission / Rebecca E. Irwin	
15.45 – 16.15	Coffee break	
16.15 – 16.30	Bees' favourite plants – identifying keystone species for wildflower strips	Jonas Kuppler
16.30 – 16.45	Plant-pollinator networks in human changed habitats	Aleksandra Żmuda **S**
16.45 – 17.00	Accumulation of heavy metals from pollen, depending on the feeding regime, in developing red mason bees and honey bees	Hajnalka Szentgyörgyi
17.00 – 17.15	Nesting material, phenology and landscape complexity influence nesting success and parasite infestation of a trap nesting bee	Maxime Eeraerts
17.15 – 17.20	Genomic divergence and a lack of introgression between commercial and wild bumblebees, *Bombus terrestris*	Cecilia Kardum Hjort **S**
17.20 – 17.25	Effects of land use intensity on pollinator behavior in agricultural landscapes	Markus Birkenbach **S**
17.25 – 17.35	Comfort break	
17.35 – 19.15 / 9th session (chair 9: Magne Friberg) / AGRICULTURE & POLLINATORS		
17.35 – 17.50	On-farm experiences shape farmer knowledge and perceptions of pollinators and their decision-making	Julia Osterman **S**
17.50 – 18.05	Effects of agricultural landscape structure, insecticide residues, and pollen diversity on the life-history traits of the red mason bee *Osmia bicornis*	Agnieszka Bednarska

18.05 – 18.20	Integrated pest and pollinator management and a case of the insecticide thiacloprid in apple orchards	Bjørn Arild Hatteland
18.20 – 18.35	Pesticide residues in pollen and nectar of crops and wild plants from agricultural fields in Ireland	Elena Zioga **S**
18.35 – 18.40	Bee pollinators in Styrian oilseed pumpkin	Marzena Masierowska
18.45 – 18.50	How does exposure to a pyrethroid and an organophosphate effect bumblebee foraging behaviour and pollination services?	Alison O'Reilly **S**
18.55 – 19.00	Insecticides in the landscape – a potent mix for a bumblebee colony	Jessica Knapp
19.05 – 19.10	Landscape drivers of pesticide use patterns and their risk to pollinators	Charlie Nicholson
19.10 – 19.45	Getting ready...	
19.45	Conference dinner	
21.30 – late	Party	

Sunday, 24 Oct	
7.00 – 9.45	Breakfast and check-out
10.00	Bus to Warsaw

S – student

KEYNOTE SPEAKERS ABSTRACTS

Nectar neurobiology: facts and hipotheses

Nepi Massimo

Departament of Life Sciences, University of Siena

In recent years, the "partner manipulation hypothesis" concerning nectar chemistry has been proposed. According to this theory, nectar secondary compounds may have evolved in nectar to stabilize relationships between flowers and pollinators and to maximize pollination efficiency. In this regard, nectar secondary compounds that may directly influence insect neurobiology and thus insect behaviour are of particular interest. The presence of important neurotransmitters or compounds that can interact with receptor proteins found on neurons have recently been highlighted in nectar, paving the way for nectar neurobiology. This contribution is an overview of what we know about these compounds and their effect on insect neurobiology and behaviour and a chance to discuss possible evolutionary hypotheses.

The role of floral traits in pollination and pollinator disease transmission

Rebecca E. Irwin

North Carolina State University

Floral traits play key roles in mediating pollinator foraging behavior and pollination success. Yet, these same flower traits that attract pollinators can also promote the transmission of pathogenic pollinator-associated microbes. This walk will focus on nectar and pollen traits and floral morphology more generally and how they are involved in bumble bee pollinator foraging behavior and pollination processes, as well as the transmission of bumble bee pollinator diseases. Results suggest that various nectar and pollen components and some aspects of floral morphology can affect one or more steps in the disease transmission process. This information is valuable when considering which plant species to choose in pollinator habitat restoration.

ORAL PRESENTATION ABSTRACTS

Friday 22nd October
1st session

Plant niche width and dominance influence structure of pollinator spectra of generalist plants

Zdeněk Janovský[1], Jakub Štenc[1]

[1]Dept. of Botany, Charles University

Floral traits are assumed to be the main determinants of plant's pollinator spectrum, but this does not seem to be the key factor in most temperate European plants, where plants with traits allowing pollination by multiple groups dominate. Nevertheless, there is still variation in composition of their pollinator spectra and this is likely to be influenced by the plant's environments, i.e., by abundance of its conspecifics and by other co-flowering species. Both locally dominant species and species with more diverse surroundings (i.e., with broader niches) can be expected to have more generalised pollinator spectra. To test these hypotheses, we assembled a database of >250 plant species' pollinator spectra from literature. We relate degree of generalisation of plant's pollinator spectrum, its composition and proportion of important functional groups to plant niche width and local dominance extracted from the Czech National Phytosociological Database. We found species with broader niches to indeed have on average more generalised pollinator spectra but not so for locally dominant species. The main gradient of pollinator spectra stretched from bumblebee-dominated spectra to diptera- and/or nitidulid beetle-dominated spectra and plants with bumblebee-dominated spectra had neither the broad generalised niches nor were they the strict specialists. Among plants with diptera- and/or nitidulid- dominated spectra, plant's local dominance increased the degree of domination of muscids in pollinator spectrum, while hoverflies showed the opposite pattern. Honeybees, though rather infrequent in pollinator spectra, also showed a strong preference for locally dominant plant species, possibly attributing to their foraging strategy. We can conclude that composition of plant's pollinator spectrum is not independent of other aspects of plant's life-history strategy constituting its niche. Broader niches result in more variable pollinator spectra further supporting the existing notion that pollinator specialisation is beneficial mainly for less abundant species with narrower niches.

Differentiation in diurnal pollen presentation schedule as a mechanism for minimising plant competition for pollinators?

Jakub Štenc[1], Lukáš Jánošík[1], Zdeněk Janovský[1]

[1]Department of Botany, Faculty of Science, Charles University

Sharing pollinators between co-flowering species is supposed to result in competition between plant species and cause a subsequent negative effect on plant sexual reproduction. One of the ways how to avoid such a competition is hypothesised to be species' temporal differentiation in pollen release and presentation schedules during the day. However, there is a lack of studies on pollen presentation schedules that would be coupled with pollinator diurnal activity aiming to test the existence of such differentiation. Hence, we selected three co-occurring and co-flowering species at the same site and investigated their relationship between the timing of pollen release during the day, pollinator daily visi-

tation pattern and amount of conspecific pollen carried by the pollinators. The studied species belonged among the dominants at the site and were pollinated by generalist pollinators visiting many other species (including often the other two). We found differentiation in pollen presentation of studied species and visitation patterns of their pollinators during the day. We also expect the same pattern to be seen in the pollen carried on the pollinator body according to our preliminary results. Our results, therefore, highlights the possible importance of pollen presentation schedule as another dimension in plant-pollinator interactions.

Resin for bees: an underrated resource?

Sara Diana Leonhardt[1], Benjamin Kaluza[2], Nora Drescher[2]

[1]Technical University of Munich; [2]University of Lüneburg

It is widely known that bees collect pollen and nectar from flowers. It is hardly known that many bees, both solitary and social, also collect substantial amounts of plant resins from various plant species. Bees use this intriguing substance to construct and defend their nests, to support their immune system and to increase the chemical and functional diversity of their cuticular profiles. We are studying the collection and use of resin as well as the influence of landscape-related availability and diversity of resin-providing plants on the collection behavior and health of social bees. For both temperate and tropical regions, we revealed a broad spectrum of resin sources generally targeted by bees. However, the spectrum of resin collected depends on the surrounding landscape and plant community. Just as flower diversity, resin diversity is reduced in intensively used agricultural areas, with negative effects on its functional properties. Resin may thus play a strongly underestimated key function in the wellbeing of resin collecting bees.

Pollination ecology of the African cycad *Encephalartos ghellinckii*

Terence Suinyuy[1], Steven Johnson[2]

[1]University of Mpumalanga; [2]University of KwaZulu-Natal

Heat and odour production can have profound effects on pollination in cycads. It is therefore expected that these traits would co-vary geographically with pollinator assemblages. Such intraspecific variation, may lead to the evolution of pollination ecotypes. We investigated whether geographical divergence in cone volatiles emitted by the African cycad *Encephalartos ghellinckii* can be linked with functions for attracting different pollinators. We tested the pollination effectiveness of different insects and investigated whether daily fluctuations in cone temperature are correlated with insect pollinator activity. We also performed field bioassays to test the responses of insects to key volatiles and laboratory y-maze experiments to determine whether insects discriminate among cones of the two forms. Experiments confirmed that the beetles *Metacucujus goodei* and Erotylidae sp. nov. are the most effective pollinators of the mountain and lowland forms, respectively. A peak in cone temperatures in the afternoon was associated with extensive movement of insects among cones of mountain plants, but only limited movement of insects among cones of lowland plants. In field bioassays, (3E)-1,3-octadiene, a main component of the scent of mountain plants attracted *M. goodei* beetles, whereas Erotylidae sp. nov. responded to camphene emitted mainly by lowland plants. When offered a choice, beetles preferred cones from the local population over those from a different population. The results suggest that *E. ghellinckii* consists of two pollination ecotypes with modifications in scent chemistry being correlated with an apparent shift between different pollinators. The relationship between thermogenesis and pollinator activities varies between ecotypes, with mountain plants showing a push–pull type of system and the lowland plants a system in which insects depart from cones with declining quality. This study highlights the role of insect pollinators in driving the evolution of cycads and the importance of thermogenesis and volatile emissions for mediating some beetle pollination systems.

Time of Day Affects Abundance of Various Pollinator Taxa in Oilseed Rape Fields

Arrian Karbassioon[1], Dara Stanley[1]

[1]University College Dublin

There is an overlap in the ideal weather for pollinator activity and pesticide application in agriculture. Primary and secondary exposure to pesticides is known to cause sublethal effects which can have harmful effects on insect pollinators and the ecosystem services they provide. Furthermore, pesticide application guidelines that take pollinators into account are typically shaped around the behavior of the honeybee (*Apis mellifera*) and exclude native pollinators whose behavior is known to be different. We aimed to evaluate how active various pollinator groups are at different times of day, to understand how this may influence their potential contact with pesticide application. We walked transects from 0600 to 2200h at three Oilseed Rape (*Brassica napus*) farms in Ireland, to capture the abundance of native and managed pollinators across daylight hours. We found that taxa and time of day are strong determinants of pollinator abundance. Honeybee and solitary bee activity was highest in the middle of the day while bumblebee (*Bombus* spp.) activity was more consistent throughout daylight hours. Hoverfly abundance peaked towards the late afternoon and early evening. This diversity of response among pollinator species to time of day should be accounted for when forming guidelines around the optimal spray time of chemicals to minimize direct or secondary exposure of beneficial insects to pesticide application.

Evidence of the neuroactive octopamine in the floral nectar of *Echium vulgare* L.

Marta Barberis[1], Gherardo Bogo[2], Laura Bortolotti[2], Simone Flaminio[2], Emanuele Giordano[3], Massimo Nepi[3], Marta Galloni[1]

[1]Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Bologna; [2]Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Centro di ricerca agricoltura e ambiente (CREA-AA); [3]Dipartimento di Scienze della Vita, Università di Siena

The chemistry of nectar is central to ecology, since it mediates interactions with pollinators, flower-visiting antagonists and microbes. Hundreds of secondary metabolites have been found in nectar starting from the 70s and several studies demonstrated that some of them show a variety of different functions involved in modulating the behavior of floral visitors. Biogenic amines are nitrogenous compounds which are known to act as neurotransmitters, neurohormones and neuromodulators in insects, and their consumption modulates several behavioral traits such as locomotion, reward-seeking, learning and social communication. Since they can be generated by microbial decarboxylation of free amino acids, it is believed that they may be found in nectar as a product of yeast activity rather than being a plant product. Nevertheless, at the best of our knowledge, biogenic amines haven't been reported yet. In this study, we verified the presence of biogenic amines in the floral nectar in *Echium vulgare* L. For the purpose, 25 nectar samples were collected by glass microcapillaries from functionally female flowers in four Italian populations, in order to investigate their chemical composition through HPLC. Of all biogenic amines investigated, the only one found resulted octopamine, varying in concentration depending on the population, ranging between a minimum value of 273 nmol/ml and a maximum of 1211 nmol/ml. Since this compound has been demonstrated to enhance learning performance, motivation and arousal in bees, its presence in floral nectar may exert beneficial effects on the plant reproductive success and further investigations need to be addressed in order to understand its ecological meaning.

Nectar robbing induces assymetric competition between invasive and native bumble bees in Patagonia

Nick Rosenberger[1], Marcelo Aizen[2], Rachel Dickson[3], Lawrence Harder[4]

[1] Graduate Group in Ecology, University of California - Davis;[2] Laboratorio Ecotono-CRUB, Universidad Nacional del Comahue and INIBIOMA;[3] Department of Biological Sciences, University of Montana-Missoula;[4] Department of Biological Sciences, University of Calgary

To gain access to otherwise inaccessible nectar, flower visitors may bite through corolla tissue to create holes and gain nectar access (nectar robbing). Holes created by nectar robbers to access nectar can initially deplete nectar availability, but also alter nectar access for subsequent visitors. This modification of flowers may facilitate resource access for conspecifics, potentially alleviating intraspecific competition, but exacerbate interspecific competition for "legitimate" flower visitors by reducing nectar rewards. Legitimate flower visitors could behaviorally respond to nectar robbing and robbing holes by: 1) continuing visits to floral openings (tolerate); 2) use nectar robbing holes to access remaining nectar (adopt); or 3) seek alternative floral resources (avoidance). To evaluate behavioral responses of legitimate visitors to nectar robbing, we studied a unique plant-pollinator system in Argentine Patagonia where invasive Bombus terrestris nectar robs the long-tubed flowers of Fuchsia magellanica normally visited by long-tongued B. dahlbomii. We characterized the visitation and behavior dynamics of these bumble bees throughout the plant's protracted flowering period (December-April) using daily plant surveys of pollinator visitation and nectar robbing. After initially visiting flowers through floral openings, B. terrestris shifted exclusively to nectar robbing and increased conspecific abundance 20-fold within 10 days. Furthermore, the incidence of robbed flowers varied positively with increased visitation by B. terrestris. In contrast, during B. terrestris dominance, B. dahlbomii abundance remained low and varied negatively with the incidence of robbed flowers. However, of the few B. dahlbomii individials visiting F. magellanica flowers they either tolerated (legitimate visits) or adopted robbing holes (robbing visits). When B. terrestris ceased visiting F. magellanica flowers, the prevalence of robbing holes diminished until robbed flowers senesced and B. dahlbomii abundance increased 6-fold. This result suggests legitimate visitors can avoid some negative effects of nectar robbing by seeking alternative floral resources and partially compensate for nectar competition.

2nd session

A comparison of the identification and quantification success of insect-dispersed pollen with novel pollen identification methods

Elena Motivans Švara[1], Demetra Rakosy[1], Thomas Hornick[1], Alexander Keller[2], David Boho[3], Patrick Mäder[3], Tiffany Knight[1], Susanne Dunker[1]

[1]Helmholtz-Centre for Environmental Research – UFZ; [2]Julius Maximilian University of Würzburg; [3]Technische Universität Ilmenau

The identification and quantification of insect-dispersed pollen is important to understand pollen transfer and its effects on plant reproduction as well as to reconstruct past communities and climates using paleo-pollen. However, the principle method for pollen identification, microscopy, is time-intensive and requires strong taxonomic knowledge of pollen grains; it has thereby hampered the ability to answer large-scale research questions involving pollen. In addition to morphological identification, many recent advances have been made to automatize the identification of pollen, including DNA and image-based methods that promise accuracy, efficiency, and the potential to process large amounts of data. As these methods are relatively new, it is unknown how the output of these methods compares to the gold standard of microscopy or to each other. Therefore, we compared three methods for pollen identification,

comprising metabarcoding, imaging flow cytometry coupled with machine learning, and microscopy, on the pollen loads taken from thirty pollinators collected in the field. Here, we present the results from our study, comparing species and abundance differences of pollen detection at different taxonomic scales (species, genus, and family). With these results, we can highlight the differences in detection limits between different methods and different pollen compositions.

Filtering approaches of pollen DNA metabarcoding data: strategies and ecological consequences

Paolo Biella[1], Nicola Tommasi[1], Andrea Ferrari[1], Massimo Labra[1], Andrea Galimberti[1]

[1]ZooplantLab, Department of Biotechnology and Biosciences, University of Milano-Bicocca, Italy
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DNA metabarcoding of pollen mixtures has been increasingly applied to the field of pollination biology. For example, this technique has been used in our research on the impact of landscape alteration on plant-pollinator interactions in Italy, Tanzania and Maldives, and in experiments testing bumblebee foraging after workforce reduction. However, methodological and interpretation issues arise due to the high sensitivity of this molecular methodology. A key step concerns filtering or maintaining false positives, contaminants, and rare taxa or molecular features, that could lead to different ecological results. We overviewed the filtering technique used in the published literature on pollen DNA metabarcoding, which highlighted a very high heterogeneity of methods. We also assessed how these different filtering strategies shaped pollen community assemblage composition, species richness and interaction networks. To do so, we compared four processing methods: unfiltering, a proportional threshold 1% of sample reads, a fixed cut-off value of 100 reads, and the ROC statistical approach. We found that filtering impacted species composition and reduced species richness, with ROC emerging as a conservative approach. Moreover, unfiltered dataset resulted in plant-pollinator networks that were very different from the filtered versions in ways indicating that filtering better describes interactions. Overall, filtering or not, is a key aspect of DNA metabarcoding data and each option should be carefully evaluated and justified on biological or methodological bases in order to strengthen the ecological interpretations of the systems we study.

What do bees really need? – Comparing bee-plant visitation and pollen DNA based networks

Susanne Butschkau[1], Sara Diana Leonhardt[1], Alejandra Parreno[1], Alexander Keller[2]

[1]Technical University of Munich [2]Ludwig Maximilian University of Munich

Wild bee populations have been declining rapidly over the past years. Land-use is one major factor threatening plant-bee interactions along with other anthropogenic factors. This decline is a threat for animal-pollinated plant species. To uphold the mutualistic relationship between bees and plants, a diverse community of both is necessary. To gain more information about the foraging choices of wild bees in utilized agricultural landscapes, we caught bees on plots differing in land-use intensity, which are part of the framework of the German Biodiversity Exploratories. This survey is part of a bigger project, which studies the effect of land-use and landscape components on plant and bee biodiversity and their reproductive success. Based on observations of bee-plant visitations and plant species information obtained from metabarcoding pollen of those bees, we evaluated (i) if bees seek flowering plant sources outside of plots with high or low land-use intensities and (ii) how this affects network interaction patterns. Pollen samples were analyzed using DNA-metabarcoding based on the ITS gene region. We present first results of observation vs. pollen based interaction networks for 104 bee species sampled in 2020. We discuss differences between network structures and implications for bees and plants based on e.g. the type of floral resources collected by bees from outside the investigated plots.

BRASILICO. A country-wide monitoring of bees

Samuel Boff[1], Andre Rech[2], Alan Eriksson[3], Aline C. Martins[4], Antonio Aguiar[4], Breno Magalhães[5], Camila Aoki[3], Daniela Parizotto[6], Evandson J. dos Anjos Silva[7], Favizia Freitas de Oliveira[8], Fernanda Santos[9], Ingrid Gomes[10], Laércio Peixoto do Amaral Neto[11], Larysson Feitosa dos Santos[5], Luisa Carvalheiro[12], Maria Auxiliadora Milaneze Gutierr[13], Maria Cristina Gaglianone[14], Marina Muniz Moreira[15], Nayara Carvalho[16], Patricia Nunes-Silva[17], Pietro Maruyama[18], Rodrigo Gonçalves[19], Thiago Mata Barreto[8], Vivian Freitas Maranhães[14], Marcelo Mello[11], Lucas Padula Abbade[11], Marcos Yudi Nagaoka Godoy[20], Luis Gustavo de Sousa Perugini[13], Jousé Raizer[21]

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Brasilico was born as a pollinator monitoring project in Brazil with the aim of carrying simultaneous sampling of bees during the pandemic situation of covid 19. Since most of the activities at the Brazilian universities were restricted, we stablished a common protocol to ensure standardized sampling of bees in the garden of brazilians researchers. The key point was the choice of a common plant species. The species, Ocimum basilicum, popularly known in Brazil as "manjericão" (basil), was chosen because it is a common plant in the garden of Brazilians and widely visited by small and medium size bees. In our first monitoring season (summer - December 2020-February 2021) there were collaborators from four regions of Brazil, totaling 17 sampling municipalities placed mostly in urban sites. So far, we have identified 30 genera of bees visiting basil flowers and the number of species sampled ranged from one to 16. During Scape 2021 we aim to present our preliminary results and show a protocol for worldwide monitoirng program for bees using basil as a focus plant since basil plants grows and flourishes at most countries of the world.

Relatively high outcrossing rates despite frequent within-plant pollinator movement in self-compatible *Arabidopsis lyrata*

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In species that have transitioned from self-incompatibility to self-compatibility, high rates of self-fertilization may isolate self-compatible (SC) lineages from self-incompatible (SI) ancestral lineages. Secondary contact between SC and SI lineages might thus only re-establish gene flow if SC lineages remain capable of outcrossing. By contrast, if intrinsic features of SC plants reinforce high rates of self-fertilization, this could drive further evolutionary divergence. In the North American *Arabidopsis lyrata*, SC lineages have evolved multiple times, and there are several SC-dominated populations with high rates of self-fertilization. It is unclear whether these high rates of selfing by SC plants have intrinsic or extrinsic causes. To test this, we estimated outcrossing rates and patterns of pollinator movement for 38 SC and 40 SI parents sampled from a common garden experiment with 1512 plants from five SC and five SI populations. As expected, plants from SI populations had higher outcrossing rates (mean $t_m = 0.78 \pm 0.05$ SE) than plants from SC populations (mean $t_m = 0.56 \pm 0.06$ SE). Pollinator movement likely drove this difference, as 40% of floral visits were followed by visits to other flowers on the same plant. However, outcrossing rates among SC plants were substantially higher than previous estimates from natural populations. These relatively high rates of outcrossing for SC plants under standardized conditions indicate that selfing rates in natural SC populations of *A. lyrata* are facultative and not driven by intrinsic features of SC plants.

The effect of elevated developmental temperature on mortality and morphology of butterflies

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The optimal temperature is one of the most fundamental factors during developmental process of ectothermic animals such as insects. Deviation from the optimum developmental temperature such as heat stress has been shown to cause detrimental effects on the body and/or organs developement in some species of insect pollinators such as bumblebees. In addition, heat stress can increase the rate of mortality during various developmental stages and adulthood. Butterflies are a group of insect pollinators that go through complete metamorphosis and mostly rely on the ambient temperature during the four developmental stages. Throughout the pupal stage when the body organs start to shape and develop, exposure to elevated temperature can disturb organ growth rate and may even cease the eclosion process. However, so far we know little about how and to what extent the heat stress over the course of development can affect the survival rate and morphology of butterflies. To answer this question, we implemented a study by exposing the pupae of the *Pieris napi* butterfly at 32 °C and compared their morphology and survival rate with the pupae from 23°C. We found a significantly higher rate of pupal mortality in high-temperature treatment with only 37% eclosion. We also observed that after eclosion, individuals under the heat stress condition had smaller proboscis and wing area compared to adults from the control treatment. However, high temperature during the pupal stage did not have any significant impact.

Evolution of floral rewards in the newly circumscribed Maxillaria sensu lato

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Maxillaria sensu lato comprises 17 newly circumscribed genera of Neotropical orchid. Some species reward pollinators with nectar, resins, food-laden trichomes or papillae. Most species, however, are rewardless and employ various deceit pollination strategies. Those species that have insectiform flowers display sexual deceit. Pseudocopulation has arisen independently several times in the evolution of Orchidaceae, and at least twice in Maxillaria s.l. (in Trigonidium and Mormolyca). Some members of Maxillaria s.l. produce pseudopollen. This is a mealy, yellowish-white material composed of food-laden cells formed by detachment or fragmentation of moniliform labellar hairs. In some members of the M. grandiflora complex, pseudopollen-forming cells contain a protein body and starch. Others produce pseudopollen that contains abundant starch and no proteins, whereas yet others produce pseudopollen that lacks any nutrients. Lipid droplets, when present, usually occur in minute quantities. These observations suggest that a dual deceit strategy operates in some species, since pseudopollen not only mimics powdery pollen, but in many instances lacks a food-reward. Cryptic evolutionary changes to pseudopollen content may confer biological advantage by reducing expenditure of material and energy in food-reward production, while trichome micro-morphology simultaneously encourages pollinator visits. The presence or absence of particular foods may, in turn, result in pollinator selection. Conversely, in the absence of food-rewards, insect behaviour is unlikely to be reinforced, possibly to the detriment of the orchid. We attempted to investigate the evolution of floral rewards in Maxillaria s.l., and the course it followed.

3rd session

Components of local adaptation and divergence in pollination efficacy in a coevolving species interaction

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Selection leading to adaptation to interactions may generate rapid evolutionary feedbacks and drive diversification of species interactions. The challenge is to understand how the many traits of interacting species combine to shape local adaptation in ways that directly or indirectly result in diversification. We used the well-studied interactions between *Lithophragma* plants and *Greya* moths to evaluate how plant and moth together contribute to divergence in pollination efficacy between local populations of *Lithophragma bolanderi* (Saxifragaceae) and their two specialized *Greya* moth pollinators (Prodoxidae). Both moths pollinate *L. bolanderi* plants during nectaring, and *G. politella* also pollinates while ovipositing through the floral corolla into the floral ovary. We studied *L. bolanderi* in contrasting environments in two regions of the Sierra Nevada, California. Firstly, field surveys of the abundance of *Greya* pollinators and co-pollinators, and surveys of the presence of *G. politella* eggs and larvae in developing capsules, showed that one population is visited only by *G. politella* and few co-pollinators, whereas the other population is visited by both *Greya* species and co-pollinators. Secondly, the two *L. bolanderi* populations differed in several floral traits of putative importance for successful pollen transfer. Thirdly, both *Greya* species were more efficient pollinators of their local *L. bolanderi* population during nectaring, and the pollination efficacy of ovipositing *G. politella* females was higher for *L. bolanderi* plants from the population that relied more heavily on *G. politella* in nature. Finally, *G. politella* females of different population origin performed different oviposition behaviors, suggesting local adaptation also among *Greya* populations. Collectively, our results serve as a rare example of the components of local adaptation contributing to divergence in pollination efficiency in a coevolving interaction.

Spatiotemporal variations in seed set and pollen limitation in populations of the rare generalist species *Polemonium caeruleum* in Poland

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A vast majority of angiosperms are pollinated by animals, and a decline in the number and diversity of insects often affects plant reproduction through pollen limitation. This phenomenon may be particularly severe in rare plant species, whose populations are shrinking. Here, we examined the variability in factors shaping reproductive success and pollen limitation in red-listed *Polemonium caeruleum* L. During a 5-year study in several populations of *P. caeruleum* (7–15, depending on year), we assessed the degree of pollen limitation based on differences in seed set between control and hand-pollinated flowers. We analysed the effects of flower visitors, population size, and meteorological data on plant reproductive success and pollen limitation. Our study showed that pollen limitation rarely affected *P. caeruleum* populations, and was present mainly in small populations. Pollen limitation index was negatively affected by the size of population, insect visitation frequency, and honeybee visits. Only visits of hoverflies influenced positively seed set in both control and hand-pollinated flowers, while visits of honeybees, solitary bees, beetles and butterflies negatively influenced seed set in hand-pollinated flowers. As generalist plant *P. caeruleum* can be pollinated by diverse insect groups, however, in small populations their main visitors, the honeybees and bumblebees, may be less attracted, eventually leading to the disappearance of the populations. In pollination of *P. caeruleum* managed honeybees may play a dual role: while they are the most frequent and efficient flower visitors, their presence decreases seed set in hand-pollinated flowers, which is most probably related to efficient pollen collection by these insects.

Intraspecific variation in floral longevity: a meta-analysis

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Floral longevity determines the time of exposure to pollinating agents and, therefore, the amount of pollen that is received and exported. But the costs associated with the maintenance of the sexual organs leads to (1) a cost-benefit balance in floral longevity, or (2) plasticity in floral longevity in response to changing pollination environments. Environments with few pollinators favor longer longevity. However, there is no consensus in the literature about how other factors would affect intraspecific variation in flower longevity. Here, the magnitude of intraspecific variability in floral longevity and the effect on this variability of five variables were studied: elevation, latitude, flower size, dichogamy and autogamy. Data on floral longevity in pollinated vs. unpollinized flowers were collected from the bibliography. A meta-analysis was performed to quantitatively summarize the magnitude of the effect and the heterogeneity between studies in effect size was calculated. To explain this heterogeneity, the influence of continuous variables - elevation, latitude and flower size - was further analysed using meta-regressions; the discrete variables - dichogamy and autogamy - were additionally meta-analyzed. An increase in floral longevity was observed in the absence of pollinators. Heterogeneity values were high and four of the covariates studied - latitude, elevation, autogamy and protandry - showed an impact on the effect size. In all covariates except elevation, the expected effect on floral longevity was consistent with existing hypotheses.

Climate, pollinators, and flower colour polymorphism in *Anemone coronaria*

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Flower colour is usually uniform within a population, and the few cases of intra-population colour polymorphism can shed light on the drivers of phenotypic variation in nature. We tested the role of abiotic (climate) and biotic (pollinators) factors as drivers of flower colour polymorphism in the Mediterranean herb, *Anemone coronaria*. Flowers in populations of *A. coronaria* are either uniformly red, or polymorphic with red, white, pink and purple flowers. Using citizen science we mapped the colour polymorphism in Israel and confirmed the well-established restriction of polymorphic populations to Mediterranean-climate sites. We found that mean annual precipitation of 450 mm rain is the low threshold for non-red flowers, while in semi-arid and desert climates only red flowers exist. To test whether the red morph is associated with drought adaptations, we compared water loss and carbon assimilation within and among colour morphs in three populations, in arid, semi-arid and Mediterranean climate regions. We found no significant differences in either physiological parameter, nor in stomatal density and conductivity between colour morphs. We tested for pollinators behavior in a common-garden experiment, where beetles, bees and flies were tracked to quantify potential pollen movement within and among colour morphs. We found that pollinators discriminate among colours, where glaphyrid beetles visit almost exclusively red flowers, but bees and flies visit all other colours. We conclude that pollinators may drive the maintenance of flower colour polymorphism, where in Mediterranean climate the synchronization of both glaphyrid beetles and bees with the flowering season of the anemones provides similar fitness to both red and non-red plants. Overall, our study suggests that colour polymorphism is driven and maintained by the combined effect of climate adaptation and pollinators behavior.

Individual flowering schedules and floral display size in monkeyflower: a common garden study

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Flowering patterns often vary widely and can have important consequences for reproductive success. Variation among individuals in the timing of flowering onset may result in reduced flowering overlap, especially when flowering durations are short, since plants that flower early in the season are unable to mate with plants that flower later. How plants deploy their flowers over the season is also important for reproductive success. In populations where individuals deploy their flowers in pulses, with large day-to-day variation in daily floral display size, flowering may be more asynchronous so that on a given day, only a portion may be in flower. Asynchrony reduces total floral abundance, so successful outcross reproduction may decline through insufficient pollinator attraction. However, although large daily floral displays may enhance pollinator visitation and promote pollen transfer, they may also promote increased self-fertilization as pollinators transport pollen among flowers on a single plant. This type of selfing is costly because pollen that would otherwise be available for outcrossing are instead used for selfing. In this study, we raised individual plants grown from seed from 9 natural populations of *Mimulus ringens* in a common garden. *M. ringens* is a wetland perennial native to central and eastern North America, and plants produce flowers that last for only half a day. We recorded the daily floral display for the duration of the flowering period for 20 individuals from each of the 9 populations. We then analyzed the components of the flowering phenology, including date of first flower, total flower number, flowering duration, and flowering synchrony. Flowering schedules and components vary widely within and among populations. Plants are asynchronous in peak flowering, which may reduce mate diversity and effective population size.

Just showy or simply honest? Signaling of the floral reward in yellow iris (*Iris pseudacorus* L.)

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Flowers of angiosperms vary in size, shape and color. Animals attend to these visual signals to gain a nutritional reward, such as nectar and pollen. Pollinators and herbivores, however, are addressed by the same signal. Therefore, to avoid the loss of the reward for pollinators, pollen and nectar are often hidden within flower parts, e.g. petals. To assess the potential abundance and quality of the rewards, pollinators may for example use the size of the flowers as an indirect signal of the available reward. In honest plant-pollinator relationships, the strength of the visual flower signals is potentially related to the quantity and quality of the reward offered in the flowers. To gain more insight in the factors shaping plant-pollinators interaction we tested the relation between the visual features of *Iris pseudacorus* flowers and the quantity and quality of the food reward offered in the flower. Our results show that *I. pseudacorus* flowers were visited mainly by *Apis mellifera*, which searched for nectar and pollen. We did not find, however, correlation between flower features and the nectar properties. We also did not find correlation between flower properties and the frequency of visits. Our results indicate that potential pollinators can not assess the quality of the reward by the visual characters of *I. pseudacorus* flowers. The results of our research also showed no correlation between the frequency of visits and seed production.

4th session

Pollinator-mediated selection on three deceptive *Dactylorhiza* Marsh orchids.

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[1]Lund University

It has been shown that pollinator-mediated selection on floral traits of food-deceptive orchids. However, few studies have disentangled the mechanisms linking floral traits to performance and fitness, providing an opportunity to gain a deeper understanding of the process of natural selection. In this project, we studied trait-performance-fitness relationships on three food-deceptive *Dactylorhiza* orchids in Sweden.
We built a fitness function linking each phenotypic trait to pollinator visitation, pollen deposition, pollinarium removal, and fruit set. We then used the fitness function to estimate pollination-related selection on each phenotypic traits.
Our results show that advertisement traits, such as height and number of flowers are under strong and positive pollinator-mediated selection on the three orchid species. The strength and direction of selection acting on traits related to the mechanical fit of the pollinator varied among the three species.

Flower colour evolution in sexually deceptive *Ophrys* flowers

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Sexually deceptive plants attract pollinators by presenting flowers that resemble female pollinators. Fascinating examples of sexual deception and mimicry showed high similarity between floral scent and pollinator pheromones or between the microstructures of flowers and pollinators. Beyond their smell and shape, sexually deceptive flowers can also visually mimic female pollinators via colour and patterning, although few studies have investigated the visual resemblance of sexually deceptive flowers and their pollinators quantitatively.
In this talk, I present the first results from our ongoing studies on the optical properties of *Ophrys* flowers and their insect pollinators. We investigated the spectral characteristics and anatomy of more than 30 species of *Ophrys* from all major clades and their respective bee, wasp and beetle pollinators.
There is a high similarity in colour and/or achromatic contrast between different flower structures and pollinator body parts. Dark labellum structures are similar to pollinator abdomens and (glossy) blue patches to pollinator wings. Flower interior and surface structures are tuned to floral pigments, so increasing the flower's visual resemblance to female pollinators. Intriguingly, numerous *Ophrys* species feature a bright yellow rim around their labellum and/or have pink sepals – extremities that cannot be linked to any pollinator body part. We show that these yellow and pink appendices create visual contrast very similar to that of a pollinator on a yellow or pink flower, which are commonly used as mating place in natural habitats.

Pollinator-mediated floral divergence in *Castilleja*: long corolla tubes may reflect adaptation to novel hawkmoth pollinators

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Pollinators shape the fitness and mating patterns of many plants via interactions with flowers, and therefore play a central role in the evolution of flowering plants. However, given the difficulty in disentangling floral visitation from true pollination, studies may conflate pollinator foraging patterns with their potential to exert selection on floral traits, which depends on their pollination effectiveness. This study explores whether pollinator-mediated selection may underly patterns of floral divergence within the genus *Castilleja* (paintbrushes). We documented variation in assemblages of floral visitors among 23 populations of *Castilleja* sessiliflora and the species of the *C. purpurea* complex (*C. purpurea*, *C. citrina*, and *C. lindheimeri*), in addition to measuring plant fitness in relation to visitation by distinct pollinator groups. We identify variation in the composition of floral visitors among populations and species and connect this to variation in floral traits and reproductive fitness (seed set) of populations. In the widespread species *C. sessiliflora*, characterized by long corolla tubes compared to its congeners, we found that hawkmoths (*Hyles lineata*) were frequent floral visitors in the southern range, but, contrary to expectations, we found no association with increased corolla length and visitation by hawkmoths. Nonetheless, we noted that population-level fruit set was higher in populations visited predominantly by hawkmoths. To reconcile these findings, we performed a day-versus-night pollinator exclusion experiment in seven natural populations to test whether nocturnal pollinators, including hawkmoths, contributed to greater fruit set compared to diurnal pollinators, and whether this depended on corolla length. For long-tubed populations visited by hawkmoths, fruit set was higher in plants exposed to nocturnal pollinators. Our results support the hypothesis that long corollas in *C. sessiliflora* may represent an adaptation to a novel pollinator group by increasing pollination effectiveness of hawkmoths, providing a possible example of pollinator-mediated evolution of floral traits.

Adaptive generalization: the neglected side of floral adaptation to biotic interactions

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Pollination biologists often assume that floral specialization to a particular pollinator group is adaptive, and that generalized systems are quasi-adaptive in that flowers sacrifice effectiveness in exchange for reproductive assurance. While this idea is intuitively appealing, the difficulty comes in accounting for the fact that empirical evidence for strong phenotypic trade-offs entailing fitness valleys has only been demonstrated in a few highly specialized systems. Moreover, it has been implicated in recent studies that a generalized pollination system represents a stable endpoint, as reflected in expressions such as 'dual specialization' and 'specialized bimodal pollination.' Bearing these in mind, we explored whether and how flowers could simultaneously adapt to multiple groups of pollinators and, more broadly, flower visitors. Inspired by a series of studies on floral color change, we suggest that flowers could evolve to eliminate fitness valleys due to strong trade-offs among adaptations to distinct groups of visitors, and that such 'adaptive generalization" may lead to convergent evolution of trait combinations or floral syndromes. In this talk, we would argue that such possibilities have been overlooked in earlier studies and that reframing generalized interactions in the context of adaptation may help reconcile the long-standing controversy on the discrepancy between observed flower visitors and those predicted based on floral phenotype.

Sexual selection in hermaphroditic flowering plants: an experimental test of Bateman's principles

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Variation in male reproductive success (RS) is fundamental to models of reproductive trait evolution, yet is rarely quantified in hermaphroditic flowering plants. Bateman (1948) hypothesized that variation in male RS will often exceed variation in female RS, since it is usually limited by mating opportunities, rather than by resources. Although Bateman's three principles have largely been studied in dioecious animals, Bateman suggested that they could be extended to hermaphroditic flowering plants. However, this idea has been challenged by other researchers who note that hermaphroditism imposes a constraint on the evolution of sexually-selected floral traits. Here we quantify male and female RS and mate diversity in a hermaphroditic plant to test Bateman's key predictions: 1) Higher variance in RS for male function than for female function. 2) Higher variance in mate number for male function than for female function. 3) Male RS is strongly dependent on mate number, whereas female RS is only weakly influenced by mate number. We established replicate experimental populations of monkeyflower and utilized genetic markers and paternity assignment to quantify male and female function and male and female mate number. We found strong support for all three of Bateman's principles in monkeyflower. Both the opportunity for sexual selection, and the intensity of sexual selection, were greater through male function.

5th session

The repeatability of floral scent across a geographic mosaic of coevolution in *Oenothera cespitosa* ssp. *marginata*

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In widely distributed flowering plants, population differentiation can occur in response to variation in multiple selective agents, from the abiotic environment to biotic interactions. Although many plants provide multimodal signals to mutualists and antagonists that consist of both visual and chemical cues, most studies of intraspecific variation to date have focused on visual traits. As such, our understanding of intraspecific variation in chemical traits including floral scent remains limited. In this study, we examine population differentiation in floral morphology and floral scent and variation in floral scent among flowers, plants, and populations in a widely distributed, animal-pollinated perennial species. Because it occurs in most non-coastal biomes in western North America, trait variation in *Oenothera cespitosa* ssp. *marginata* could be influenced by variation in both the abiotic environment as well as variation in the co-occurring mutualists (hawkmoths, bees) and antagonists (ovipositing moths). Plants were grown in a greenhouse common garden from seeds sourced from five populations that span the range of *O. c. marginata*, and morphological traits and floral scent were measured on one to eight flowers per plant. We found that variation in the scent, morphology, and combined datasets was explained by source population. Multiple scent metrics (total scent emission, compound diversity per scent sample, and emission rates of some compounds and groups of compounds) and measures of floral morphology varied across the source populations. For our 13 scent variables, most of the explained variance was among plants (average: 14%) and populations (average: 16%). Taken together, these results indicate that both visual and chemical traits can be differentiated across populations, and that future studies should consider the potential for variation in floral scent below the population level.

Adding compound-specific information in chemodiversity measurements to understand the ecology and evolution of floral scents

Hampus Petrén[1], Tobias G. Köllner[2], Robert R. Junker[1]

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Floral scent mediates multiple kinds of ecological interactions between plants and other organisms, including pollinators, antagonists, and microbes. The scent bouquet of a plant represents a complex phenotype, consisting of a mixture of compounds with potentially different functions. Many chemical ecological studies aim at identifying individual compounds that are central for a given interaction. However, evidence from multiple systems suggest that further characteristics of the scent phenotype than simply the presence or absence of certain compounds may influence ecological interactions. We are developing statistical methods that allow for new ways of analyses on floral scents. This includes measuring novel aspects of the phenotype, such as the diversity of the floral scent bouquet, and analyses of the structural and biochemical similarity of scent compounds, representing an important but often overlooked dimension of chemical variation. With these statistical methods, we hope to provide tools for more nuanced analyses of phytochemical variation, allowing for new insights into links between floral scent and ecological interactions.

Measuring, comparing, and interpreting phenotypic selection on floral scent

Øystein Opedal[1], Karin Gross[2], Elodie Chapurlat[3], Amy Parachnowitsch[4], Nina Joffard[5], Nina Sletvold[5], Otso Ovaskainen[6], Magne Friberg[1]

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Floral fragrances are thought to play key roles in the ecology and evolution of plant reproduction and in plant speciation. Efforts to measure natural selection on floral fragrance composition are complicated by the high-dimensional nature of floral fragrances, which typically comprise numerous volatile compounds. A promising approach to analysing natural selection on floral scent and other high-dimensional phenotypes is to leverage statistical methods that explicitly seek multivariate axes of variation that are under selection. We use Bayesian reduced-rank regression to jointly estimate the major axes of selection on floral scent and the strength of selection acting on these axes, as well as additional morphological and phenological traits. To assess and compare variation in selection on scent across species, time, and space, we reanalyse data from 4 previous studies and a total of 22 datasets comprising floral-scent, morphology, and reproductive-success data for 1793 individual plants of 6 species. In most cases, selection on floral scent could be well characterized by reducing variation in floral scent into a single 'scent selection axis'. Using this approach, we found that selection on floral scent (as a composite trait) was highly variable, and overall about as common and strong as selection on other plant phenotypic traits. These results are consistent with an important role of floral fragrance composition for pollinator attraction. Our approach to measuring selection on floral fragrance composition proved efficient and should be useful for similar high-dimensional problems.

The evolution of floral scent rewards

Laura Hildesheim[1]

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Floral scent can serve to attract or reward pollinators and evolves in response to shifts in pollinator communities. Pollinator shifts may occur gradually (quantitative pollinator shift), or immediately (qualitative pollinator shift). Even small changes in the scent profile can lead to the attraction of a set of different pollinators. In the genus *Dalechampia* (Euphorbiaceae) flowers are pollinated by Euglossine bees, which collect resin- and scent rewards. Pollinator shifts from resin-collecting female Euglossine bees to scent-collecting male bees have occurred 3 to 4 times independently. The scent rewards may have evolved either via pre-adaptation by modifying scent advertisements produced in different floral tissues, or as a biosynthetic novelty. I study how the pollinator shifts and the evolution of scent rewards occurred in this genus by quantifying variation in floral scent composition and linking it to the pollinator communities.

Does increasing water stress and elevated nitrogen influences phenotypic plasticity of floral scent in three Brassicaceae species?

Rebecca Höfer[1], Manfred Ayasse[1], Jonas Kuppler[1]

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Floral scent plays a crucial role in pollinator attraction and thus, changes in its quantity and quality can affect plant-pollinator interactions. Climatic factors, such as drought, can induce an in- or decreasing emission of floral scent compounds with effects on flower-visitor interactions and plant fitness. In addition, changes in nutrient have also shown to change scent emissions. Thus, both factors in combination can affect scent emission, especially as soil nitrogen can reduce plants' water stress, but in high concentrations may amplify this stress. Therefore, to understand how abiotic factors affect the plasticity of floral scent, it is crucial to explore interacting effects of water stress. Here, we investigated combined effects of water stress and overfertilization at an early plant stage influences scent in three related Brassicaceae species. Plants individuals were reared in a green house and randomly assigned to one of four treatments: (1) well-watered without nitrogen, (2) well-watered with nitrogen, (3) dry-down without nitrogen, (4) dry-down with nitrogen. Nitrogen was applied once when plants reached a height of 10 cm and the dry-down started after at least 5 flowers emerged. We collected scent using dynamic headspace at four time points after water treatment started: 0h, 48h, 7 days, 14 days. Additionally, we measured soil humidity at each time point and pre-dawn and mid-day stem water potential at day 7 on five individuals per species and treatment. In previous studies, we found no differences between treatments in *S. arvensis*, when collecting scent at a single time point after several weeks in treatments, indicating that *S. arvensis* could have adapt to maintain scent emission under stressful condition. These new results will show how related species response to water stress and elevated nitrogen and if we could find differences between control and drought treatments when water stress persists for a shorter time.

The Chemical Landscape of *Arabis alpina*

Hanna Thosteman[1], Sotiria Boutsi[2], Hampus Petrén[3], James Buckley[4], Loretta Pace[5], John M. Halley[6], Mark C. Mesher[7], Consuelo M. de Moraes[7], Magne Friberg[1]

[1]Lund university; [2]Harper Adams University; [3]Philipps-University; [4]University of Plymouth; [5]L'Aquila University; [6]University of Ioannina; [7]ETH Zürich

Floral scent is a complex plant trait which co-evolves with interacting insect species as the compounds emitted can attract efficient pollinators or repel unwanted visitors. There is ample evidence for interspecific variation in which compounds are emitted and to what amount, as well as their role when attracting or repelling insects. Recent studies into alpine rock-cress *(Arabis alpina* L. Brassicaceae) have revealed significant intraspecific variation in floral scent, where populations differ similar to the interspecific variation. To extend our knowledge of the chemical landscape of *A. alpina*, we expand our studies of the chemical compounds emitted by *A. alpina* to include the stress related compounds glucosinolates and consitutive/induced green leaf volatiles. If local floral scent variation is driven by local variation in pollinator composition, then variation in the GLVs and glucosinolates should be less pronounced and unrelated to the floral scent variation.

Saturday 23rd October
6th session

Are plant centred restoration efforts successful in restoring plant-pollinator interactions?

Demetra Rakosy[1], Elena Motivans[1], Jana Jersáková[2], Tiffany Knight[1]

[1]Helmholtz Centre for Environmental Research - UFZ; [2]Faculty of Sciences, Univ. of South Bohemia

Ecological restoration of human-degraded ecosystems provides an important tool to recover biodiversity and ecosystem services. While in the past most ecological restoration targeted the recovery of plant diversity and composition, there is comparatively little known about the efficiency of this approach in restoring entire community networks and ecosystem services. In the present study we aim to assess weather plant centred restoration efforts in a hay meadow complex in Central Europe have succeeded in also restoring the associated pollinator community and the structure and function of plant-pollinator networks. We found that, even though restoration efforts were focused on the plant community, plant diversity was higher in natural sites and flowering plant community composition was significantly different between restored and natural sites even after more than a decade after restoration with local seed mixtures. Pollinator diversity and composition was in contrast similar between restored and natural sites, a pattern which seems to have been driven by highly frequent species. Plant-pollinator network structure also highlights the effect of the most frequent species on shaping similar interaction patterns in restored and natural sites. However, when pollen transport was analysed, we found that in restored sites these species showed lower fidelity towards particular pant species, potentially leading to increased deposition of heterospecific pollen and impacting the reproductive success of the plants. Our data highlights that while restoration efforts have been successful in at least recovering the most frequent pollinator species, remaining differences in plant diversity, abundance and composition may affect the efficiency of pollination services rendered. We propose that future assessments of restoration success should go beyond recording plant and insect diversity and also focus on plant-pollinator interactions and their contribution to the fitness of each partner.

Wild bee flower visitation patterns along a land use and plant diversity gradient in agricultural land

Alejandra Parreno[1]

[1]Technical University of Munich

Wild bees are one of the most relevant pollinators in meadows and agricultural land. Yet there is still much unknown regarding their nutritional needs as well as the overall effect of land use on plant-insect interactions. In this talk I will present preliminary results on wild bee visitation patterns from a one-year field campaign in German and Belgian meadows, carried in 40 plots along a land use intensity and plant diversity gradient. We recorded flower visitation patterns from more than a 130 bee species from April-July, and built visitation networks for each type of landscape. Results show a complex system that is dynamic along the plant diversity gradient, with strong influence from land use activities as well as the surroundings of agricultural plots. This study serves as a platform for new analyses and working hypotheses, for example regarding the effects of land heterogeneity on bee species distribution and the role of diet generalism on species resilience faced to land use changes.

Potential consequences of pollinator decline for plant population recovery and extinction risk

James Rodger[1]

[1] Stellenbosch University

We recently showed that about half of all angiosperms rely on animal pollinators for over 80% of their seed production, including one third of species which are entirely dependent on pollinators for reproduction. This suggests that substantial numbers of plant species are vulnerable to pollinator declines through reduced seed production and consequently, reduced recruitment. In this study, we investigate the consequences of reduced reproduction for population growth and extinction risk of plant populations. As plant populations are also frequently affected by anthropogenic disturbance, we focus on transient population dynamics (i.e., for populations under non-equilibrium conditions). To do so, we combine data on pollination from pollination databases and demographic data from the compadre demographic database. We find that, for populations that have experienced disturbance and reduction in population size, diminished reproduction hinders recovery by reducing population growth rate, resulting in increased risk of extinction.

Clover rich leys as a potential complementary food resource for pollinating insects in semi-natural grasslands

Julia K. M. Weber[1]

[1]Department of Biology, Lund University

To mitigate loss of farmland biodiversity, including insect pollinators, much effort has been spent on preserving and managing semi-natural grasslands. However, our ability to reverse current negative trends using only this approach is limited, since already lost grasslands are difficult to restore and costly to manage for increased benefits to biodiversity. In addition, previously often mowed semi-natural grasslands are today mostly managed by grazing, resulting in a lack critical floral resources for many insects during summer. Hence, floral resources in the surrounding landscapes may during the summer be critically important for the persistence of flower-dependent insects in grasslands. In this talk I will present how we take an alternative approach and investigate if proper management of the surrounding landscape can enhance the conservation value of grasslands for flower-visiting mobile insects. Specifically,

how we study measures that create complementary/supplementary food resources, particularly late in the season when grasslands are often heavily grazed, and thereby potentially reduce extinction risks and enhance population sizes of pollinating insects in semi-natural grasslands. Using a variety of empirical approaches, we focus on consequences of availability and management of leys that produce nectar and pollen resources from blooming clover. I will present the first preliminary results from field data gathered during 2020 and 2021, which hopefully will give implications on whether clover rich leys in the landscape increase the conservation value of semi-natural grasslands for increased benefits to biodiversity.

Global research in plant-pollinator communities in the Mediterranean biome

Afroditi Kantsa[1], Consuelo De Moraes[1], Mark Mescher[1]

[1]ETH Zürich

Mediterranean-type ecosystems (MTEs) represent biodiversity hotspots in five global regions. Their extraordinary and often underexplored plant and pollinator diversity, the high production of insect-pollinated crops, as well as the uncertainties about their resilience to environmental change and their future distribution, make them key ecosystems for global change ecology. In this work, we reviewed the literature on MTE plant–pollinator communities to assess our current understanding on their responses to the major environmental stressors for pollinators. Our findings revealed a lack of community interaction surveys along with pronounced taxonomic biases and geographical gaps, which are presented in detail. Coordinated efforts are needed to understand the responses of MTE communities to changing environments. In this context, we identified specific research priorities and approaches for tackling the current shortfalls and enabling future predictions.

Street food for pollinators: how urban landscape shapes the nutritional featus of bumblebees diet

Emiliano Pioltelli[1], Paolo Biella[1], Lorenzo Guzzetti[1], Luca Campone[1], Massimo Labra[1], Andrea Galimberti[1]

[1]University of Milano-Bicocca

Pollinator insects inhabiting highly anthropized landscapes face multiple challenges posed by the deep environmental alterations attributable to human activities. One of the major impacts is caused by habitat fragmentation, which affects nesting resources, flower availability in the landscape and foraging for resources. These issues may also play a key role in shaping pollinators' diet composition in terms of availability and nutritional quality of floral resources. Despite this topic has gained growing attention in the last years, a wide knowledge gap still persists. The aim of this study is to assess the correlation existing between environmental features and the nutritional composition of pollen collected by bumblebee foraging in the urban landscape. 15 commercial colonies of *Bombus terrestris* were dislocated at 14 sites in the city of Milan, Italy, spanning along an environmental gradient. The sampling took place in 2020 leading to the collection of more than 3000 individual corbicular pollen samples that were analyzed for their protein, lipid, sugar, free amino acids and antioxidant compounds composition. Colony weight was also recorded along the sampling season as a proxy of their growth rate. Such investigations could inform mitigation policy aimed at ensuring suitable strategies for urban green management and pollinators communities safeguarding.

Pollination in the city center. Small and isolated patches of urban greenery are attractive for pollinators

Barbara Płaskonka[1], Marcin Mazurkiewicz[1], Katarzyna Roguz[1]

[1]University of Warsaw Botanic Garden, Faculty of Biology, University of Warsaw

Cities are among the fastest growing ecosystems on Earth, with the increase of urbanization influencing many ecological interactions, for example pollination. We still do not fully understand the influence of urbanization on this plant-animal interaction, however, there are studies showing that pollination is in danger due to human-induced stressors related to urbanization e.g., a loss of diversity in food sources for pollinators. In our study we examined the frequency of visits to flowers of *Fritillaria imperialis* (early spring) and *Hemerocallis* sp. (midsummer) growing in the center of Warsaw (Poland) in four isolated patches of urban greenery surrounded by impervious areas. Additionally, with the use of quantum dots we tracked pollen transfer between these populations. Our results show that pollinators' activity depends strongly on the weather conditions and it changes during the season. We recorded more pollinators during days with high temperature and in the middle of summer compared to early spring. Our study also showed that pollinators move between small, isolated patches with flowering plants, even when these populations are surrounded by impervious areas. Ongoing urbanization and alarming data showing severe declines in biodiversity make it necessary to rethink the role of cities in the conservation system. However, formulating recommendations for wildlife conservation activities in cities requires a broad, innovative approach to the problem, as well as taking into account the impact of urbanization on both the plants and the pollinators, as well as their interactions.

7th session

Floral preferences of mountain bumble bees are constrained by trait matching but flexible through elevation and season

Douglas Sponsler[1], Katharina Kallnik[1], Fabrice Requier[2], Alice Classen[1], A. Fabienne Maihoff[1], Johanna Sieger[3], Ingolf Steffan-Dewenter[1]

[1]University of Würzburg; [2]University of Paris-Saclay; [3]Naturpark Frankenhöhe

Patterns of resource use by animals can clarify how ecological communities have assembled in the past, how they currently function, and how they are likely to respond to future perturbations. Using ~13,000 records of bumble-bee-wildflower interactions along a 1400 m elevation gradient, we find that the selection of floral morphotypes by bumble bees is driven both by the directed process of trait-matching and the neutral effect of floral abundance. Patterns of floral preference also vary by elevation and season, which may be an adaptation to the strong spatiotemporal turnover of mountain floral communities. The flexibility of bumble bee foraging will be tested in coming years as climate and land use change alter floral resource distribution in time and space, particularly in the mountain ecosystems that host the world's richest communities of bumble bees and their floral mutualists.

Pollinator foraging behaviour in diseased plant patches

Klára Koupilová[1], Jakub Štenc[1], Zdeněk Janovský[1]

[1]Dept. of Botany, Charles University

Pollinator foraging behaviour plays a crucial role in transmission of pollinator-borne plant diseases. However, very little is known about the way pollinators respond when confronted with diseased plants during their foraging bouts. Given that diseased plants often contain lower rewards for pollinators, we asked whether pollinators avoid diseased plants and/or adjust visit duration in order to optimise energy intake. To answer these questions, we observed behaviour of pollinators foraging in experimental patches of pre-grown plants of *Dianthus carthusianorum* that were either healthy or infected with anther smut disease (*Microbotryum violaceum*). We also measured floral rewards and floral traits to identify the differences between healthy and diseased plants. We found that pollinators showed only weak avoidance of diseased plants, but subsequently probed fewer flowers on the diseased plants than on the healthy ones. Additionally, we found striking differences in foraging behaviour of main pollinator functional groups. The pollen-foraging pollinators (solitary bees and hoverflies) displayed stronger response to diseased plants than the nectar-feeding butterflies did, presumably because pollen was absent in diseased plants, while nectar was still present although in reduced amounts. Since diseased flowers offered lower rewards, the observed pollinator behaviour was consistent with the prediction of optimal foraging models that pollinators should spend less time exploring less rewarding patches or plants. Such behaviour could profoundly affect the spatial pattern of pollen dispersal and disease transmission in plant populations.

Are bees at risk of exposure to herbicides?

Linzi Thompson[1], Stephen Smith[1], Jane Stout[2], Dara Stanley[1]

[1]University College Dublin; [2]Trinity College Dublin

The effects of non-insecticide pesticides on bee health have received increasing attention in recent years. Herbicides are one of the most widely applied pesticide groups globally, and are designed to target and kill plants. Since plants typically die shortly after herbicide treatment it is possible that bees may avoid these plants, especially if there are healthy plants available. This in turn may reduce their potential contact with herbicides in the environment, through both oral and topical routes. In this study we aimed to test if bumblebees would forage on plants recently sprayed with the herbicide glyphosate when there were healthy control plants available. We further evaluated this relationship over time to see if bumblebees would forage on plants as they began to die from glyphosate treatment. A choice test was conducted where individual bumblebees were observed foraging in an exclusion cage containing both control and glyphosate treated plants. The rate and duration of interactions with each plant was recorded at both 24 and 48 + hours post spray. We found that there was no significant difference in the rate or duration of foraging interactions between glyphosate treated or control plants, and that time since plant treatment did not effect this. Therefore, we conclude that bees indiscriminately forage on glyphosate treated plants in the period before the plants die, which means bees could be exposed to this herbicide while foraging in the wild.

Impact of landscape configuration and composition on pollinator communities across different European biogeographic regions

Irene Bottero[1], Christophe Dominik[2], Olivier Schweiger[2], Jane Stout[1]

[1]Trinity College Dublin [2]Helmholtz-Zentrum für Umweltforschung GmbH – UFZ

Habitats that are heterogeneous in both their composition (i.e. land use, diversity of habitat types) and their configuration (i.e. spatial arrangement habitats and their boundaries) are likely to support higher diversity, richness and abundance of pollinators. On the contrary, the degradation of the habitats is correlated to phenomenon, such as habitat loss and fragmentation, that negatively affects pollinator insect communities. Despite these general trends, pollinator communities respond to habitat heterogeneity in different ways, depending on many factors (i.e. taxa, landscape characteristics and scales, weather and climate condition...). Since the agricultural landscape constitutes around 39% of the land cover in Europe, it affects habitat heterogeneity, with consequences for pollinators. In this context, the landscape surrounding cultivated crops can play a role in supporting insect communities, or not. Our study investigates the habitat surrounding mass-flowering crops and aims to evaluate the impact of both compositional and configuration characteristics of the landscape on the abundance of some pollinator taxa. We collected data on the abundance of five insect pollinator groups (honeybees, bumblebees, solitary bees, syrphids and butterflies) in oilseed rape crops and apple orchards distributed across 8 European countries, characterised by different habitats. We mapped the landscape surrounding each one of the 128 sites (at a 1 km radius), collecting information about compositional and configurational matrices – e.g. area and diversity of the different habitats, number of patches and their aggregation, isolation – and climate/weather parameters. Our preliminary results show that pollinators respond to the habitat with taxon-specific response and suggest a combined effect of climate, and compositional and configurational aspects of the landscape, in shaping insect pollinator communities.

Differential equation model for central-place foragers with memory: Implications for bumble bee crop pollination

Pau Capera-Aragones[1], Rebecca Tyson[1], Eric Foxall[1]

[1]University of British Columbia

Bumble bees provide valuable pollination services to crops around the world. However, their populations are declining in intensively farmed landscapes. Understanding the dispersal behaviour of these bees is a key step in determining how agricultural landscapes can best be enhanced for bumble bee survival. Here we develop a partial integro-differential equation model to predict the spatial distribution of foraging bumble bees in dynamic heterogeneous landscapes. In our model, the foraging population is divided into two subpopulations, one engaged in an intensive search mode (modeled by diffusion) and the other engaged in an extensive search mode (modeled by advection). Our model considers the effects of resource-dependent switching rates between movement modes, resource depletion, central-place foraging behaviour, and memory. We use our model to investigate how crop pollination services are affected by wildflower enhancements. We find that planting wildflowers such that the crop is located in between the wildflowers and the nest site can benefit crop pollination in two different scenarios. If the bees do not have a strong preference for wildflowers, a small or low density wildflower patch is beneficial. If, on the other hand, the bees strongly prefer the wildflowers, then a large or high density wildflower patch is beneficial. The increase of the crop pollination services in the later scenario is of remarkable magnitude.

How many animals are pollinators?

Sissi Lozada Gobilard[1], Yuval Sapir[1]

[1]Tel Aviv University

Pollination mediated by animals is crucial for the reproduction of most flowering plants. In 2011 Ollerton and collaborators, estimated that 87.5% of flowering plant species are pollinated by animals, mostly by insects. Indeed, when it comes to pollination, the most "typical" groups we think of are probably bees, butterflies, moths, wasps and flies, all insect groups; but also birds and bats and mice are well-known pollinators. However, more studies are unraveling many other "non-typical" pollinators groups, such as ants, thrips, cockroaches, snails, among invertebrates; and shrews, monkeys, marsupial and lizards among vertebrates. In this study, we describe all the "non-typical" pollinator groups that have been identified as effective pollinators to date. In addition, using an extensive dataset of papers that focus on plant-pollinator interactions, we estimate the proportion of animal groups (at family level) identified as pollinators, in both "typical" and "non-typical" groups. Our study shows for the first time, a quantitative estimation of how many animal groups have a role as pollinators, contributing to the public awareness and conservation of these plant-pollinator interactions.

8th session

Bees' favourite plants – identifying keystone species for wildflower strips

Jonas Kuppler[1], Hannah Burger[1], Sebastian Hopfenmüller[1], Antonia Mayr[1], Ulrich Neumüller[1], Rainer Prosi[2], Schanowski Arno[2], Hans Schwenninger[2], Manfred Ayasse[1]

[1]Ulm University; [2]Wildbienenkatasteramt

Recent pollinator decline is partially driven by the shortage or lack of floral food sources. To address this shortage, there is an increasing effort to create wildflower strips in agricultural landscapes to improve the food availability for pollinators. The plant species composition of these flower strips often depends on logistics, e.g. the availability of plant species seeds, and advice from experts. Thus, information on actual bee visitation frequencies are not readily incorporated. One possibility to overcome this shortcoming is to identify key flowering plants that support a high diversity and abundance of bee species based on empirical data. In our study, we explore which flowering herbaceous plants harbor the largest wild bee species richness and abundance and explore differences between generalist, specialist, and rare species. Therefore, we utilized the large-scale and long-term data sets of the BienABest project and the Wildbienen-Kataster on flower visitations by wild bees across seasons and combine these data with literature data on pollen collection by bees. Specifically, we wanted to answer two questions: 1) Which plant species host the highest species richness and abundance of generalists, specialists, and rare wild bees across plant communities within and across seasons? 2) Which plant species overlap in their attractiveness for all and rare species? Our results show that specific plant species, such as *Echium vulgare* or *Centaurea scabiosa*, can serve as key species for flower strips. The plant species change between seasons, e.g. early and late summer differ in key species. Therefore, we identified core sets of plant species that support a wide range of bees including rare and specialized ones which can be supplemented with specific plant species to support distinct bee species. Overall, our study highlights the optimizing potential of specifically combining plant species from different sets to support bee diversity including specific focal species.

Plant-pollinator networks in human changed habitats

Aleksandra Żmuda[1], Magdalena Lenda[2], Justyna Kierat[3], Agnieszka Nobis[1], Michał Kolasa[4], Matthias Albrecht[5], Anna Gajda[6], Peter Neumann[7], Robert J. Paxton[8], Olivier Schweiger[9], Josef Settele[9], Hajnalka Szentgyörgyi[1], Adam Vanbergen[10]

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Bees are crucial in maintaining the stability of most land ecosystems. Progressing anthropogenic changes forcing bees to adapt to human-changed habitats. The aim of our study was to determine the spring and late summer plant-pollinator networks in three human-changed habitats - urban, ruderal and agricultural. Plant and pollinator samples were collected in July 2020 (summer) and May 2021 (spring) on four sites in each of the following habitats: urban in Cracow, ruderal and agricultural in the vicinity of Cracow. Bees together with the flowers visited were collected during a two-hour walk on 1 km transects on each study site, additionally, floral resources were documented on ten 1m^2 plots. During the summer we have collected 991 bees (from 57 species) and 672 (from 45 species) over spring sampling. Honey bee specimens were 40% and 55% of all collected bees, respectively. On urban sites almost twice as many specimens were caught than in the two other landscape types in both sampling periods. The diversity of urban bees was the highest in comparison to rural and agricultural sites over summer sampling but in the spring there were no significant differences between them. The floral resources included 97 species (26 families) of flowering plants during the summer and 55 species (17 families) in the spring. Bees were collected with 49% and 25% of all flowering plant species, respectively. The dominant plant species in spring was Taraxacum officinale which accounted for 85% of all samples collected with bees. The diversity of flowering plants in agricultural sites was lower than on rural and urban sites in both sampling periods.
The study was funded by Biodiversa 2018-19, project "VOODOO" (PL: NCN UMO-2019/32/Z/NZ8/00006; FR: ANR-19-EBI3-0006; CH: SNSF 31BD30_186532/1; DE: DFG PA 632/10-1,12/1 and BMBF 16LC1905A).

Accumulation of heavy metals from pollen, depending on the feeding regime, in developing red mason bees and honey bees

Hajnalka Szentgyörgyi[1], Katarzyna Zięba[2], Paweł Miśkowiec[2], Agnieszka Moos-Matysik[2], Krystyna Czekońska[3]

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Heavy metal (HM) pollution of the environment is a potential cause of developmental changes in living organisms. Nevertheless, research is still scarce on the accumulation of HMs in developing bees. The aim of our research was to determine the levels of HM accumulation in developing bee larvae depending on their larval feeding regime. We have chosen one solitary species (raw pollen feeder), the red mason bee (*Osmia rufa*) and a social one (royal jelly and bee bread feeder), the honey bee (*Apis mellifera*). Our research was carried out in 2017 and 2018 on nine study sites in Poland: four near the zinc smelter in Bukowno and five in and around the city of Kraków. At each site, we sampled three honey bee colonies and three reed trap nest aggregations with red mason bees, populated with cocoons in April each year. At the end of September, the trap nests were collected and pollen samples together with red mason bee cocoons were extracted, while three sampling rounds were done for honey bees collecting bee bread and capped larvae from each hive. From the collected samples (pollen/bee bread and bee larvae/cocoon), the concentration of three heavy metals (Cd, Pb and Zn) were measured and their accumulation ratios to bee or larvae bodies were counted (bee/pollen). HM concentrations in pollen samples were generally higher in red mason bee collected pollen than in honey bee collected ones (Cd–550%; Pb-1286%; Zn-691%), sim-

ilarly, but to a lesser degree also in bee bodies (Cd–238%; Pb-240%; Zn-118%), Contrary to our expectations, the accumulation ratio was generally lower for Pb (19%) and Zn (36%) in the raw pollen feeder red mason bee and only higher for Cd (299%) compared to the royal jelly and bee bread feeding honey bee. Our research was funded by NCN: UMO-2016/21/B/NZ9/01163.

Nesting material, phenology and landscape complexity influence nesting success and parasite infestation of a trap nesting bee

Maxime Eeraerts[1], Rik Clymans[2], Vincent Van Kerckvoorde[3], Tim Beliën[3]

[1]Washington State University; [2]Ghent University; [3]PCFruit vzw

Solitary bees are receiving increasing attention as they are very effective crop pollinators. However, widespread implementation of pollination management with solitary bees in practice is hampered by a lack of targeted and practical guidelines. Indeed, evidence-based guidelines are scarce about the preferred type of nesting material, how to control nest-associated macroparasites and how to promote a healthy offspring with sufficient female bees. This study investigated whether different types of artificial nesting materials – cardboard tubes and wooden grooved boards – are preferred by the European orchard bee (*Osmia cornuta*). In addition, we explored how the development of the bees' offspring and infestation of macroparasites are influenced by type of nesting material, landscape complexity and timing throughout the active nesting period of *O. cornuta*. We found that *O. cornuta* preferred to nest in cardboard tubes compared to wooden grooved boards. Successful cocoon development was higher in cardboard tubes, whereas the sex-ratio of the bees' offspring was higher in wooden grooved boards. Both successful cocoon development and the sex-ratio decreased throughout the nesting activity period of the bees. The bees' sex-ratio also increased with increasing landscape complexity. Cardboard tubes reduced the infestation rate of kleptoparasitic mites. In addition, the infestation of both kleptoparasitic mites and kleptoparasitic fruit flies increased with time. These findings present relevant evidence to aid efficient implementation of mason bees to manage crop pollination. Using cardboard tubes, or similar materials, over wooden grooved boards and enclosing the nests to prevent parasite infestation at the end of the bees' activity should be advised to growers as an effective management strategy to enhance successful bee development and to reduce parasites infestation. Conservation or creation of semi-natural habitat around the fields will promote the proportion of female bees in the produced offspring.

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

Cecilia Kardum Hjort[1]

[1]Lund University

Human-mediated movement of non-native commercial bumblebees used for agricultural pollination services can affect local pollinator populations via competition, the spread of diseases and hybridization. However, the extent of genomic introgression and evolutionary divergence between wild and commercial bumblebee species has yet to be fully explored. It is therefore important to get a deeper understanding about the consequences of introgressive hybridization since the 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. To address this, we compared whole genome sequencing data from wild (N = 72) and commercial (N = 17) *Bombus terrestris* (buff-tailed bumblebee) from sites in southern Sweden with long-term exposure to imported *B. terrestris* and sites without such exposure. We examined evidence of introgression, dispersal, genome-wide selection signatures and genomic structural variants, between the two groups. Despite the detection of commercial *B. terrestris* individuals in natural environments at sites where commercial bum-

blebees where used, as well as wild *B. terrestris* "drifters" within commercial hives, we found no evidence of wide-spread genomic introgression among wild and commercial *B. terrestris* in southern Sweden. This suggests that the use of commercial B. terrestris does not pose a genetic threat to local *B. terrestris* populations. We did find that wild *B. terrestris* were slightly more genetically diverse than commercial *B. terrestris* and identified a highly divergent region on chromosome 11 of commercial *B. terrestris*, which provided evidence for differential evolutionary processes operating on wild and commercial *B. terrestris*.

Effects of land use intensity on pollinator behavior in agricultural landscapes

Markus Birkenbach[1]

[1]Ulm University

Effects of land use intensity on pollinator behavior in agricultural landscapes Markus Birkenbach, Manfred Ayasse, Florian Straub, Lena Wilfert, Jonas Kuppler Ulm University, Institute of Evolutionary Ecology and Conservation Genomics Pollinators provide essential ecosystem services and are currently threatened by a variety of anthropogenic influences and changing environmental conditions. In intensively used agricultural areas, pollinators suffer from resource limitation, exposure to pesticides and habitat loss. These stressors could lead to a change of pollinator behavior, e.g. impaired foraging ability or increased floral handling time, which might ultimately result in reduced pollination services. We conducted behavioral observations of two pollinator species (*Bombus lapidarius* and *Episyrphus balteatus*) on 50 grassland plots of the Biodiversity Exploratories, a research platform providing plots with varying land use intensity embedded in an agricultural landscape. We used a field observation software to track time spend on flowers, numbers of flowers visited per plant individual, distance between two plants, flight duration and plant species. Preliminary results indicate that not land use intensity per se, but biotic factors such as plant species composition or identity of the plant visited, play the most important role explaining difference in pollinator behavior. Further, abiotic factors such as temperature or light intensity can impact behavior. Overall, our results show that specific stressors, which might be influenced by land use intensity affect pollinator behavior.

9th session

On-farm experiences shape farmer knowledge and perceptions of pollinators and their decision-making

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Animal pollination underpins the viable production of two-thirds of the crops produced globally but declines reported for several pollinator groups might threaten their service delivery and resilience. Mitigation measures in agricultural-dominated landscapes require the involvement of farmers and their willingness to adopt pollinator-friendly strategies. However, growers` knowledge, perceptions, and actions are rarely evaluated. To close this knowledge gap, growers from 11 countries (N = 560) were interviewed, cultivating at least one of four widely grown pollinator-dependent crops with the focus on non-bees. We found that farmers perceive the importance of pollinator groups differently, with bees being considered more important pollinators than non-bees. However, around 75% believe that non-bees contribute to the pollination of their crop, seeing them as additional pollinators rather than substitutes for bees. Despite farmers rating their own observations as being the most important source of information, their knowledge aligned closely with available scientific studies across crops and countries. Farmers` perceptions, as well as governmental subsidies, were also linked with their managing practices. Farmers adopt practices to enhance pollination services depending on the crop, which indicates an understand-

ing of differences in the pollination ecology of crops. Almost half of the farmers changed the on-farm pollination management in the past 10 years, indicating the lack of clear guidance from scientists on best practices. Our findings highlight the importance of studies investigating farmers` knowledge and perceptions, to further understand how on-farm biodiversity can be enhanced to provide sustainable and pollinator-integrated food production.

Effects of agricultural landscape structure, insecticide residues, and pollen diversity on the life-history traits of the red mason bee Osmia bicornis

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Agricultural landscapes have changed substantially in recent decades, shifting from the dominance of small fields (S) with diverse cropping systems toward large-scale monoculture (L), where landscape heterogeneity disappears. In this study, artificial nests of the red mason bee, *Osmia bicornis*, were placed in S and L landscape types on the perimeter of oilseed rape fields representing different oilseed rape coverages (ORC, % land cover). The local landscape structure around each nest was characterised within a 100, 200, 500, and 1,000 m radius using ORC and 14 landscape characteristics, which were then reduced by non-metric multidimensional scaling (nMDS) to two axes: nMDS1 characterised the dataset primarily according to land fragmentation and the main crop, whereas nMDS2 captured the prevalence of more natural areas in the landscape. Pollen diversity and insecticide risk levels in the pollen provisions collected by the bees were analysed, and their dependence on the landscape structure was tested. Thereafter, the effects of pollen diversity, insecticide risk, and landscape structure on the life-history traits of bees and their sensitivity to topically applied Dursban 480 EC were determined. Pollen taxa richness in a single nest ranged from 3 to 12, and 34 pesticides were detected in the pollen at concentrations of up to 320 ng/g for desmedipham. The *O. bicornis* foraging range was relatively large, indicating that the landscape structure within a radius of ~1,000 m around the nest is important for this species. Pollen diversity in the studied areas was of minor importance for bee performance, but the ORC or landscape structure significantly affected the life-history traits of the bees. Contamination of pollen with insecticides affected the bees by decreasing the mass of newly emerged adults, which were highly sensitive to Dursban 480 EC.

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Integrated pest and pollinator management and a case of the insecticide thiacloprid in apple orchards

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Integrated pest and pollinator management (IPPM) is a rather recent concept building on well established concepts of integrated pest management (IPM). The latter involves multiple approaches including prevention, monitoring, sound-decision making and minimizing the use of pesticides. Sustainable management of pests could be argued to be especially important for perennial growing systems, like fruit orchards, of which ecosystem services such as natural enemies of pests and pollinating insects can potentially be crucial. In the presented study we have investigated environmental effects of the use of the insecticide thiacloprid in apple orchards as well as the potential economic losses without this broad-spectrum insecticide. We will present results on the uptake of this insecticide in honeybees and bumble bees collected in the field after treatment. We will also present economic calculations based on crop losses by pests with and without thiacloprid. Finally, we will discuss these findings in a IPPM perspective and the importance of alternative measures.

Pesticide residues in pollen and nectar of crops and wild plants from agricultural fields in Ireland

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Most pesticides applied in Ireland, in terms of volume, are Plant Protection Products (PPPs), including herbicides, fungicides and insecticides. Systemic PPPs applied via spraying or as seed treatments get dispersed in soil, and can be translocated through the plant tissues, contaminating nectar and pollen of both crops, and nearby growing wild plants. Pollen and nectar are the main food source for bee pollinators and this oral exposure, along with direct contact through spraying, is of concern for their health and for the delivery of pollination services. To determine potential levels of exposure, there is a need to assess the presence and quantify the concentrations of these PPPs found in pollen and nectar, within and beyond the target plants. To address this issue in a European context, the most extensively used systemic PPPs in Ireland were selected for analysis, as systemic PPPs have potentially negative impacts on pollinating insects. Oilseed rape and field bean were chosen as model crop species since they are the most pollinator attractive of the crops cultivated in Ireland. Since brambles are abundant and a valuable food source for bee pollinators in field edges during the summer months, they were chosen as model wild plant species. Several fields in the south east of Ireland were included and a minimum of 1000 flowers were collected from each model plant in every site, to extract the required amounts of pollen and nectar for chemical analysis (~ 100 mg and ~ 100 µl respectively). For the PPP chemical analysis, extraction protocols including QuEChERS were utilised. The frequency of detection and the concentration of the target PPPs in samples from each site were determined by the appropriate validated Liquid Chromatography - Mass Spectrometry (LC-MS) method, to estimate the PPP exposure risk for pollinators. Preliminary findings and future challenges will be discussed.

Bee pollinators in Styrian oilseed pumpkin

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Styrian oilseed pumpkin (*Cucurbita pepo* subsp. *pepo* var. *styriaca* Gerb., Cucurbitaceae) is a spontaneous mutant with hull-less seeds, which arose in Styria (Austria). Recently, the seeds of oilseed pumpkin are gaining more popularity in the world as a valuable source of high-quality oil and as a food snack. There is an expanding market for hull-less pumpkin seeds and thus their yield must be elevated. Styrian oilseed pumpkin is a monoecious, xenogamous, and obligatory entomophilous plant. Due to the specific features of pollen grains, its potential pollinators are bees. The aim of our research was to determine the diversity of bees visiting flowers of oilseed pumpkin in SE Poland and study their performance as pollinators. We evaluated (a) the size and purity of the pollen load delivered to the stigma of the 'virgin' ♀ flower during the following categories of bees' visit: 2-4, 5-9, 10-15, >15 and open pollination (control). Moreover, the effect of these visits on (b) fruit set and weight, and (c) number and weight of seeds per fruit was determined. Our results show that the principal visitors to oilseed pumpkin flowers were honeybees and bumblebees. Numerous ants often disrupted pollination by bees. Due to their foraging behavior bumblebees seem to be more efficient pollinators to oilseed pumpkin than honeybees. The size of pollen load was very variable in each category of visits. It was the biggest when flowers were freely visited by insects and differed significantly from the pollen loads delivered to a stigma even after more than 15 visits. Flowers that obtained less than 10 visits produced fewer and smaller fruits with a lower number of seeds as compared to those from open-pollinated flowers. We conclude that oilseed pumpkin crops should be supplemented with bees when less than 10 visits per ♀ flower are noted.

How does exposure to a pyrethroid and an organophosphate effect bumblebee foraging behaviour and pollination services?

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Bumblebees are important pollinators of crops and wild plants meaning that threats to pollinator decline also pose a risk to the sustained provision of these important pollination services that they provide. One of the suggested factors contributing to population decline is the use of pesticides which bumblebees become exposed to when foraging on contaminated pollen and nectar in agroecosystems. Evidence suggests that exposure to field realistic levels of insecticides can affect bumblebee foraging behaviour, however the majority of these studies have investigated this in the case of the neonicotinoid class of insecticides only, with even fewer investigating the potential impacts of exposure on the success of bumblebees delivering pollination services. We conducted a novel study to address some of these knowledge gaps. Bumblebee colonies were exposed to two of the current most widely used insecticide compounds in Ireland; lambda-cyhalothrin (a pyrethroid) and dimethoate (an organophosphate), both non-neonicotinoid insecticides. Colonies received four rounds of insecticide treatment via sprayed pollen feed at field realistic doses based on the recommended spray rate and frequency for each compound on oilseed rape (37.5ppm for lambda-cyhalothrin and 336ppm for dimethoate). Post-exposure, colonies were brought to large outdoor exclusion cages and were observed foraging on potted oilseed rape using Boris software to record individual behaviour (foraging bout duration, flower handling time, time spent moving between flowers, time spent 'learning' to handle flowers etc.). Activity at the colony level and visitation rates to the crop were also recorded across treatment. The oilseed rape plants were kept in the cages until the pods were ready to harvest, which were then used to record yield as a measure for delivery of pollination services (pod production, pod weight, number of seeds, average seed weight). The preliminary findings of this study will be discussed for this talk.

Insecticides in the landscape - a potent mix for a bumblebee colony

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Whilst pesticides can reduce pest densities, they may negatively affect pollinator populations and pollination services. Understanding how multiple pesticdes co-occur in the landscape, across multiple crops and seasons, is essential for identifying common pesticide mixtures that may pose a risk to pollinators. Following extensive residue analyses in pollen and nectar collected by sentinel honeybees (*Apis mellifera* L.), bumblebees (*Bombus terrestris* L.) and solitary bees (*Osmia bicornis* L.) placed next to different flowering crops and in different landscape contexts in southern Sweden, we identified two compounds that occurred frequently, in high concenrations and were relatively toxic for bees. We used these compounds, singly and in combination, in a highly-replicated, controlled field-based feeding study on *B. terrestris* colonies. Early results indicate that one compound's toxicity can negatively affect a colonies growth and development and that even in combination with another compound, there are no additive or synergistic effects. Future work will explore impacts on colony dynamics and queen hibernation success. With this work, we aim to quantify the consequenses of commonly-occuring pesticides in the agricultral landscape to improve pollinator risk assessment.

Landscape drivers of pesticide use patterns and their risk to pollinators

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Recent calls to overhaul environmental risk assessment of pesticides advocate for a socio-ecological systems-based approach, and advancing from a single product, single crop focus. Integral to this approach is an explicit consideration of how multiple pesticides integrate across agricultural landscapes to determine risk. Linking landscape pattern, pesticide use and their risk to beneficial organisms is a first critical step for such an explicit consideration and a foundation for understanding the benefits, and potential trade-offs, of diversified agriculture. To advance this, we 1) explored the relationship among cropland heterogeneity and pesticide use in northern California and 2) quantified pesticide residues in nectar and pollen collected by sentinel of three bee species situated at 24 focal fields of three flowering crops in southern Sweden. In California, we find reduced pesticide use, in terms of both frequency and intensity of application, in diversified, spatially-heterogenous landscapes. In Sweden, we found that the diversity (i.e., number of active ingredients) and risk (i.e., pesticide hazard quotient) of pesticides varied with crop identity. Pesticide risk was also related to the proportion of agricultural land use in the surrounding landscape, but this relationship depended on bee species with a stronger relationship for the wild bee species than for honeybees. We found that the risk was correlated among the different bee species and also that bee-collected pollen was predictive of bee-collected nectar risk, even if pollen indicated higher risk. Together these results provide important insights into the spatial and taxon-specific factors that influence the risk of non-target organisms to agricultural pesticide use. Our results are relevant for informing future field-based pollinator risk assessment.

POSTER PRESENTATION ABSTRACTS

Floral displays suffer from sulphur deprivation

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Nutrient deficiency is known to constrain plant growth in numerous ways, but how it impacts floral displays and pollination success remains unclear. Here we investigate how insufficient availability of sulphur – a vital plant nutrient that is a limiting factor in natural and agricultural regions throughout the world – influences the production of floral displays in *Brassica rapa*, *Physalis philadelphica* and three *Petunia* species of *Petunia* with differently coloured flowers. Sulphur deficiency led to a drastic reduction in the number of open flowers, an aberrant flower morphology and smaller pollen with an altered mineral nutrient content. Intriguingly, sulphur deprivation also led to a clear reduction in pigmentation of yellow flowers, but not in flowers with white, purple and red colours. The decreased pale yellow flower colour was associated withdue to decreased contents amounts of violaxanthin, lutein and other carotenoids, suggesting that the carotenoid synthesis pathway is particularly susceptible to sulphur deficiency. Additional experiments with nitrogen and phosphorus depletion confirmed that observed colour and morphological changes were not a general nutrient limitation response, but could be ascribed to sulphur depletion specifically. Taken together, our results show that (mild) sulphur deficiency deteriorates a suite of floral traits, and that the effects may cascade to pollinators and so have the potential to undermine (agro-)ecosystem functioning.

Floral metabolomes and insect visitation assemblages of two *Phaseolus* species

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The genus *Phaseolus* includes selfing and outcrossing species, introduced into Europe after the travels of Columbus. Given the dispatch from their adaptive optimum due to speciation, domestication, and the extensive dissemination outside their centers of origin, bean species represent an ideal model to study the evolution of floral traits concerning pollinators and their significance for plant yield. Building on the underlying idea that manipulation of flower metabolites may result in increased yield, we investigated floral metabolomes and insect visitor assemblages of *Phaseolus* species. For this pilot experiment, we have chosen a selfing species of *P. vulgaris* (common bean) with purple flowers and two outcrossing varieties of *P. coccineus* (runner bean) bearing white and red flowers. The volume of secreted nectar significantly differs between the two species, being substantially less abundant in common bean flowers than in the outcrossing runner bean species. Similarly, the chemical profile of secreted nectar mirrors taxonomy, as runner bean species segregate from common bean based on the annotation of carbohydrates, amino acids and organic acids. However, the taxonomic composition of insect visitor assemblages showed a higher degree of similarities between purple common bean and white runner bean flowers. Indeed, while all flowers are primarily visited by species of the genus *Bombus*, and to a minor extent by insects of the genus *Apis*, the proportion of *Apis* species that visit red runner bean flowers is very small. Composed false-color photos in bee view showed remarkable differences across flowers of all colors, as well as the profile of emitted volatile organic compounds that also do not reflect the taxonomical classification of species.

The pollination ecology of the Brazilian peppertree and impacts on native plant pollination

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Invasive plants can readily recruit pollinators in invaded landscapes. Such associations can facilitate their reproduction and alter native plant-pollinator interactions, with potential consequences for native plant reproduction and availability of preferred floral resources for native pollinators. Brazilian peppertree (*Schinus terebinthifolius* Raddi) is an invasive tree that has spread throughout large parts of Florida. It has a diecious flowering system and requires insect vectors to transport its pollen. Because seedling recruitment is an important mode of reproduction for this species, evaluating the contribution of pollinators to its reproduction will enhance understanding of its invasiveness. The objectives of this research are to identify primary insect pollinators of *S. terebinthifolius*, evaluate spatial-dependent impacts of *S. terebinthifolius* on the reproduction of native plants and on pollinator diversity, and compare the floral resources of *S. terebinthifolius* to those of native plants. In fall 2020, surveys of pollinator visitation to *S. terebinthifolius* and cooccurring plants were conducted at five sites in southern Florida. Timed visual observations were conducted along 50-m transects, and pollinators were collected for identification and to conduct pollen analyses. Honey bees (*Apis mellifera*) and flies (Diptera) had the greatest visitation rates to *S. terebinthifolius*, followed by small bees (Halictidae) and wasps. Pollinators were observed visiting 12 cooccurring plant species, which compete with Brazilian peppertree for pollinators. Pollination efficacy, pollen deposition, and visitation rates of different pollinators to *S. terebinthifolius* and native plants will also be discussed. The data suggest *S. terebinthifolius* successfully attracts specific pollinator taxa, warranting further research on mechanisms and impacts.

Seams in the forest fabric: the role of pollinators in supporting forest-dependent livelihoods

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Insect pollinators may play an important role in Central African forests for providing forest products to local people who rely heavily on natural resources. The majority of the rural population in Africa are subsistence farmers, depending on agriculture for their livelihood and are disproportionately reliant on crop pollination services for producing good quality, nutritious crops, vital for meeting their nutritional needs. Despite the importance of pollinators in rural Africa for mitigating already high poverty and food insecurity levels, few studies have assessed the perception and understanding of the role of insect pollination for providing the products and crops that many rural livelihoods rely on. This information is required to educate and promote sustainable use of forests and pollinator habitats by forest managers and communities and to mitigate damages inflicted by deforestation, a threat which is devastating forest habitats globally. We find that while local communities farm many pollinator-dependent crops, utilise many pollinator-dependent forests products, and use beekeeping as a supplementary source of income, understanding of the role of even the relatively well-known honeybee as a pollinator is limited as is the knowledge of other bee species native to the area. While many agree that forests are important for bees, indicating an understanding of the importance of forests as habitats for bees, few showed an understanding of the role of bees as pollinators for forest tree species. Additionally, knowledge on bee ecology seems to largely be related to honeybee ecology, indicating that knowledge of other bee species is limited. Establishing the role and importance of pollinators in providing important forest products and crops on which rural communities depend will inform land-use practices that are likely to impact on pollinators, such as deforestation and the spread of shifting slash and burn agriculture.

From Roots to Pollinators: How above- and below-ground organisms interact through plants

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While the value of biodiversity to agriculture is being increasingly recognized, such as the role of below-ground organisms to healthy soils, and the contribution of insect pollination to crops, there is increasing recognition that the above- and below-ground terrestrial sub-systems are linked. This research aims to investigate how below-ground interactions (soil biodiversity and plant roots) might alter floral traits and in turn affect pollinator behavior, and how these interactions may be affected by pesticide use. A manipulation experiment will be used to create a soil biodiversity gradient (sterile to field realistic communities) and test its effects on floral traits. A pollinator choice experiment will investigate the preference of a key group of pollinators, bumblebees, for one plant over another. This study will be the first to investigate soil-plant-pollinator interactions (i) in a multi- species setting, (ii) incorporate the plant root system and (iii) in a pesticide contamination context.

Field- and landscape-level honey bee stocking density effects on crop visitation in highbush blueberry

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Recent studies about crop pollination have detected great variations in honey bee (*Apis mellifera*) visitation, yet we struggle to predict the abundance of honey bees visiting crops. In this study we surveyed pollinators in 16 northern highbush blueberry (*Vaccinium corymbosum*) fields during bloom in Washington State, USA. In addition, we located and quantified all honey bee hives in a radius of 2 km around each field and we characterized the surrounding landscape (natural habitat, blueberry fields, etc.). A total of 11744 honey bee hives were located and mapped. Field stocking density ranged from 3.5 hives to 25.3 hives per ha. No clear relationship between farm area and field stocking density was detected. The number of hives was positively correlated to the proportion of blueberry fields around the study site (landscape scale 500 m, 1000 m and 2000 m). In addition, we found that the visitation of honey bees was best predicted by the number of honey bees hives within 1 km. The honey bee hive stocking rate of a field and semi-natural habitat did not influence honey bee visitation. We conclude that the proportion of pollinator-dependent crops is a good predictor of the number of honey bees visiting pollinator-dependent crops. Furthermore, natural habitat did not reduce honey bee visitation and could provide a valuable refuge for supplemental wild pollinators.

Critical role of the food K:Na ratio for ecology, and evolution and of bees

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Bees provide important ecological services and are threatened globally, yet our knowledge on wild bee ecology and evolution is limited. While evolving from predatory ancestors, bees had to overcome specific difficulties and to utilize specific strategies of coping with limitations posed on them by plant-based diet. Nectar provides energy, and pollen is extraordinary food, nutritionally similar to meat. However, both display one characteristics common for plants, i.e. high ratio of potassium to sodium (K:Na). This makes nectar and pollen diet inadequate for animals, leading to their underdevelopment, health problems and death. We argue that K:Na is critical factor shaping ecology, physiology, behavior, life histories and ultimately evolution of bees. We discuss why and how K:Na contributes to bee ecology and evolution, and how considering this factor in future studies will provide us new knowledge, bridging bees with their environments and needed to understand how they function.

To help wild bees we should consider nutrient demand and supply in a changing environment

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Wild bees often cannot access the optimally balanced diet required for their survival because local and global changes affect which pollen varieties are available to them in the environment. Understanding how the nutritional quality of various pollens affects bees could help us determine whether and how floral diversity and composition shape bee communities and populations. Therefore, to study how the nutritional quality of pollen influences wild bee fitness-related traits (survival, cocoon development and body and cocoon sizes), we asked questions about bee functioning in environments offering various nutrient diversities and compositions via available pollen species. Utilizing a feeding experiment, we show that the nutritional quality of the pollen diet eaten by bee larvae is shaped not by pollen diversity per se but by a specific pollen species composition that results in specific nutrients being scarce or sufficient and affects bee fitness-related traits. Suboptimal concentrations of certain nutrients in pollen produced by specific plant species resulted in increased mortality, decreased size and underdeveloped cocoons, and the strength of the observed negative effect was sex dependent and alleviated if scarce nutrients were added to the pollen diet. Therefore, nutritional stress caused by habitat loss and transformation and further alterations due to global changes, e.g., pollen nutrient dilution associated with rising atmospheric CO_2 levels, may be direct drivers of observed wild bee declines. Accordingly, we propose that the functioning of bee populations and communities may depend on the floral diversity of the local habitat, which determines whether a nutritionally balanced pollen diet obtained from certain species can be provided to bee larvae. Considering bee fitness and health holistically in this manner could reveal important interactions between bees and other parts of the food web as well as lead to new ways of conserving bees and the critical roles they play in ecosystems.

Pollen carryover capacity of the main functional groups of pollinators

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Pollinator functional groups differ in their pollen carryover capacity, which is an important determinant of their effectiveness. Pollen carryover can be estimated by quantity of pollen grains on the bodies of pollinators, but this estimate is always to traits of plants they collected pollen from (mainly pollen production, but also pollen availability, pollen stickiness, plant adaptations to prevent pollen loss etc.). Most existing studies included in a comparable way only a fraction of functional groups of pollinators, even though an overall knowledge of approximate relationships between carryover capacities of different pollinator groups would greatly improve our interpretation of data on visitation (e.g. pollination networks). The aim of the present work is to compare in a comparable way carry-over capacities of all main pollinator functional groups. The comparability is achieved through selecting a single though diverse site in the same time of the year and with the same climatic conditions. All pollinator functional groups thus choose from the same set of plants with known relative abundancess, which can be taken into account in the analysis of detected pollen loads. The method of collecting pollen grains from pollinator's body by slices of fuchsine jelly was used, followed by counting the amount of pollen grains and identification of their species. Solitary bees and honeybees has the largest pollen carryover capacity. On the other side, the smallest pollen carryover capacity has butterflies and other Hymenoptera. These results agree with results of similar works on this topic. Bumblebees has smaller pollen carryover capacity then group of big hoverflies. It wasn't expected, because in literature it's different. Different heterogeneity of individual functional pollinator groups and inaccurate determination of species of pollen grains may have affected results.

The ground-nesting bee Anthophora plumipes as a potential test organism for investigating risks to bees of pesticide residues in soil

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We introduce Anthophora plumipes as a prospective test species for investigating pesticide exposure via soil. Pesticide exposure has been identified as a risk to non-target insects, particularly bee pollinators. In agrochemical risk assessment, the honeybee has long been the main test species of interest. Recently, wild pollinators such as *Bombus* terrestris have been included in standard risk assessment, and the solitary *Osmia bicornis* is on track to be included. Although these additions help broaden the knowledge on risks of pesticide exposure to wild bees, virtually nothing is known about the impact of pesticide residues in soils on ground-nesting bees, even though the majority of wild bees nest in soil. In order to address this issue, we established a protocol for rearing the widespread Eurasian ground-nesting bee *A. plumipes* in artificial nest boxes filled with soil. We successfully harvested brood cells containing provisions, larvae, and adult bees for controlled laboratory exposure and fitness measures. We experimentally tested nesting success in soil contaminated with the neonicotinoid insecticide imidacloprid vs. uncontaminated soil by placing nest boxes next to a natural aggregation, quantifying the changes in number and size of brood and brood cells between treatments. We[RJP1] also propose a new method for assessing risk of pesticide contamination from soil to larval provisions by testing the uptake of compounds from contaminated soil through the brood cell wall into provisions and bee bodies. In conclusion, *A. plumipes* is an ideal novel test species for soil residue risk assessment, representing a much-needed addition to the ongoing work to elucidate the hazard of pesticides to bees.

Global warming as a threat to pollen germination of wild plant species – a pilot experiment

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Pollen germination efficiency is crucial for reproductive success of many plant species.The increasing temperature caused by global warming can represent a significant threat for this fundamental phase in plant life cycle. Many studies have focused on pollen germination of various crop species. However, we lack studies on the effects of temperature on pollen germination of wild plant species. We chose nine meadow species common in termophilous and ruderal areas across the Czech Republic. We selected the traditional Brewbaker & Kwack (BK) medium for the germination experiments. The pollen grains of all species were evenly distributed on Petri dishes and exposed to 20, 30, 37 and 42 °C. Successful pollen germination was confirmed in only three species: *Lotus corniculatus*, *Vicia cracca*, and *Salvia verticillata*. The success rate of pollen germination differed among the three species and in response to temperature levels. Additionally, we measured pollen tube length, which varied among plant species and temperatures, similarly to pollen germination rate. We conclude that temperature-dependence in pollen germination may be an important constraint on the ability of wild plants to cope with the ongoing climate change.

Influence of the quantity and composition of floral resources on pollinators in agricultural landscapes

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Pollinating insects are declining and the pollination ecosystem service may no longer be provided in an optimal manner in the near future. Among the causes of this decline, changes and decreases in the nutritional resources, i.e., floral pollen and nectar, are decisive, particularly in agricultural areas. Thus, our thesis project is to identify and estimate the quantities and nutritional qualities of floral resources at the scale of foraging areas and during the development season of these insects. Our initial hypothesis is that complex and mosaic landscapes allow for greater diversity and abundance and a better health status of wild bees. We selected 30 sites in Belgium. After mapping the biotopes, we will identify the floral and bee species present and the pollens collected by these bees. We will analyse the chemical compositions of the pollens of the species highly collected. We will link these quantities, availabilities and compositions to health status proxies of the bees. This set of approaches and techniques will ultimately allow us to assess the quality of an agricultural landscape from the point of view of bee pollinators and to propose appropriate management or planning according to agricultural and biogeographical regions.

Cro Buzz Klima – Wild pollinators of Croatia and adaptation to climate change

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Project Cro Buzz Klima investigates wild pollinators of Croatia in the context of climate change adaptation. The motivation for this project was a general lack of data and expertise on wild pollinators in Croatia, especially concerning wild bees (Anthophila) and hoverflies (Syrphidae). Our objective is to collect the first systematic data on wild bees and hoverflies of Croatia and to determine how climatic and other environmental factors (habitat type, management, richness and abundance of flower resources) affect species richness, diversity, and community composition of wild pollinators. We will collect wild bees and hoverflies at five project areas across three biogeographic regions of Croatia (continental, Alpine, and the Mediterranean). We chose project areas for their specific climatic conditions, vulnerability to climate change, and habitat types that are particularly important for pollinators. They include four natural protected areas (Nature park Žumberak Samoborsko gorje, National parks Risnjak and Plitvice lakes, Natura 2000 site HR2001357 Krk Island,) and the city of Zagreb. The additional goals of project Cro Buzz Klima are to test the monitoring protocol proposed at the EU level and raise awareness about the importance of pollinators and about the climate change in Croatia. The results of this project will provide the needed groundwork for effective pollinator conservation planning through identifying measures for improving their status and increasing their climate resilience. The planned duration of the project is three years.

Pollinators in Norwegian fruit orchards: Surrounding landscapes and foraging strategy

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Bees provide an essential ecosystem service through pollination, of which around 35% of world crops are dependent. In recent years, concerns about loss of pollinator diversity and abundance have been raised. Where investigated, these concerns seem to hold true. This is amplified by the expected effects of climate change on future biodiversity and species abundance, and the reliance on commercial honeybee colonies, which are declining worldwide. It is likely that we will be more dependent on wild bees in the future. Several studies have also suggested that wild bees are more efficient crop pollinators, compared to honeybees. Earlier work has shown that natural and semi-natural habitats, flower strips and hedgerows are important resources that attract bees. Here, we investigate the relation between the surrounding landscapes of ten Norwegian apple orchards, at different scales (0-3000 meters), and the abundance and diversity of solitary bees and bumblebees visiting these orchards. Initial results reveal that on scales from 0-500 meters, the amount of land covered with forest has a significant effect on the abundance and richness of solitary bees, as well as areas specifically covered with coniferous forest. On scales over 500 meters from the orchard center, we did not find any effect for solitary bees. If confirmed, these findings supplement earlier findings by showing at which scales we can expect the surrounding landscapes of orchards to influence bee presence. Such knowledge is important to succeed in implementing wild bee friendly land management practices in the future. In a separate project, we tracked and timed the movements of honeybees and bumblebees between trees and flowers in apple and pear orchards. The goal was to investigate differences in foraging strategy between these groups. First impressions of the raw data suggest that bumblebees have shorter flower visits, potentially pollinating more flowers than honeybees.

Flower morphology predicts the sex of visiting bees in natural plant communities

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Identifying broad interaction patterns in plant-pollinator communities has been the focus of much recent research. Female and male bees of numerous species differ considerably in their flower visitation patterns (Roswell et al., 2019), but what floral features differentially attract each sex is still unknown. To explore this question, I recorded the sex of bumblebees captured on eight flower species in a plant community in the UK. I gathered information on the flowers' symmetry and corolla tube length, for this and for Roswell et al.'s (2019) datasets. In both datasets, male bees visited radially symmetrical flowers more often than females. Flower species visited by males had shorter corolla tubes than those visited by females, although males were generally larger than females. Radial, short-tubed flowers are considered more easily accessible to insect visitors than bilateral, long-tubed flowers. To test for additional potential foraging implications of these traits, I compiled published data on corolla symmetry, corolla tube length and nectar production in 184 flower species. Bilaterally symmetrical flowers produced more nectar than radially symmetrical flowers, and nectar production generally increased with corolla tube length. The combined results suggest that male bees orient to flower morphologies that are easier to access, but possibly also lower-rewarding, compared to females. Males spend much of their adult life seeking mates, while females focus on foraging. In addition, males forage only for their own needs, whereas females also collect food to provision brood. These life-history traits may restrict the time available to males for learning to handle restricted-access flowers, and shift their optimal foraging choices towards more accessible flowers with lower rewards.

Pantropical pollination syndromes and pollinator shifts in Melastomataceae

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Pollination syndromes are defined as suites of floral traits, which have evolved repeatedly across angiosperms in adaptation to distinct functional pollinator groups. These syndromes were developed to classify flowers under a functional ecological perspective by their most efficient pollinator, irrespective of their phylogenetic relationship. Several studies show strong support for the concept of pollination syndromes while others raised concerns about their reliability. Melastomataceae offer an ideal system to test the concept of pollination syndromes, since many different pollinators and specialized floral morphologies have been reported for the family. The large, pantropically distributed family is dominated by bee-buzz pollination (95.5% of species), where pollen grains are released from tubular, poricidal anthers through vibrations. In at least six (of eighteen) tribes, shifts to different vertebrate pollinators (i.e. bats, rodents, hummingbirds, passerine birds, flowerpiercers) have occurred. Although only studied at a small scale up to now, these shifts seem to associate with marked changes in floral functional traits such as reward type, mechanisms of pollen release, and corolla shape. In the frame of my PhD project, we will record 32 pollination-relevant floral traits across 404 species, spanning the whole family. We will focus on system-specific functional floral traits but also include traits traditionally used in pollination syndromes. Using multivariate statistics, machine learning algorithms, and phylogenetic comparative methods, we will evaluate the concept of pollination syndromes across the family. Preliminary results based on analyses from four New-World tribes, indicate strong support for four well differentiated pollination syndromes: widespread buzz-bee pollination, pollination by mixed assemblages of nectar-consuming vertebrates such as birds, bats and rodents, pollination by food-body-consuming passerines, and generalized systems. Whether these New-World syndromes, investigated only in a small number of species, can also be found in the Old-World, remains unknown.

The path of caffeine from root to vegetative organs in *Vicia faba* bean plants

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Judit is interested how naturally occurring alkaloids in plant nectar alter the behaviour of plant visitors, especially how caffeine influences the robbing behaviour of *Bombus terrestris* bumble bees. During her studies Judit found that caffeine as a natural alkaloid does affect the robbing behaviour of *B. terrestris* bees (Poster presented on SCAPE conference 2020). Caffeine is present in the water circulation of the Earth as a human contaminant (Loos et al, 2010) and the hydrophobic properties of caffeine allow its passage through all biological membranes (Fredholm et al, 1999). An idea presented itself when Judit was observing orchids at her home: Does caffeine get transmitted into the plants from water sources and does the alkaloid get into the circulation of plants which do not contain caffeine naturally? Through a preliminary experiment she showed that caffeine does enter the circulation of *Vicia faba* plants. Judit is working on her main and final experiment of her PhD: she aims to find out if caffeine gets also into the nectar of *Vicia faba* bean flowers

Predicting bee activity levels under climate change with a mechanistic model of thermoregulation

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Bees' body temperature must be within a specific range in order for them to be able to fly, but their body temperature varies with the environment as well as their own internal heat production. Bees are therefore highly dependent on weather conditions for foraging activity, and so climate change has the potential to have a big effect on pollination services. This link, however, is not well understood, making predictions about the effects of climate change on pollination services difficult. Mathematical models are an important tool in making these predictions. Mechanistic models combine data collected in field and lab studies with mathematical representations of the physical or behavioural mechanisms, which increases their predictive power compared to statistical models. By combining knowledge from varied disciplines, such as fluid dynamics, physiology, and more, with existing understanding of bee thermoregulation and behaviour, we have developed a mechanistic ordinary differential equation model for heat exchange and thermoregulation in honeybees and bumblebees. This model uses physical characteristics of the bees, such as mass and surface area, and thermoregulatory behaviours, to predict bees' thorax temperatures. We use this model to illuminate the bees' activity levels as a function of weather conditions both currently and using projected conditions 20-40 years into the future.

Eristalis tenax choose flowers based on combination of flower colour and size, but not shape

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Knowledge of preferences of hoverflies for different floral traits is key to our understanding of the hoverfly choices of foraging plants. Individual floral traits may affect hoverfly preferences separately or in interaction with others. In natural systems, it is rather difficult to find plant species that would exhibit all possible trait combinations which would allow us to test both separate and joint effects of the individual floral traits. To find out how the different combinations of floral traits interact with each other, we printed artificial flowers differing in up to 3 floral traits on a 3D printer. We manipulated these following traits: colour (yellow or purple), size (small or large) and shape (actinomorphic or zygomorphic). The artificial flowers were then used for testing preferences of individuals of the model hoverfly *Eristalis tenax*, L. The naive hoverflies were offered to choose flowers within arrays composed of two artificial flower morphotypes set in 1×1 m arenas in laboratory conditions. We also run a field experiment on a meadow where *E. tenax* is one of the most frequent floral visitors to compare naive and native Eristalis. The large and yellow flowers were the most preferred and small yellow flowers were preferred over the purple flowers. There was also a significant difference between the small yellow flowers and large purple even though the difference was much smaller. Our results show that the colour and size are much more important than the shape and that the colour is probably more important than the size. The minute effect of flower symmetry (i.e. shape) was similar to other studies, which found low effects of floral symmetry for bees. Our results further emphasize that effects of individual floral traits on pollinator preferences need to be studied in the context of other floral traits

Effects of pesticide mixtures on survival of the red mason bee *Osmia bicornis*

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Many plant protection products are used in agriculture, including a range of insecticides applied to crops potentially attractive for pollinators. Apart from direct effects of single insecticide, which are evaluated following legal requirements, insecticides applied in mixtures may potentially interact with each other, causing unpredictable effects on pollinators. The mixture effects of insecticides on bees are still poorly recognized, especially for non-*Apis* bees which, in contrast to honey bees, are not included in any standard procedures for ecological risk assessment of pesticides, but may respond to insecticide exposure differently due to differences in physiology and ecology. Moreover, the sensitivity of bees to a particular active ingredient is usually tested, while toxicity of commercial formulations to non-*Apis* bees is again neglected. In this study, we tested the effect of the three agrochemical formulations representing different insecticide types (Dursban 480 EC containing the organophosphate chlorpyrifos, Sherpa 100 EC with the pyrethroid cypermethrin, and Mospilan 20 SP with the neonicotinoid acetamiprid) on survival of *O. bicornis* females. The insecticides were applied topically in binary mixtures in a range of concentrations close to field realistic: up to 1×RAC (Recommended Application Concentrations) for Dursban 480 EC and up to 5×RAC for both Sherpa 100 EC and Mospilan 20 SC. A very high toxicity was observed for Dursban 480 EC with LT_{50} of 1 day for the two highest RAC, whereas survival of bees exposed to either Sherpa 100 EC or Mospilan 20 SP was not affected seriously ($LT_{50} \geq 25$ days). The GLM analysis did not indicate any interactive effect - neither for Dursban 480 EC × Sherpa 100 EC nor for Mospilan 20 SP × Sherpa 100, but confirmed a strong effect of Dursban 480 EC ($p<0.0001$) on survival of *O. bicornis* females.

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Assessing the impact of changes in land use on genetic diversity and adaptive potential of butterfly species

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Anthropogenic land use changes have resulted in great changes to the landscape composition that natural populations have evolved in. Though the direct impacts on ecosystem and species diversity have received great focus in landscape ecology literature, genetic diversity - the variation needed for populations to adapt to changing environment - has received little focus. Here, we present our progress examining the impacts of land use changes on four blue-wing butterfly species (Polyommatini; *Polyommatus icarus*, *Cyaniris semiargus, Plebejus idas, Plebejus argus*). These four species were selected for their differences in mobility (greater in *P. icarus* and *C. semiargus*) and habitat specialization (greater in *C. semiargus* and *Plebejus* spp.). We collected population-level samples of each species from multiple sites across southern Sweden with varying amounts of habitat availability in the surrounding landscape. Landscapes with low habitat availability were selected from regions with a high proportion of cropland or production forest, whereas high habitat availability landscapes were sampled from regions with a high proportion of grasslands. Using whole genome resequencing, we will determine how diversity differs within species across these differing land use regimes. Additionally, we will scan for indications that populations may be experiencing selective pressures from habitat loss and fragmentation. This modern data will be additionally complemented with historical genomic samples from museum specimens, to determine if diversity has been lost as agriculture has intensified in Sweden. Using both the results from the spatial and temporal comparisons, we can determine how diversity is being impacted within species, making generalizations based on how they differ between species with different life histories. We expect diversity to be more heavily reduced in species with more sedentary and/or specialized lifestyle, as they are at greater risk of losing diversity to population bottlenecks and cessation of gene flow as habitats become smaller and more fragmented.

Reproduction and pollination in bilberry (*Vaccinium myrtillus*) along two elevation gradients in western Norway

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Global warming influences ecosystems across the world and may alter the timing of phenological events, such as flowering and pollinator activity as well as distributions of species. Shifts in phenology between symbiotic species, like plant-pollinator interactions, could lead to loss of biodiversity and important ecosystem services. However, plant-pollinator interactions seem to be resilient biological networks. This study used both observational and experimental approaches to investigate the plant-pollinator interactions in a keystone species in Norway, bilberry (*Vaccinium myrtillus*), both outcrossed by insects and self-pollinated, along two elevational gradients, over two growing seasons (2020 and 2021). The elevational gradients represent different temperatures and onset of flowering. We use the spatial distribution of flowering and pollinator diversity and activity to investigate whether sub-populations of bilberry and wild pollinators along the gradient experience different synchrony and reproductive output. We also conducted a hand-pollination experiment to investigate the importance of wild pollinators on reproductive ability in bilberry. Bumble bees were abundant along both elevational gradients. Bilberries flowered 17 days earlier in the warmer sites and there were some differences between the gradients. In the presentation we will present preliminary results and reflections.

A meta-analysis of single visit pollination effectiveness comparing honeybees and other floral visitors

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Premise – Many animals provide ecosystem services in the form of pollination, including honeybees which have become globally dominant floral visitors. A rich literature documents considerable variation in single visit pollination effectiveness, but this literature has yet to be extensively synthesized to address whether honeybees are effective pollinators. Methods – We conducted a hierarchical meta-analysis of 168 studies and extracted 1564 single visit effectiveness (SVE) measures for 240 plant species. We paired SVE data with visitation frequency data for 69 of these studies. We used these data to ask: 1) Do honeybees (*Apis mellifera*) and other floral visitors differ in their SVE?; 2) To what extent do plant and pollinator attributes predict differences in SVE between honeybees and other visitors?; and 3) Is there a correlation between visitation frequency and SVE? Key results – Honeybees were significantly less effective than the most effective non-honeybee pollinators but as effective as the average pollinator. The type of pollinator moderated these effects. Honeybees were less effective compared to the most effective and average bird and bee pollinators but were as effective as other taxa. Visitation frequency and SVE were positively correlated, but this trend was largely driven by data from communities where honeybees were absent. Conclusions – Although high visitation frequencies make honeybees important pollinators, they were less effective than the average bee and rarely the most effective pollinator of the plants they visit. As such, honeybees may be imperfect substitutes for the loss of wild pollinators and safeguarding pollination will benefit from conservation of non-honeybee taxa.

Impact of the invasive alien plant *Impatiens glandulifera* on the parasite *Nosema bombi* occurrence in bumblebees

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The microsporidium *Nosema bombi* is an obligatory intracellular parasite of bumblebees, causing the disease nosemosis. The parasite infects and destroys host cells and infects subsequent individuals by oral route for example by sharing the same food sources. Infection with *N. bombi* increases bumblebee mortality and can lead to disturbances of the life cycle. Some invasive plant species form compact, long-flowering patches, attracting numerous pollinators sharing the same food resource. Herein I investigated whether the spread of the invasive Impatiens glandulifera affects bumblebee populations regarding parasite prevalence and infection level. I also checked if the invaded sites have a different pollinator species composition than non-invaded ones. The study was conducted on ten study sites in 2020 (five with invasion and five without invasion) in southern Poland. There was no difference in *Nosema* prevalence among bumblebees from invaded and non-invaded sites, the parasite was equally widespread and accounted for 77-100% infected bumblebees in the tested material. The proportion of infected individuals increased over time (from June to September). Bumblebee infection levels also increased as the season progressed. On control sites it reaches 38 thousand *Nosema* spores/bumblebee in June, reaching 1.4 million spores/bumblebee in August. On invaded sites the infection level was higher and reached 1,7 million spores/bumblebee in September. On both site types the most numerous pollinators were two bumblebee species: *B. pascuorum* and *B. terrestris*, constituting over 80% of the collected individuals. The preliminary results show that the presence of a foreign invasive plant species *I. glandulifera* doesn't impact the frequency of infection but primarily affects the level of infection among bumblebees and the dynamics of infection over the flowering season.

Overview of *Osmia bicornis* pollen choices

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Urban development and agricultural intensification have a profound impact on bees' food resources. *Osmia bicornis* (syn. *O. rufa*), the red mason bee, is an effective pollinator of spring crops, e.g. apple and cherry orchards and some ornamental and wild plants. Yet, it is still unknown if this species is conservative or plastic in pollen choices in different environments. To check that, new breedings of *O. bicornis* were established along urbanization gradient, namely in urban (90% of built-up infrastructure), suburban (55–65%), and rural (up to 20%) sites. Randomly chosen samples of pollen provisions from each nest were collected and analysed. Additionally, literature data on botanical origin of pollen collected by *O. bicornis* was compiled to test the significance of plant type and pollen grains characteristics (pollen coating and size) in pollen choices of the bee. In the field study we showed that in more human-modified environments, the bee collected lower diversity of pollen types (Simpson diversity index was 3.7 in rural, 2.8 in suburban and 2.2 in urban sites). In general, *O. bicornis* repeatedly collected pollen from commonly available trees like oaks, maples, horse chestnut and elms. This pattern was especially explicit in urban sites, while in suburban and rural ones, also shrubs and herbaceous plants contributed significantly to pollen resources used by *O. bicornis*. Pollen grain size did not matter to bee foraging choices. In urban environments, high share of pollen from anemophilous species was found in bee provisions. Our analyses revealed that *O. bicornis* tends to harvest significant amounts of pollen from trees. Keeping trees, even solitary ones, is especially advisable in urban sites where they may complement the food resources for the red mason bee.

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Effects of six invasive plant species on pollinators in Hungary

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Invasive plant species alter the availability of floral resources, affecting pollinators in negative, positive or neutral ways. Understanding the role of invasive plant species on pollinators in a wider context has a special importance for ecology, conservation and economy. We studied the impact of six invasive plant species *(Ambrosia artemisiifolia, Asclepias syriaca, Erigeron canadensis, Gaillardia aristata, Solidago gigantea, Symphyotrichum lanceolatum* agg.) on floral resources, wild bees, honey bees and hoverflies. We sampled invaded and control site pairs, in Hungary, once before and once during the flowering of invasive species. We analysed the differences in abundances and species richness. Invasive species affected differently the plant-pollinator systems; however, the effects mostly varied between the non-flowering and flowering period of the invasive species. Flower abundances tended to be higher in the control sites before, and in the invaded sites during the flowering of the focal invasive species. Species richness of flowers was higher in the control sites. Wild bee abundances and species richness were higher in the control sites before, while higher in sites invaded by *S. lanceolatum* during its flowering. Honey bees were usually more abundant in the invaded sites during the flowering of the invasive species. Hoverfly abundances and species richness tended to be higher in control sites before, while mostly higher in invaded sites during flowering of invasive species. Some invasive species had no effects on certain pollinator groups (neutral effects). The cover of the invasive plants varied widely. The invasive plants with relatively low cover did not replace all the native floral resources and seemed to have a lower impact on pollinators. Furthermore, the high difference in effects before and during the flowering of invasive plants highlight the importance of repeated samplings over the vegetation season.

A compendium of in vitro germination media for pollen research

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The correct choice of in vitro pollen germination media (PGM) is crucial in basic and applied pollen research. However, the methodological gaps (e.g., strong focus of current research on model species and cultivated plants along with the lack of general rules for developing a PGM) makes experimenting with pollen difficult. We closed these gaps by compiling a compendium of optimized in vitro PGM recipes from more than 1800 articles published in English, German, and Russian from 1926 to 2019. The compendium includes 1572 PGM recipes successfully used to germinate pollen grains or produce pollen tubes in 816 species representing 412 genera and 114 families (both monocots and dicots). Among the 110 components recorded from the different PGM recipes, sucrose (89% of species), H3BO3 (77%), Ca2+ (59%), Mg2+ (44%), and K+ (39%) were the most commonly used PGM components. PGM pH was reported in 35% of all studies reviewed. Also, we identified some general rules for creating PGM for various groups of species differing in area of research (wild and cultivated species), phylogenetic relatedness (angiosperms vs. gymnosperms, dicots vs. monocots), pollen physiology (bi- and tri-cellular), biochemistry (starchy vs. starchless pollen grains), and stigma properties (dry vs. wet), and compared the component requirements. Sucrose, calcium, and magnesium concentrations were significantly different across most categories indicating that pollen sensitivity to sugar and mineral requirements in PGM is highly group-specific and should be accounted for when composing new PGM. This compendium is an important data resource on PGM and can facilitate future pollen research.

Stingless Bees in Cementeries: Exploring the Relations between Land Use and the Composition of Bee Assemblages in the Colombian Andes (Hymenoptera: Meliponini)

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Stingless bees are essential pollinators within pantropical ecosystems and vary extensively in behavior and nesting habits. Although meliponiculture is a widespread practice, many uncertainties remain about the effects of urbanization on stingless bees' assemblages present in cemeteries. Urban cemeteries are areas of exceptional biodiversity and, as such, constitute invaluable fields to study Meliponini behavior in cities. Our goal was to determine how bees interact with local landscape features, such as land cover, and how urban, agricultural, and natural areas enclosing the cemeteries mediate the species richness and the nest abundance of assemblages of stingless bees in Colombia. We sampled 27 cemeteries near urban environments of different cities close to the central mountain range in the Andes, Colombia. We found 364 nests belonging to eight species of stingless bees. Our results suggest that the cemeteries with a higher percentage of natural areas present higher species richness and abundance of nests; in cemeteries within a denser urban area, there is no difference in species richness and nest abundance. Natural areas will be most effective at attracting a large and diverse stingless bee community. However, with proper measures, some bee species can adapt to agricultural expansion and urban intensification, overcoming the loss of local biodiversity. Our results show that cemeteries provide shelter and nesting resources for stingless bees, contributing to maintaining propose to continue research on the ecological dynamics of these pollinators in urban environments and provides evidence on how to optimize green areas for their conservation.

Bee diversity and pollination in apple orchards of Western Norway and effects of surrounding habitats

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The global decline of pollinating insects is a serious challenge for food production of numerous crops. Pollination by bees is crucial for apple production. Apple blossoms is an important food source for bees, but other recourses outside of the intense blossoming period are necessary. In my master's thesis I am investigating the effects of nearby vegetation on bee diversity in 10 apple orchards in two Norwegian fjord regions. These areas have not been notably sampled since the 1960s. Bees were collected during the apple blossoming period in 2020 with netting and pan traps. In addition to 881 honeybees, we collected 97 bumblebees representing 14 species, 289 solitary bees representing 23 species and a total of 85 hoverflies. To study how the surrounding vegetation affects the bee diversity, the vegetation in a 200m radius surrounding the orchards was recorded. I mapped how much of this area was orchards, forest, urban areas, and flowering meadow. It is expected that a higher level of flowering meadows positively impacts bee diversity. This project also explores how beehives placed near the orchards impacts wild bees. To look at the quality of the pollination, we also look at apple seed development. More developed seeds indicate a more successful pollination. I counted the seeds of 100 apples from each orchard, classifying the seeds into three categories: fully, partly, and not developed. These data will be used to analyse whether a higher bee diversity leads to better pollination.

Linear effects of Spiraea tomentosa invasion on native pollinators of wet meadows

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Freshwater wetlands are important refuges for hygrophilous and hygrobionic plants and animals and biological invasions are one of the most important reasons for their degradation. Invasive plants disrupt the functioning of these ecosystems at different levels of their organization. Among animals, insects, including pollinators, are particularly sensitive to disturbances resulting from plant invasions. Data on the impact of invasive plants on pollinator populations are still scarce. It is often assumed that the impact of alien plants is proportional to their population density. In this study, we assessed the impact of the density of invasive plant population on the number and species diversity of potential pollinating insects of wet meadows. The North American steeplebush (*Spiraea tomentosa* L.), highly invasive in wetlands of central and northern Europe, was used as a model for alien plant species. The research was carried out in a wet meadow and forest landscape located in south-western Poland. In 2020 a total of 27 patches were distinguished, where S. tomentosa coverage ranged from 0% to 100%. Insects visiting research plots were caught with white Moericke's traps. In total, 332 individuals of 65 species of bees Apoideae, 564 individuals of 90 species of butterflies Lepidoptera and 2753 individuals of 136 species of hover flies Syrphoidea were captured. Data were analysed using generalized linear mixed models. We found that the number of bee, butterfly and hover fly species significantly decreased linearly with the increase of *S. tomentosa* cover. Also, the number of pollinator individuals depended negatively on the invasive shrub cover, indicating that invasion of S. tomentosa in wetland ecosystems has a strong and negative impact on the abundance and diversity of potential pollinators. This results in the fact that only a part of the original species pool may persist in areas heavily affected by invasion of this shrub. List of participants:

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