SCAPE 2018

The 32nd annual meeting of the Scandinavian Association of Pollination Ecologists

October 18th – 21st

Avon Rí, Blessington, Ireland

The Great Yellow Bumblebee (*Bombus distinguendus*) approaching *Trifolium pratense* in the west of Ireland. Photo: Dara Stanley

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SCAPE 2018 PROGRAMME

Thursday 18th October

18.00	Supper	
	1st session (Chair: Dara Stanley)	
19.00-19.05	Jane/Dara	Welcome
19.05-19.20	Ola Olsson	Flowering resources distract pollinators from crops: model predictions from landscape simulations
19.20-19.35	Yoko Dupont	Where do honeybees forage in an agricultural landscape?
19.35-19.50	Pierre Ouvrard	Landscape structure is more determinant for flower-visiting insects than the type of managed strip agri-environment schemes
19.50-20.05	Asma Akter	Increasing habitat loss and anthropogenic activities in the Sundarbans: Can plant-pollinator community sustain the threat?
	Comfort break	
	Keynote lecture (Chair: Jane Stout)	
20.20	Elli Leadbeater	Bee cognition in a changing world
21.00	Networking/socialising/sauna	

Friday 19th October

07.45	Breakfast/sauna	
	2nd session (Chair: Jon Ågren)	
09.00-9.15	Justyna Ryniewicz	Geographic differences in flower morphology influence plant reproductive biology. The case of a rare *Polemonium caeruleum* L. (Polemoniaceae).
09.15-9.30	Leana Zoller	A glimpse into the past: a comparison of historic and present-day plant-pollinator interactions at high northern latitudes
09.30-9.45	James Murphy	Market and non-market based approaches to valuing ecosystem services provided by pollinators
09.45-10.00	Kristina Buch	Bumblebees use flower symmetry to optimise flower approach in artificial 3D flowers
10.00-10.15	Anna Vojtkó	A novel approach in pollination ecology using the trait-based community ecology toolbox
10.15	Coffee break	
	3rd session (Chair: Renate Wesselingh)	
10.45-11.00	Saorla Kavanagh	Honey: the good, the bad and the ugly
11.00-11.15	Sarah Gabel	Factors driving Syrphid abundance, diversity, and community composition in arable cropping systems
11.15-11.30	Thomas Sawe	Timely and sufficient availability of pollinators and neither fertilizer nor irrigation increase quality and quantity of yield watermelon (*Citrus lanatus*)
11.30-11.45	Lynn Jørgensen	Effect of pollination boxes on relative densities of *Eladobius kamerunicus* populations
11.45-11.50	Knut Hessen	The distribution of insect pollinators in an oil palm plantation
11.50-11.55	Thomas Dally	Acoustic differentiation between insect pollinator groups using wing-beat frequencies – a future monitoring tool
11:55-12.00	Fergus Chadwick	Making Sense of Messy Data: Incorporating Opportunistic Records into Pollination Research
12.00	Lunch	
	4th session (Chair: Jeff Ollerton)	
13.30-13.45	Dorothy Christopher	Co-occurring bumblebee species differ strongly in their effects on mating patterns in monkeyflower
13.45-14.00	Gita Benadi	Frequency dependence of pollinator visitation rates suggests that pollination niches can promote plant species coexistence
14.00-14.15	Karin Gross	Polyploidy and floral evolution in the highly variable nursery pollinated *Lithophragma bolanderi* (Saxifragaceae)
14.15-14.30	Laura Russo	Impacts of fertiliser and herbicide runoff on plant-pollinator interactions
14.30-14.35	Julie Sørlie Paus-Knudsen	Interacting effects of neonicotinoids and temperature on bumblebee (*Bombus terrestris*) behaviour
14.35-14.40	Sebastian Köthe	Impact of scent marks, colour and location on the selection of food sources in Brazilian stingless bees and the Western honey bee
14.40-14.45	Cian White	Interaction networks along human disturbance gradients
14.45	Coffee break	
15.00	Poster-session (Chair: Marcin Zych, 20 posters)	
	5th session (Chair Yuval Sapir)	
16.30-16.45	Michael Bartoš	Correlation of floral and life history traits with self-compatibility and autonomous selfing at wet meadow communities
16.45-17.00	Petra Janečková	Reproduction system of critically endangered species *Gentianella praecox* subsp. *Bohemica*
17.00-17.15	Sabine Konzmann	Pollination ecology of *Rhynchanthera grandiflora* (Melastomataceae) in Brazil
17.15-17.30	Zdenek Janovsky	Butterflies and hoverflies respond differently to changing plant spatial aggregation
18.00	Supper	
	Keynote Lecture (Chair: Dara Stanley)	
19.30-20.10	Steve Johnson	Pollination niches explain floral diversity in African aloes
20.10 - late	Networking/socialising/sauna	

Saturday 20th October

08.00	Breakfast/sauna	
	6th session (Chair: Anders Nielsen)	
9.30-9.45	Amy Parachnowitsch	Floral scent evolution across the Penstemons: does scent change with pollination system?
9.45-10.00	Bruce Anderson	Honeybees learn to rob flowers from other honeybees and carpenter bees
10.00-10.15	Jeff Ollerton	The evolution of pollination systems in the Apocynaceae, one of the largest plant families
10.15-10.30	João Aguiar	The role of floral colour polymorphism in deceptive pollination
10.30-10.45	Judith Trunschke	Reproductive isolation of *Drosera cistiflora* color morphs
10.45	Coffee break	
11.00	Excursion	
13.00	Lunch	
	7th session (Chair: Nina Sletvold)	
14.00-14.15	Karl Duffy	Pollinators and the geographical distribution of flowering plants
14.15-14.30	Kathleen Kay	Heteranthery as a pollen dosing strategy in Clarkia (Onagraceae)
14.30-14.45	Klaus Lunau	Everything you want to know about flower colour preferences in hoverflies
14.45-15.00	Mohamed Abdelaziz	Ecological mechanisms underlying the stability of a high-mountain hybrid zone
15.00-15.05	Christine Coppinger	Insights into the impacts of rural honey hunting in Zambia
15.05-15.10	Johanna Yourstone	The status and role of wild bees for Chilli (*Capsicum annuum*) pollination in an Indian tropical dryland
15.10-15.15	Katarzyna Roguz	Does a small change make a big difference? Diversity of nectar amino acids in the genus *Fritillaria* (Liliaceae): ecological and evolutionary implications
15.15	Coffee break	
	8th session (Chair: Yoko Dupont)	
15.45-16.00	Ana Maria Martin Gonzalez	Network meso-scale structure and species traits in hummingbird-plant interaction networks
16.00-16.15	Julia Jaca Estepa	Network mesoscale measures to study indirect interactions in Aride Island, Seychelles.
16.15-16.30	Robert Tropek	Effects of altitude and season on the structure of pollination networks on Mount Cameroon
16.30-16.45	Yannick Klomberg	The role of floral traits in plant-pollinator interactions in tropical montane forest of Mount Cameroon
16.45-16.50	Pawel Kolano	An automated monitoring system for monitoring individual bumblebees.
16.50-16.55	James Rodger	Heterogeneity in local density allows a positive evolutionary relationship between self-fertilisation and dispersal
16.55-17.00	Marcos Mendez	Revisiting the role of petaloid bracts in *Lavandula*: function transfer for pollinator attraction?
17:00-17:05	Malin Aarones	Measuring concentrations of Clothianidin, a neonicotinoid pesticide, in bumblebees (*Bombus terrestris*)
17.05	Comfort break	
	9th session (Chair: Laura Russo)	
17.30-17.45	Steph Maher	Solitary bee nesting ecology; novel methods and first results
17.45-18.00	Paolo Biella	An empirical attack tolerance test on real plant-pollinator networks
18.00-18.15	Magne Friberg	Intraspecific variation in floral scent – a meta-analysis
18.15-18.30	Øystein Opedal	Measuring, comparing and predicting phenotypic selection on floral traits
18.30-19.30	Getting ready…	
19.30-21.30	Conference dinner	
21.30–22.30	Céilí	
22.30-late	The bar is open…	

Sunday 21st October

09.00-10.00	Breakfast
11.00	Check out
11.00	Bus departs for TCD

KEYNOTE ABSTRACTS

Pollination niches explain floral diversity in African aloes

Steven D. Johnson

School of Life Sciences, University of KwaZulu-Natal, P Bag X0, Scottsville, Pietermaritzburg 3209, South Africa

Pollinators can be considered niches in the sense that they represent ecological opportunities for plant reproduction. Plants with certain combinations of floral traits can exploit these niches and shifts between pollination niches should thus be associated with floral diversification. We have been investigating these issues in *Aloe* which is one of the most iconic African plant genera. Most *Aloe* species possess a late-acting self-incompatibility system which results in highly inefficient conversion of ovules into seeds and considerable potential for ovule discounting resulting from geitonogamy. The three main pollination systems we have identified for aloes involve specialist sunbirds, opportunistic birds, and bees. These three systems are associated with characteristic suites of floral traits. Bees, especially pollen-collecting individuals, visit almost all *Aloe* species, but their contribution to pollination is highly variable. Recent experiments have shed new light on why honeybees are such poor pollinators of many *Aloe* species. Because aloes generally hybridize easily, the degree of pollinator and flowering time overlap among sympatric *Aloe* species can affect the likelihood of their stable coexistence in communities. In conclusion, *Aloe* shows a classic pattern of pollinator-driven floral diversification, involving shifts between three major pollinator groups.

Bee cognition in a changing world

Elli Leadbeater

Royal Holloway University of London

Bees have long been a wonderful model to understand cognitive evolution, because their relatively simple brains are under selection to solve the complex ecological problems inherent in central-place foraging within an unpredictable environment. However, classic behavioural and cognitive paradigms have recently taken on an additional new role, as tools to help understand the threats faced by bees from multiple sources. In this talk, I will give a broad overview of how this development can contribute to the study of two major anthropogenic stressors for pollinators: land-use change and insecticide exposure. Focussing upon *Bombus terrestris* and *Apis mellifera*, I will (a) illustrate how dance-decoding can be used as a tool to study floral resource availability (b) show that maze-based cognitive protocols can allow rapid assessment of sub-lethal behavioural effects, and (c) present ongoing work that aims to assay the relevance of cognitive and behavioural traits for pollinator fitness in the wild.

ORAL PRESENTATION ABSTRACTS

Thursday 18th October
1st session

Flowering resources distract pollinators from crops: model predictions from landscape simulations

Charlie C. Nicholson[1], Insu Koh[2], Taylor H. Ricketts[1], Henrik G. Smith[3], Eric Lonsdorf[4], Ola Olsson[5]

[1] The Gund Institute for Environment and Rubenstein School of Environment and Natural Resources, University of Vermont, VT, USA, [2] The Department of Pathology and Laboratory Medicine, University of Vermont, Burlington, VT, USA, [3] Centre for Environment and Climate Research, Lund University, Lund, Sweden, [4] Institute on the Environment, University of Minnesota, St. Paul, MN, USA, [5] Biodiversity Unit, Department of Biology, Lund University, Lund, Sweden

Enhancing floral resources is a widely accepted strategy for supporting wild bees and promoting crop pollination. Planning effective enhancements can be informed with pollination service models, but these models should capture the behavioral and spatial dynamics of service providing organisms. Model predictions, and hence management recommendations, are likely to be sensitive to these dynamics. We used two established models of pollinator foraging to investigate whether behavioral detail improves model predictions; whether habitat enhancement improves crop visitation; and whether this effect is influenced by pollinator traits and landscape pattern. The more detailed optimality based central place foraging model better predicted variation in data on bee visitation observed between habitat types, because it includes tradeoffs between patch quality and distance from the nest. Both models performed well when predicting visitation rates across broader scales. We apply the models to simulations of real agricultural landscapes where we enhance floral or nesting resources, to identify the conditions under which habitat enhancements are most likely to increase pollination services. Three design principles emerge from these results: 1) enhancing only flowers can diminish services by distracting pollinators away from crops, 2) providing nesting resources is more likely to increase bee populations and thereby crop visitation, and 3) the benefit of enhancements will be greatest in landscapes that do not already contain abundant habitat.

Where do honeybees forage in an agricultural landscape?

Yoko L. Dupont, Julie Ø. Frederiksen, Annika S. Jeppesen, Peter B. Sørensen
Dept. of Bioscience, Aarhus University, Denmark

Both wild and managed bees are under pressure from multiple stressors, most notably lack of flowers and nesting habitats, pesticide use and diseases/parasites. In agricultural landscapes a range of different pesticides are used, some of which have adverse effects on bees. Current pesticide risk assessment methods are mostly based on laboratory standard toxicity tests of honeybee individuals, which do not take into account for complexities in the field. To address these challenges, EFSA (the European Food Security Agency) initiated a project: the MUST-B project that aims to combine modelling and experimental/field data for honeybees, in order to assess the effects of multiple stressors in the hive and the surrounding landscape, and to determine their influence on honeybee colony loss and weakening. The core of the project is an individual-based model, which simulates the behaviour and population development of the bees. Hence, a particularly important question is to know where the bees forage in the landscape. In order to investigate this, we carried out a small field study, in which we made simultaneous observations of (1) honeybee waggle dances (indicating direction and distance of resource rich patches in the landscape), (2) large floral resources in a 3 km

circle around the experimental hive, and (3) determined botanical composition of pollen collected from returning worker bees. We found that the bees collected pollen from only a few plant species on each observation day. Decoding of honeybee dances gave a good indication of where the bees were foraging, in particular when combined with palynological data, although it was not possible to pinpoint the exact spatial location of resources.

Landscape structure is more determinant for flower-visiting insects than the type of managed strip agri-environment schemes

Pierre Ouvrard and Anne-Laure Jacquemart
Research team "Genetics, reproduction, populations", Earth and Life Institute - Agronomy, Université catholique de Louvain, Belgium.

Since 1992, European Common Agricultural Policy encourages farmers to set up various agri-environment schemes (AES) to support biodiversity and associated ecosystem services in intensively cultivated farmlands. In Belgium, AES strips to provide seed resources for wild birds (bird-strip AES) and flower resources for pollinating insects (pollinator-strip AES) are implemented, but their attractiveness for flower-foraging insects has not been compared yet. The primary objective of this research was to compare floral resources quantities and qualities provided by both AES strips. We monthly recorded densities and diversities of flowers during three years on six pollinator-strips and four bird-strips in intensively cultivated farmland.
The second objective of our research was to compare the number and diversity of insects foraging on both AES strips, comparing to local insect diversity. We monthly recorded diversities of flower-visiting insects on the ten studied AES strips, and we used pan-traps to assess the local insect diversity.
The sown and spontaneous plant communities of both types of strips provided nectar and pollen to numerous insect species, especially common polylectic species, known as efficient pollinators. Floral resources of both types of strips were mainly produced in summer and by sown and spontaneous Asteraceae species. Extra-strip available floral-resources are so particularly required by insects. These extra-strip resources should provide spring resources and allow insects to find pollen complementary to the essential-amino-acid-deficient Asteraceae pollen.
The local flower-foraging insect diversities were richer than the flower-visiting insect diversities observed on flowers. The insect diversities were more affected by the biogeographical region than by the type of implemented AES. In their current configuration, the AES strips were not sufficient to compensate the anthropogenic landscape perturbations.
Synthesis: the Belgian bird- and pollinator-strip AES are both effective AES that provide floral resources to pollinating insects in summer and that support ecosystem services in intensively cultivated farmland. Nevertheless, the spring flower resources remain weak, and insects have to find floral resources outside the strips until June. The surrounding landscape was more important than the type of AES strips to explain insect communities' diversity. Therefore, the location of AES strips within the landscape is of particular importance to improve the strips effectiveness to support insects.

Increasing habitat loss and anthropogenic activities in the Sundarbans: Can plant-pollinator community sustain the threat?

Asma Akter[1,2], Paolo Biella[1,2], Mohammad Raqibul Hasan Siddique[3], Jana Jersakova[2], Péter Batáry[4], Jan Klečka[1]

[1]Institute of Entomology, Biology Centre CAS, Czech Republic; [2]University of South Bohemia in Ceske Budejovice, Czech Republic; [3]Khulna University, Bangladesh; [4]University of Göttingen, Germany

The Sundarbans, the largest single patch mangrove forest in the world, has been facing an increasing pressure of habitat loss and human exploitation over the years. Yet, no information is available about how these factors affect the plant-pollinator interactions in this world heritage ecosystem. This research was first effort to study the impact of habitat loss and anthropogenic activities on plant-pollinator interactions and plant reproduction. For this study, 12 Sites were selected in Shyamnagar, north-western region of the Sundarbans in Bangladesh, along the gradient of increasing habitat loss and human activities from continuous pristine forests to forest fragments near the human settlements. Pollinators were observed and collected from two focal plant species, *Avicennia marina* and *Acanthus ilicifolius*. Giant honey bee (*Apis dorsata*) and solitary bees were found to be the most important pollinators in this forest but declined along the gradient of increasing habitat changes. *Apis dorsata* were mostly abundant in the deeper forest but decreased in the forest patches nearby villages, where they were replaced by the *Apis cerana*, commonly found managed honey bee. Both plant species received a wide range of solitary bees but only *A. marina* received other pollinators like flies, wasps and butterflies. Seed production was 30% higher per fruit for *A. ilicifolius* in the least disturbed forest sites, indicated that mangrove pollinators are more efficient. We conclude that plant-pollinator interactions are sensitive to anthropogenic activities and the loss of mangrove pollinators have negative impacts on the pollination success of native plants in the Sundarbans.

Friday 19th October
2nd session

Geographic differences in flower morphology influence plant reproductive biology. The case of a rare *Polemonium caeruleum* L. (Polemoniaceae).

Justyna Ryniewicz[1], Katarzyna Roguz[1], Mateusz Skłodowski[1], Emilia Brzosko[2], Beata Ostrowiecka[2], Izabela Tałałaj[2], Ada Wróblewska[2], Edyta Jermakowicz[2], Paweł Mirski[2] & Marcin Zych[1]

[1]Botanic Garden, Faculty of Biology, University of Warsaw, Warsaw, Poland; [2]Department of Plant Ecology, University of Białystok, Białystok, Poland

Polemonium caeruleum is a red-listed, boreal plant species with SW limit range in Poland. Flowers of *P. caeruleum* are hermaphrodite, dichogamous and protandrous, pollinated mainly by bumblebees and honeybees, although visits of insects from other taxonomic orders also are recorded. Previous study showed that *P. caeruleum* reproduces only by seeds and sufficient insect services are necessary for adequate seed production. This plant often grows in small and isolated populations, with some of them in decline, which may be the result of climate change and human-mediated transformation of ecosystems. Our previous research showed that seed production, mating system and insect visitor assemblages vary spatially and we speculated that floral morphology may be involved in shaping those features. To verify our hypothesis we conducted field experiments on 7 to 15 populations of *P. caeruleum* (depending on a year) distributed throughout Poland. In years 2014 to 2018 we investigated the level of pollen limitation, mating system, insect visitors and coupled them with the biometric measurements of flowers (in 2018).

Our results showed that morphology of flowers varied between populations and may influence plant reproductive success, seed production by self-compatible plants, and insect visitors (frequency of visits and types of pollinators). The project was supported financially by the Polish National Science Centre grant no. 2014/15/B/NZ8/00249 (to MZ).

A glimpse into the past: a comparison of historic and present-day plant-pollinator interactions at high northern latitudes

Leana Zoller[1,3], Tiffany M. Knight[1,2,3]

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The majority of the world´s plants rely on animal pollinators for reproduction, making pollination a key ecosystem service for the maintenance of natural and cultivated plant communities. However, pollinators are experiencing a severe global decline. Amongst other anthropogenic drivers, climate change is considered responsible for this decline. In arctic and mountainous regions, climate change is projected to be especially pronounced. Understanding the impact of climate change on ecosystems is challenging, since the effects may take decades to transpire. We aim to overcome that challenge by using a historical dataset collected by F. Silén in the summers of 1895-1900. He recorded flower visitors of 87 different plant species in the surroundings of Kittilä, Finland, providing us with a valuable insight on plant-pollinator interactions from over a century ago. For our project, we resample plant-pollinator interaction networks in Kittilä and compare them with the historical data in order to explore the changes that occurred during the last century in plant-pollinator networks in high northern latitudes. In my talk I will present to you key insights from Silén´s 1900 dataset as well as preliminary results from the comparison with present day data.

Market and non-market based approaches to valuing ecosystem services provided by pollinators

James Murphy[1], Jane C. Stout[1]

[1]School of Natural Sciences, Trinity College Dublin, Ireland

The concept of valuing nature is a complex topic with different approaches to derive estimations of value in both monetary and non-monetary terms. The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) identified various methodologies for valuing nature and highlighted the importance of developing an inclusive valuation approach for nature's contributions to people. However, difficulties exist in reconciling various incommensurable approaches to valuing nature (from monetary to socio-cultural) into a holistic framework for decision-making processes. The current body of literature on economic valuation of pollination services take a number of different approaches to estimate market value that vary in their complexity. These range from the simple use of crop prices as a proxy for pollination service value to more complex production functions which attempt to quantify the relationship between crop production and pollination services. All of these approaches are restricted to capturing the market price of crop production that pollination services underpin and therefore do not capture the complete value (market and non-market) of these services. On the other hand, various methodologies can be utilized to elicit monetary value associated with non-market benefits of ecosystem services, such as questionnaires and willingness-to-pay calculations. The aim of this research is to review the main approaches to valuing nature, as identified by the IPBES, and to integrate them into a multi-dimensional conceptual framework for valuation.

Bumblebees use flower symmetry to optimise flower approach in artificial 3 D flowers

Kristina Buch[1], Klaus Lunau[1]

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Bumblebees are known to respond to various flower parameters when selecting, approaching and visiting flowers. Among the principal relevant known visual parameters are size, shape, symmetry, colour, floral guide and microtexture. The orientation of a bumblebee's body on the flower upon landing is important to render its foraging most efficient and, from a flower's perspective, to support the bumblebee's search for reward and to deposit the pollen on a safe site on the pollinator for pollination. We investigated if, how and from which distance, bumblebees use symmetry cues from three-dimensional artificial flowers in their landing approach. We further examined, whether the rotation of the flower in the transverse plane changes this approach behaviour. Using videographic analysis, the bumblebee's body position in respect to the flower's principal vertical axis of symmetry was determined at 9, 4, 1.5 and 0 cm to the central flower front at five different transverse rotational angles of the flower. We show that bumblebees align to the principal vertical axis of symmetry of three-dimensional artificial daffodil flowers in preparation for landing, irrespective of the flower's rotational angle in the transverse plane. The results suggest that bumblebees perceive the global form and symmetry of a flower from a distance, without compromising on the shortest approach route to the frontal principal vertical axis of the flower.

A novel approach in pollination ecology using the trait-based community ecology toolbox

Anna E-Vojtkó[1,2], Francesco de Bello[1,2], Lars Götzenberger[2]

[1]Department of Botany of the University of South Bohemia, České Budějovice, Czech Republic;
[2]Institute of Botany of the Czech Academy of Sciences, Třeboň, Czech Repubic

Pollination ecology uses a wide range of methodological approaches to study plant-pollinator interactions. However, pollination studies often explore populations of single plant species or genera and their corresponding pollinators, and – except for the currently flourishing network-studies – community scale research is rather scarce. Exploring local community assembly patterns can bring us closer to understanding the rules of species coexistence shaped by habitat filtering, facilitation and competition for resources. The study of plant community assembly through functional traits is a field with established set of theories, data-handling techniques and methodological approaches. So far, its focus has predominantly been on vegetative traits, which have repeatedly been shown to have strong and consistent responses to abiotic conditions such as climate or nutrient and water availability. However, functional traits connected to sexual reproduction and pollination success have rarely been considered in this context despite their fundamental role in shaping plant fitness, and their importance for community assembly has just started to be acknowledged by ecologists. In this presentation we are bringing these two sub-disciplines closer together by providing examples of the methodological approaches that are well established in trait-based community ecology and can potentially be used to answer questions in pollination ecology. We present a case study using a large dataset of vegetation surveys covering the most abundant Central European habitat types as well as functional and phylogenetic diversity measures in order to explore spatial patterns in floral trait variation in plant communities. We are also calling attention to the limitations this "hybrid-field" has to face at present and project forward potential ways that could help to incorporate floral traits into the trait-based community assembly framework.

3rd session

Honey, the good, the bad and the ugly

Saorla Kavanagh[1], Jane Stout[2], and Blánaid White[1]

[1]Dublin City University; [2]School of Natural Sciences, Trinity College Dublin, Ireland

The composition of honey can vary in terms of both beneficial and non-beneficial constituents. The phenol composition of honey influences how beneficial it is to human and bee health, but varies according to its botanical origin. Honey can also contain non-beneficial chemicals, including, but not limited to, pesticides. Among pesticides, neonicotinoids have been implicated in declines in bee populations. Due to their wide application, persistence in soil and water and uptake by wild plants, neonicotinoids are widely bioavailable to bees which can result in the presence of neonicotinoids in honey.

Regional variation in land use and vegetation composition, and thus availability of forage sources for bees, is likely to influence honey chemical properties, but this has not previously been examined. We sampled multi-floral honey from 76 *Apis mellifera* hives from urban, rural and intermediate locations across Ireland, identified and quantified phenolic and neonicotinoid content and using HPLC-UV and HPLC-MS, and classified surrounding land use, up to 5km around hive sites.

We found that urbanisation and agricultural land use influences the phenolic and neonicotinoid content of Irish honey. More phenols were present, and their concentration was greater, in honeys from urban centres, and the amount of green urban areas had an overall positive relationship with phenol composition. Some phenols were completely absent from honey from landscapes containing a high proportion of pastures. Finally the number of occurrences of neonicotinoids was highest in honeys from agricultural landscapes and at least one of the three tested compounds (clothianidin, imidacloprid and thiacloprid) was detected in 70% of all samples.

Factors driving Syrphid abundance, diversity, and community composition in arable cropping systems

Sarah Gabel[1] and Jane C. Stout[1]

[1]Botany Department, School of Natural Sciences, Trinity College Dublin, Dublin, Ireland

Hedgerows can provide habitat for a range of beneficial invertebrates on farmland, including hover flies (Syrphidae, Diptera), which can provide both pollinating and aphid pest-controlling services to the adjacent crop. Adult syrphids feed on flowers in the hedgerows and margins of the crop, whilst the larvae of some species are aphidophagous. Syrphid abundance, richness and community composition may be driven by a range of factors, including the abundance of food resources, which can in turn be influenced by the structure and composition of hedgerows, as well as the activity of competitors. This study investigated the relationships between hedgerow structure and composition, floral resource availability, and the abundance, richness, and community composition of syrphids, aphids, other pollinators and aphidophagous predators. Nine organic oat crop fields were surveyed across Leinster Province in the Republic of Ireland in 2017. Hedgerow structure was quantified in terms of hedge dimensions, percent gaps, and woody species diversity. Insect surveys were conducted both in the hedgerow and the adjacent crops using three methods: timed observations of floral visitors along transects, timed hand searches for pests and predators on the oat crop, and 24-hour collection of fauna in pan traps along the hedgerow. Diversity of floral families and floral abundance was also recorded. We found that there were more syrphids than bees visiting flowers, and far more parasitoid wasps than syrphid larvae attacking the aphids on the oats. The relationships between hedgerow

characteristics, floral abundance, and insect communities will be described. As hedgerows are a means by which to encourage beneficial insects in the farmed landscape, it's useful to understand how their structure might influence invertebrate communities so that farmers can manage hedges in a way to optimize populations of ecosystem service providers. Acknowledgement: Funding provided by the Environmental Protection Agency in partnership with the Irish Research Council, under the EPA Research Programme (2014-2020).

Timely and sufficient availability of pollinators and neither fertilizer nor irrigation increase quality and quantity of yield watermelon (*Citrus lanatus)*

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Insufficient pollination might limit fruit and seed set in insect pollinated plants. Thus, a low agricultural output in entomophilous crops may be due to insufficient pollination service. If this is the case, improving, growing conditions may have no or only weak effect on crop yield. In this study, we conducted an experiment to disentangle the contribution of pollination service, fertilization and watering (irrigation) to watermelon yields. We applied increased fertilization, irrigation, hand pollination and all combinations of treatments to watermelon plants growing in a common garden. In addition, some plants received pollination from the local pollinator community as well as fertilization and irrigation following common farmer practice. These plants were acting as a control. During the experiment, we monitored initial fruit set, mature fruit set and fruit abortion rate. One week before commercial harvest, we measured the yield i.e. number of fruits per plant, fruit weight, fruit shape, sugar content and flesh colour. Our results showed that improving soil conditions, i.e. adding more fertilizer and/or water, did not improve watermelon yields. On the other hand, we show that improving pollination increases the probability of a watermelon plant producing a second fruit of a commercially interesting size. We have shown that fertilization and irrigation measures taken by local farmers are sufficient, and that the limiting factor for watermelon yields in this system is pollination. We therefore suggest that farmers spend their resources on improving the conditions for the pollinator community, rather than investing in fertilizers and additional irrigation.

Effect of pollination boxes on relative densities of *Eladobius kamerunicus* populations

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The amount of land covered by oil palm plantations in Indonesia has increased from 9.6 – 11.8 million ha from 2012 until 2016. During the same time palm oil production increased by 5.5 million tons, averaging an annual production of 32.0 million tons in 2016. To meet the increasing demand for palm oil and enhance oil yields, the oil palm plantation PT. Ketapang Agro Lestari, West Kalimantan, Indonesia (PT. KAL) is testing a new concept called "pollination boxes". *Elaeis guineensis* (oil palm) is pollinated by the African weevil *Elaeidobius kamerunicus*, which feed on and deposit eggs inside of male inflorescences in anthesis. Both female and male inflorescences attract pollinating weevils by producing and excreting a strong anis-like scent. Plantation workers manually collect male inflorescences from oil palms after finished anthesis, each potentially holding up to 3000 weevil eggs and larvae when they are transferred to pollination boxes. The goal is to increase local densities of the pollinating weevils, lower production of parthenocarps (development of seedless fruit without fertilization), and ultimately increase oil yields. My research aims to examine the effect of the pollination boxes by assessing the relative densities of weevil populations at increasing distances from the boxes. The fieldwork was conducted at four sites within the plantation. At each site I established a transect consisting of four sampling points located between 5m - 400m from the pollination boxes. I collected six random spikelets per inflorescence to assess the relative weevil density. I also recorded the number of inflorescences, their sex and their state of development in 24 palm trees surrounding each sampling point. I will examine the data on distance to pollination box and local inflorescence availability in relation to yield data from the company, to evaluate the effect of the pollination boxes on their production.

The distribution of insect pollinators in an oil palm plantation

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The increased global demand for palm oil causes decreases in tropical rainforest cover due to expansions of oil palm fields. Oil palm plantations cover approximately 10% of the world´s permanent croplands, with Indonesia accounting for more than 53% (33.5 Mt) of global palm oil production. Oil palm is one of the world's most rapidly expanding crops and there continues to be an increase in vegetable oil and biofuel demands. Expansion of agricultural monocultures negatively affects all aspects of biodiversity including insects. Insects are the most important pollinator for tropical plant species, pollinating approximately 98-99% of all plants in this biome. The oil palm company, PT Austindo Nusantara Jaya, is relatively conservation minded. One of the company`s goals is to keep patches of so called "high conservation value forest" left inside the plantation. This study focused on one of their plantations, a 16,620 hectares area in Ketapang, West Kalimantan, Indonesia, run by PT Kayung Agro Lestari (KAL) that contains several small patches of "close to native forest". The aim of the study is to assess whether there is an increase in pollinator density and diversity in relation to forest patch proximity. I collected pollinators (bees) by use of pan traps placed at understory vegetation height from June to October 2017. I established four transects starting at two forest patches and collections from these were compared to collections from two control sites situated more than 1 km from any forest. The data collected in this study should allow managers to make more informed

decisions concerning insect pollinator conservation in relation to oil palm plantation establishment, management and development.

Acoustic differentiation between insect pollinator groups using wing-beat frequencies – a future monitoring tool

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Insect pollinators are currently undergoing worldwide declines due to human activity, increasing the demand for large-scale, long-term monitoring efforts to determine the extent of these losses. Monitoring schemes, in turn, rely upon tested protocols grounded in fully standardised survey methods to sample effectively. Acoustic monitoring has the potential to act as an exciting novel tool for insect pollinator surveys. It is non-invasive and can be carried out remotely, compared to the time-consuming and often lethal sampling methods traditionally employed when monitoring pollinator populations. We aim to assess whether different insect pollinator taxa can be distinguished from one-another using passive acoustic cues extracted from the sounds of their wing-beats. We recorded over 1100 instances of flower-visiting insects in flight from 538 individuals representing a broad range of taxa, including the Western Honeybee (*Apis mellifera*), eight species of bumblebee, the common wasp (*Vespula vulgaris*), four genera of "solitary" bees, nine genera of hoverflies, and one morphotype of non-Syrphid fly. Our results indicate that acoustic differentiation between broad pollinator groups is possible and, within distinct pollinator groups, particularly the hoverflies and "solitary" bees, this can also be seen at the genus- and species-level. Bumblebees showed a lower degree of inter-species differentiation than expected, possibly due to high levels of intra-specific size variation, causing different species to overlap in multivariate space. Future work aims to extend this analysis, using machine learning algorithms trained on a more detailed selection of acoustic cues to autonomously predict insect pollinator group membership.

Making Sense of Messy Data: Incorporating Opportunistic Records into Pollination Research

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In recent years the volume of data available to ecologists has grown massively due to the proliferation of recording apps, social media groups and online data repositories. These data are often messy, being opportunistic, error-prone, incomplete, and lacking in consistent levels of collection effort. However, they are often our only source of insight into the types of large scale problems that abound within pollination ecology, such as changes in landscape composition or pesticide usage, and their corresponding impact on species abundances and ranges. During my Master's degree, I have developed a new framework for robustly estimating relative abundance of species from these opportunistic data. The next stage is to combine these opportunistic data with traditional systematic surveys of pollination and pollinators, we can allow the complementary strengths of the two data types to improve our understanding of the underlying ecological processes at work. The aim of my PhD thesis is to develop the statistical framework for carrying out these analyses.

4th session

Co-occurring bumblebee species differ strongly in their effects on mating patterns in monkeyflower.

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Changes in the abundance and composition of pollinator communities are thought to have important consequences for plant reproductive success and mating patterns. Yet surprisingly little is known about the differential contributions of closely related species to mate diversity and patterns of pollen carryover. Monkeyflower (*Mimulus ringens*) is pollinated primarily by several co-occurring bumblebee species. At our study sites in Wisconsin, USA the relative abundance of 5 species of *Bombus* has fluctuated widely over the last 17 years. We have tracked foraging patterns of these bee species in experimental populations of monkeyflower, and have quantified contributions of multiple species to *Mimulus* pollen deposition and seed set. We have also used paternity analysis to quantify patterns of gene dispersal as well as mate diversity following single visits by two of the species.

Long-tongued *Bombus fervidus* was the predominant visitor to our study site during the years 2000-2004. However, the abundance of this species declined precipitously throughout Wisconsin in 2006 and is still rare at our study site. The short-tongued bee *Bombus impatiens* was the predominant species at our site during the period 2006-2008. However, over the last decade, *Bombus vagans*, a bee with an intermediate tongue length, has accounted for the majority of visits to *Mimulus ringens*. Single floral visits by *Bombus vagans* deposit significantly more pollen per stigma than do single visits by *Bombus impatiens*, leading to higher seed set.

Although *Bombus vagans* and *B. impatiens* move primarily between adjacent plants, pollen-mediated gene dispersal at our study site is extensive. Single visits by these two species result in markedly different mate diversity within fruits. Effective mate number following visits by *Bombus vagans* is 4 times as high as effective mate number following visits *Bombus impatiens*. This reflects a high rate of pollen carryover by *Bombus vagans*. This finding highlights that closely related pollinators may cause very different pollen transport dynamics, and underscores that changes in pollinator species composition may have important consequences for plant mating patterns.

Frequency dependence of pollinator visitation rates suggests that pollination niches can promote plant species coexistence

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How multiple species coexist within a trophic level is a long-standing question in Ecology. Niche partitioning is the classical answer, but in plants which share a small set of abiotic resources the possibilities for resource niches are limited. One explanation is that plant species have different pollination niches, with each species specialized to a subset of the available animal species. If this pollinator partitioning results in negative frequency dependence such that each plant species' reproduction is reduced when it becomes abundant, pollination niches could contribute to maintaining plant diversity. We tested this idea by studying the frequency dependence of pollinator visitation rates in a species-rich South African plant community. Visitation rates showed a hump-shaped relationship with relative abundance across 33 plant species, with a strong decline for the most abundant species. Pollinator niche partitioning among plant species was evident, but less pronounced than in many other

studies. Pollinators enhanced seed set in most species. The results imply that intraspecific competition for pollination could limit the reproduction of abundant species, thereby promoting plant species coexistence, while the rarest species may be subject to an Allee effect. Our findings shed new light on the role of the pollination niche in plant species coexistence.

Polyploidy and floral evolution in the highly variable nursery pollinated *Lithophragma bolanderi* (Saxifragaceae)

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Floral traits are amazingly diverse not only among but also within species. Mutations are one of the processes ultimately causing diversification. Whole-genome duplications (polyploidisation) are the most dramatic form of mutation. Polyploidy is widespread in flowering plants. It has been shown that different ploidy types can vary in size. However, much less is known how polyploidy affects diversification of complex floral traits such as floral scent. Here, we study the origin of floral scent diversity through polyploidisation in the woodland star (*Lithophragma bolanderi*). This species exhibits an incomparably high variation in floral traits and is composed of multiple cytotypes. It is pollinated by the highly specialised seed parasite *Greya politella* but also by generalised pollinators. We collected seeds from natural populations throughout the distribution range of *L. bolanderi* and grew them in a greenhouse common garden environment. From a total of 1523 plants from 492 seed families from 29 populations, we collected floral scent, measured floral morphological traits, and quantified their ploidy level. There were three major (diploids, tetraploids, hexaploids) and two minor (triploids, pentaploids) cytotypes. We present data on the covariation of complex floral traits with the geographical distribution of cytotypes and how this is linked to pollination by different pollinators. These results provide insights into the ultimate cause of the diversification of floral traits within species.

Impacts of fertiliser and herbicide runoff on plant-pollinator interactions

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In agricultural systems, pollinators have been shown to rely on weedy field edges for the floral resources they provide. At the same time, these weedy plant communities are subjected to chemicals that runoff in surface and ground water from the adjacent crop fields. Both fertiliser and herbicide runoff have the potential to affect both the health of the plants and the resources they provide to visiting insects. We constructed a plant community comprising six native Irish plant species common to agricultural areas, and one non-native species recommended for pollinator conservation in Europe. We then subjected these constructed communities to four different treatments: 1) runoff concentrations of fertiliser 2) runoff concentrations of herbicide 3) runoff concentrations of both fertiliser and herbicide and 4) a control where only water was applied. These sets of four experimental communities were replicated at four sites in Dublin in two years, where the urban environment allowed us to control the runoff concentrations. Over the course of two years, we monitored plant health and the visitation of insects to these communities. We found that these low concentrations had significant effects on plant health including both the timing and abundance of flower production. This, in turn, affected the visitation of insects to the plant community. These results could help provide insight into pollinator nutrition and conservation in agroecosystems.

Interacting effects of neonicotinoids and temperature on bumblebee (*Bombus terrestris)* behaviour

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The ecosystem service pollination is seen as essential for productive and sustainable agriculture and an important determinant for the structure and dynamics in plant communities . Another important factor for agricultural production is Plant Protection Products (PPPs), protecting crops from pests and competition from weeds. One videly used group of PPP is Neonicotinoids, insecticides that cause harm to pest insects by disturbing the transmission of signals in nicotinic acetylcholine receptors (nAChR) in the insect´s nervous system. This leads to overstimulating of the acetylcholine system, negatively affecting both target and non-target organisms. The risk posed by neonicotinoids makes it important to understand how they affect pollinators and thus the ecosystem services they provide to both agriculture and wild plant communities. However, neonicotinoids are only one of several drivers that may have negative impacts on pollinators. Though bumblebees can thrive under highly variable climate conditions, they might show contrasting responses to pesticide exposure at different temperature regimes. In this prosject we investigate the combined effect of neonicotinoid exposure and contrasting climatic conditions (temperature) on bumblebee behaviour. We focus on sub-lethal effects e.g. learning, speed of movement and amount of nectar consumed. By tracking bumblebees with cameras and analyze the video recordings by use of a costomized software, we aim to assess learing, locomotor activity and search behavior. In addition we are measuring amount of nectar consumed both in the hive and during foraging to better understand how behavioural changes migt affect the workers ability to gather floral resources.

Impact of scent marks, colour and location on the selection of food sources in Brazilian stingless bees and the Western honey bee

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Several species of stingless bees use scent to mark food plants. Additionally, colour and location are important factors for the recognition of food sources. Here we used two experimental setups in which two species of stingless bees, *Melipona subnitida* and *Plebeia flavocincta*, and the Western honey bee (*Apis mellifera*) were tested whether they chose 1) a feeder that was scent-marked by foraging workers or an unmarked feeder, 2) a blue or a yellow coloured feeder. *M. subnitida* neither showed a preference for the marked feeder nor a preference for the feeder located at the training position, but preferred the feeder at closest proximity to the nest. *P. flavocincta* and *A. mellifera* chose the marked feeder significantly more often even if it was not established at the training position or further away from the hive. *P. flavocincta* did not discriminate between the two coloured feeders while *M. subnitida* and *A. mellifera* both showed strong fidelity to the blue feeder when trained to blue but chose more randomly when trained to the yellow feeder. We conclude that *P. flavocincta* depends more strongly on scent markings than *M. subnitida*. The disparity in these two species possibly occurs due to the large differences in body size. Smaller bees are known to have a reduced visual capacity and therefore might not orientate according to visual parameters of the target such as colour hue, saturation or brightness but use scent cues instead.

Interaction networks along human disturbance gradients

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Agriculture and urbanisation are human created landscapes and thus cover a large portion of the earths land surface. These human disturbances vary in their intensity from inner city and intensive agriculture to villages and occasional cultivation. These two types of landscapes have qualitatively different land management practices and so differences in the resulting ecology are expected. Plant-flower visitor interaction networks were observed along replicated gradients of urbanisation and agriculture in east Leinster, Ireland. The initial results of the species level analysis of network structure will be presented and discussed.

5th session

Correlation of floral and life history traits with self-compatibility and autonomous selfing at wet meadows communities

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Self-compatibility and especially autonomous self-pollination might be particularly beneficial in anthropogenically degraded habitats which are often characterized by impoverished pollinator assemblages and increased pollen limitation. We evaluated experimentally the extent of self-compatibility and autonomous selfing ability in plant species growing on wet meadows in a fragmented cultural landscape in Central Europe. In a hand pollination experiment of 46 meadow plants, we revealed the potential of species for different mating strategies. Although the transition between particular strategies is commonly considered as a continuum, we found a relatively discrete distribution of species into three groups. Subsequently we tested relationships between mating strategies and selected floral and life history traits (i.e. start of the flowering, floral symmetry, number of stamens, ovule number, flower shapes, amount of sugars in nectar, and clonality. We found that the three mating strategy groups did not differ in the traits tested, except for sugar content per flower and per shoot which significantly correlated with the capability of species to set fruits after non-autonomous self-pollination. As higher sugar content typically increases the level of geitonogamous self-pollination due to changes in pollinator foraging behaviour, selection seems to favour self-compatibility in highly rewarding plants. We also found tendency of highly self-compatible plants to exert higher level of dichogamy than the other two plant groups.

Reproduction system of critically endangered species *Gentianella praecox* subsp. *bohemica*

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Gentianella praecox ssp. *bohemica* is a critically endangered species endemic to the Bohemian Massive, which is highly dependent on a management regime. In our study we show that it is also dependent on a pollinator service, as the probability of autonomous selfing is low. We did not observe any self-incompatibility and both geitonogamic and outcrossing pollination resulted in similar seed production. Three out of four populations seemed to be pollen limited. The most frequent visitors and effective pollinators were bumblebees, as previously assumed. In our study we nevertheless demonstrated that bumblebee species can largely differ in per-visit efficiency depending on their behavior. During robbing, *Bombus wurflenii* only accidentally contacted reproductive organs and in consequence had a low per-visit efficiency. We also showed that *Gentianella praecox* ssp. *bohemica* can be pollinated by honeybees and hoverflies. Our study shows that conservation activities at localities should be focused not only on making gaps for better germination and weakening the competition of other species, but also on improving conditions for pollinators. Hand pollination can be an appropriate treatment to increase the survival probability of populations which are close to extinction.

Pollination ecology of *Rhynchanthera grandiflora* (Melastomataceae) in Brazil

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Melittophilous plants face a dilemma in that bees both passively transport pollen grains among conspecific flowers and actively collect pollen to feed their larvae. Therefore, mechanisms that reduce pollen collection by bees have evolved in bee-pollinated plants. Flowers of *Rhynchanthera grandiflora* (Melastomataceae) are heterantherous, with four central feeding stamens and one elongated pollination stamen. The poricidal anthers constitute a floral filter that only grants bees capable of buzzing access to pollen. However, flower-visiting bees differ significantly in size and small bees (< 13 mm; e.g. *Trigona* sp., *Melipona* sp.) acting as pollen thieves or robbers also target the pollination anther. In contrast, large bees (> 17 mm; e.g. *Xylocopa* sp., *Centris* sp.) land in the centre of the flower and forage primarily on the feeding anthers that directly contact their ventral thorax and abdomen. Legitimate flower visitors are extensively covered with pollen after buzzing the flowers and transfer an average of 12-48 pollen grains per SVD (single-visit deposition), which means that a single visit of a legitimate flower visitor suffices to pollinate a flower. The pore of the pollination anther faces the dorsal side of a legitimate flower visitor, which rarely comes in contact with the stigma. Instead of specifically placing pollen on a safe site that also contacts the stigma (which would only allow bees of a specific size to act as pollinators), the obviously successful pollination strategy of *R. grandiflora* seems to be amply enveloping bees of various sizes in pollen to ensure pollen transfer to the stigma.

Butterflies and hoverflies respond differently to changing plant spatial aggregation

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Plants tend to be aggregated in space, which can also facilitate probability of intraspecific transfer of their pollen. However, spatial aggregation can also limit availability of their mating partners to their close kin from the same aggregation. We investigated, how two important pollinator functional groups adapt their visitation behaviour to plant spatial aggregation at both the within-cluster and among-cluster level and whether this is modified, when some of the plants in the cluster are less attractive due to being infected by a pollinator-transmitted anther smut. To pursue this goal, we grew both infected and uninfected individuals of *Dianthus carthusianorum* in pots and arranged them in field into artificial populations. We manipulated within- and among-cluster distances as well as the proportion of infected individuals in a full factorial design and then recorded visitation sequences of *Dianthus* key pollinators - butterflies and hoverflies. Butterflies responded less to plant spatial structure than hoverflies. Both groups tended more to visit multiple clusters if within-cluster structure was loose. Butterflies generally visited more plants at the periphery of the cluster than in its centre. Surprisingly little effect of the proportion of infected plants in the cluster was detected despite infection being known to decrease visitation to the individual.

Saturday 20th October

6th session

Floral scent evolution across the *Penstemons*: does scent change with pollination system?

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Multiple independent transitions from bee to hummingbird pollination has made the genus *Penstemon* an attractive choice for studying floral evolution and ecology. The transition to hummingbird pollination comes with a suite of morphological changes that are both 'pro-bird' and 'anti-bee' (Castellanos *et al.*, 2004) as well as changes in pollen presentation (Thomson *et al.*, 2000), nectar replenishment (Castellanos *et al.*, 2002),and the role of 'vestigial' staminodes in pollination (Walker-Larsen and Harder, 2001). Our goal is to assess **floral scent** across transitions between insect and hummingbird pollination to elucidate the role of scent in speciation for the genus. We are especially interested in addressing the hypothesis that transitions to bird pollination lead to scent loss. We collected scents in the field (botanical garden or wild populations) by dynamic headspace sampling for 4-6 hrs from 6-22 plants per species. Scents were then quantified and identified using GC-MS. As a preliminary analysis of differences, we used basic linear models and non-metric multidimension scaling to assess broad-scale patterns. Preliminary results show no striking differences in scent production with respect to pollination system. However, species do differ in floral scent production. While scent emission maybe effected by relatedness, it does not appear strongly driven by phenology. I will discuss the implications of our findings and the next steps.

Honeybees learn to rob flowers from other honeybees and carpenterbees

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In one of the first anecdotal accounts of social learning, Darwin hypothesized that honeybees may learn to rob flowers of their nectar by watching bumblebees. Here we test Darwin's intriguing hypothesis that honeybees learn to rob nectar by observing the actions of other bees. We trained naïve honeybees to forage for sucrose in the gullet of custom designed 3D-printed model flowers before exposing individual bees to experimental flowers. The sucrose in these identical flowers was located within the floral "corolla" tube and could only be accessed via a small hole at its base, thereby simulating secondary nectar-robbing. To explore the efficiency of different learning sources we manually moved dead conspecific and heterospecific (carpenter bees and crickets) demonstrators towards this small hole to imitate nectar robbing. Differences in the ability and speed that honeybees learned to copy this behaviour were recorded for each demonstrator treatment. Naïve honeybees learned to nectar-rob more successfully when observing honeybee and carpenter bee demonstrators than when observing cricket demonstrators or controls lacking a demonstrator. However, honeybees learned to nectar-rob significantly faster from conspecifics than any other demonstrators. This may be the first study to demonstrate socially learned nectar robbing by honeybees, and also heterospecific social learning in insects.

The evolution of pollination systems in the Apocynaceae, one of the largest plant families

Jeff Ollerton

Faculty of Arts, Science and Technology, University of Northampton, UK

Interactions between flowering plants and the animals that pollinate them are known to be responsible for part of the tremendous diversity of the angiosperms, currently thought to number at least 350,000 species. But the diversity of different types of pollination system (bird, bee, moth, fly, etc.) is unknown for most large clades of plants such as monophyletic families and subfamilies. In addition we know little about how these interactions with pollinators have evolved over time and in different parts of the world. Only a handful of large groups of flowering plants have been studied with respect to questions such as:

- What is the diversity of pollination systems in large clades?
- How is that diversity partitioned between the sub-clades, and what are the evolutionary transitions between the major groups of pollinators?
  How do these pollination systems vary biogeographically across the clade's range?

These questions have been addressed for the massive, globally distributed Apocynaceae (one of the top 10 largest angiosperm families with more than 5,300 species) using a new database of pollinators that has sampled >10% of the species in the family. In summary, Apocynaceae is emerging as an important model family for understanding the ecology and evolution of plant-pollinator interactions.

The role of floral colour polymorphism in deceptive pollination

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Many cases of flower colour polymorphism have been documented for orchids pollinated through generalized food deception. Because pollinators are able to learn and memorize floral traits that represent the presence or absence of resources, it was suggested that floral polymorphism in these deceptive species would promote more visits to flowers by disrupting the learning process of the pollinators. We tested this hypothesis by focusing on the case of the polymorphic deceptive orchid *Lonopsis utricularioides*, which varies in colour, and by assessing the learning and colour discrimination capabilities of trained bees. Floral colour polymorphism was accessed measuring the reflectance of the flowers with a spectrophotometer and plotting the results on the color hexagon as a bee vision model. We trained free flying *Scaptotrigona* aff. *depilis* (Meliponini) bees to visit a setup with artificial flowers that were manipulated in colour and presence of sugar reward during the experiments. We found that when bees are presented to a setup of artificial flowers with different colours with no sugar reward, simulating the deceptive polymorphic flowers, they have their learning process disrupted, visiting more flowers until learning that all of the stimuli presented are signals for absence of reward. Taken together, our findings show that evaluating pollination through the pollinators' point of view can lead us to a more complete understanding of complex problems in pollination studies such as generalized food deception by polymorphic flowers.

Reproductive isolation of *Drosera cistiflora* color morphs

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Animal-pollinated plants have provided some striking examples of diversification and speciation in response to biotic interactions. The Cape endemic *Drosera cistiflora* (Droseraceae) displays remarkable geographic colour variation, which is associated with differences in pollinator assemblage and pollinator preferences. While this suggests that pollinators may have played a role in driving the divergence of floral colour, their role as agents of reproductive isolation remains uncertain in zones where different colours co-exist. Here, we present a study in a population, where red and purple flowered individuals occur in sympatry, and document patterns of pre- and postzygotic reproductive isolation. While flowering phenology is partially overlapping and seeds are formed from reciprocal crosses, pollinator sharing between the two morphs is strongly limited, suggesting assortative pollen movement and pollinator-mediated reproductive isolation as major barrier to gene flow. Using quantum dot pollen labelling we determined whether different floral colours result in assortative pollen movement (more movement within morphs than between). This research will greatly contribute to our current understanding of pollinator-driven divergence in angiosperms.

7th session

Pollinators and the geographical distribution of flowering plants

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Despite their importance in governing the fecundity of flowering plants at the population scale, the influence of pollinators in determining the geographical distributions of plants is unclear. Plant species in biodiversity hotspots, such as South Africa, often rely on one or a few pollinator species. This dependence is usually asymmetric because most pollinators are generalists that do not depend on particular plant species for rewards. Using an exhaustive biodiversity database, we mapped the absolute distributions of 32 South African plant taxa and their pollinators. We used a Maxent framework to investigate the influence of pollinators on plant distributions. We found that the plant distributions are best explained by a combination of biotic (pollinators) and abiotic factors, rather than by abiotic factors alone. We then investigated whether rewarding and rewardless plants differ in their estimated niche occupancy and quantified the influence of rewarding heterospecific species on the distributions of rewardless plants. We found that rewarding taxa occupied a higher proportion of their estimated range compared with rewardless taxa, and that the distributions of rewardless plants are best explained by incorporating information on the distributions of rewarding heterospecifics. These results are consistent with the proposal that pollinators may constrain plant distributions and form a component of the ecological niche of flowering plants. This also demonstrates that information on how plants interact with pollinators is crucial to predict their distributions, particularly in the face of ongoing species loss.

Heteranthery as a pollen dosing strategy in *Clarkia* (Onagraceae)

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Heteranthery, the presence of two or more types of stamens within a flower, is commonly thought to be a way for bee-pollinated plants to divide labor between cross-pollination and providing pollen rewards. However, in heterantherous species of *Clarkia*, we previously showed that the division of labor hypothesis is not supported. The two sets of stamens mature sequentially, and both types of stamens have feeding and pollinating functions. Thus we propose that heteranthery optimizes reproductive success through the gradual dispensing of pollen, first from a set of conspicuous stamens that dehisce immediately upon flower opening and then from a set of cryptic stamens that are held in reserve until the conspicuous stamens wilt. We test this hypothesis by examining the relative contribution of each type of stamen to female and male fitness, and by experimentally manipulating the pollen release schedule to observe the effect of pollen dosing on bee behavior and pollination success. Neither set of stamens affects female fitness through seed production, but pollen dosing likely improves male fitness. Flowers that gradually release pollen have similar visitation rates to those that present pollen simultaneously, but bees spend less time per visit and appear to remove less pollen per visit, thereby reducing pollen grooming and promoting siring success.

Everything you want to know about flower colour preferences in hoverflies

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Hoverflies and bees share their need for floral nectar and pollen. Hoverflies visit predominantly melittophilous flowers, but obviously possess deviant colour preferences from those of bees. The innate colour preferences and colour learning of one hoverfly species, the dronefly *Eristalis tenax*, is studied in different experimental settings mostly with artificial flowers. The main results are as follows: Naive flies prefer yellow colours for landing irrespective of the ultraviolet reflection properties, but also accept bright and UV-absorbing non-yellow colours. The innate preference for landing can be modified by training, but training cannot fully override the preference for yellow colours. The targeted approach of the walking flies are directed to those colour stimuli that trigger the extension of the proboscis, namely ultraviolet- and blue-absorbing yellow colours. The proboscis reflex towards yellow colours cannot be modified by absolute of differential conditioning nor prolonged training. The innate preference for yellow colours for the proboscis reflex seems unique for hoverflies of the genus *Eristalis* as shown by experiments with experienced hoverflies of various genera caught and tested in the field. The data provide insight to the understanding of colour vision in flies and its representation in a fly colour space. The main conclusions are that colour choices cannot be predicted by the categorical colour vision model and that colour preference in *Eristalis* flies is complex, due to the influence of colour hue, saturation and brightness. The flower colour preferences of experienced hoverflies from observations in the field is critically reviewed in the light of our findings.

Ecological mechanisms underlying the stability of a high-mountain hybrid zone

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The species hybridization is a phenomenon, which consequences can go from the collapse and loss of diversity because of genetic introgression events, to the rise of this diversity because of hybrid speciation. The understanding of the mechanisms underlying this helps us to shed light on the consequent evolutionary processes and to identify priorities for conservations policies. We studied five populations from two *Erysimum* (Brassicaceae) species presenting a secondary contact zone in Sierra Nevada Mountains (SE Spain) and we characterized them phenotypically. Using genetic markers, we have estimated the genetic differentiation, the genetic structure, and the amount of recent gene flow between populations. A narrow unimodal hybrid zone, where the hybrid genotypes were more frequent than the parental genotypes, was found. Afterwards, we carried out two experiments to explore the pre-zygotic and post-zygotic reproductive barriers underlying the origin and maintenance of this narrow hybrid zone, as well as the selective pressures promoting local adaptation. Asymmetric reproductive barriers were found, together with significant differences between pre- and post-zygotic barriers. We re-sampled the populations 10 years after and we found similar patterns and characteristic in this secondary contact zone. Our results suggest that the pollinators are the main promoters of the hybrid zone, but a constant migration of plants from the parental population would be necessary for the long-term maintenance of that narrow hybrid zone.

Insights into the impacts of rural honey hunting in Zambia

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Honey hunting, a common practice in Zambia, typically involves damaging practices such as tree felling in order to raid feral honeybee (*Apis mellifera*) hives. Given the importance of honeybees as pollinators, it is important to understand the implications of this for honeybees. Observations on the destructiveness of these methods prompted a preliminary investigation into the impacts of honey hunting on honeybees and their woodland habitats in two representative vegetation types, a mixed mopane/riverine woodland, and miombo woodland in Zambia. Representative plots were surveyed recording all evidence of honey hunter activity, with levels of poaching impact recorded in the following categories: 1) the whole tree was felled; 2) a branch was chopped off; or 3) a hole was cut to aid honey extraction. Nesting tree species were recorded. Where poaching rates of feral hives were generally high between the two vegetation plots (mopane: 95.2%, miombo: 100%), the results suggest that the factor deciding whether more damaging honey hunting practices are employed is the level of active forest management and conservation present in the area, with the better protected mopane area only having 15% of poached trees felled completely and the less protected miombo area having 37.5% of poached trees felled. Future research could test these findings at a broader landscape scale and assess the impact of varying land-use on forests and honeybees.

The status and role of wild bees for Chilli (*Capsicum annuum*) pollination in an Indian tropical dryland

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On-going pollinator declines constitute a threat to many entomophilous crops worldwide. Multiple studies have shown negative impacts of intensified agriculture on bees in temperate regions, but similar studies from arid tropical regions are scarce. With one fifth of the world's human population, India has a high demand for food production putting pressure on its arable land. Out of the crops grown in the country, a high proportion depends on insects for adequate pollination, and the yields from insect dependent crops have not increased at the same rate as yields from other crops. Hence, there is an urgent need for research on the interactions between insect pollinators and agriculture in India. We contribute to this through a large-scale field study, monitoring the bee fauna in landscapes with varying amounts of semi-natural and natural habitats, and looking at the role of bees for pollination of chilli. Field work was conducted in southern Andhra Pradesh, January-March 2018. Bees in the general landscape and in chilli fields were surveyed with nets and pan traps three times at twelve sites, and pollinator exclusion experiments were conducted in the chilli fields. Preliminary analyses suggest that the proportion of semi-natural habitat within a 250 m radius negatively affects the abundance of bees within chili fields, but not that in the surrounding habitats. Chilli fruit set benefitted from pollinators, and the crop exhibited no pollinator deficit in the area of the study. Future studies should look into the effect on pollination services of other aspects of agricultural intensification, such as chemical input, and focus on other crops that highly depend on insect pollination.

Does a small change make a big difference? Diversity of nectar amino acids in the genus *Fritillaria* (Liliaceae): ecological and evolutionary implications

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Nectar is considered to be a primary food reward for most of the pollinators. It contains mostly sugars, but also amino acids. The significance of the amino acids concentration and composition in nectar is very often less understood than that of its volume, sugar concentration and composition. However, there is a visible trend towards broader and more holistic approach in ecological research, which helps to understand nectar properties in ecological context. The genus *Fritillaria*, exhibiting a great diversity in flower morphology, nectar composition, and dominant pollinator gives the possibility to study some of the above. We studied concentration and composition of amino acids in the nectar of 38 *Fritillaria* species attracting different groups of pollinators (bees, flies, passerine, and hummingbirds). Flowers of different fritillaries produced nectar with varying composition and concentration of amino acids. These differences were mostly associated with pollinator type, with passerine bird-pollinated species' nectar being rich in amino acids, and humming bird-pollinated species producing low amino acid nectar. The tendency of pollinators preferences were mostly visible in case of species with pollinators shift. Contrary to previous reports nectar of the insect-pollinated species did not contain a higher amount of proline.

8th session

Network meso-scale structure and species traits in hummingbird-plant interaction networks

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Networks describing pollination interactions typically show nested and/or modular meso-scale structures and highly skewed degree distributions, with few highly connected species and long tails of poorly connected ones. Highly connected species show higher closeness and betweenness centralities and are categorized as core species in nested patterns and connector or hubs in modular networks. As network structure has direct implications for the dynamics and robustness of pollination communities, it is vital to characterize properly both network structure and species' roles. For instance, central species have the capacity of affecting directly and strongly most other species in the network, whereas peripherals exert indirect, weaker and localized effects. Furthermore, depending on the structure of the network, the effects of species may span throughout the entire community or be restricted within specific modules. We study whether a core-periphery (nested) or modular partition describes more accurately the structure of 79 quantitative hummingbird-plant networks spanning throughout various biogeographical regions of America, accounting for half of the described hummingbird species and over 1000 flowering plant species. Using complementary data on species traits, we show that central species are abundant, have long phenophases, wide range-distributions and generalistic behaviors, including non-restrictive morphologies or feeding habits, i.e. can to establish numerous interactions with an ample array of partners. Contrarily, peripherals are rare species, have short phenophases, small range-distributions and specialist behaviors and/or extreme morphologies, limiting their number of potential partners. Such information is valuable to anticipate species role within communities, including potential future interactions or the behavior of invasive species.

Network mesoscale measures to study indirect interactions in Aride Island, Seychelles.

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Inter-monthly changes in community composition can affect the function of ecological communities. These ecological communities are widely represented as bipartite networks, that depict interactions between two groups of species, such as plants and pollinators. For over thirty years, the framework for characterizing the structure of bipartite networks has remained unchanged with whole network indexes (macroscale), such as nestedness or connectance, and species indexes (microscale), like the degree. However, compressing a complex network into a single metric necessarily discards large amounts of information about indirect interactions. Here we use the emerging concept of bipartite motifs to outline a mesoscale measure to capture species` indirect interactions in a three-month pollination network in Aride Island, Seychelles. We observed reduced turnover, combined with monthly changes in community structure and overall changes in plant and pollinator positions within the motifs. Also, we found that positions of the most common bird and insect flower visitors varied along the flowering period, indicating changes in indirect competitive interactions through the season.

Effects of altitude and season on the structure of pollination networks on Mount Cameroon

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Plant-pollinator interactions are crucial for structuring of tropical communities. Studying of these relationships on an entire community level can thus help us to understand various patterns of current biodiversity, as well as history of its forming. Nevertheless, our knowledge on pollination networks changes even with main environmental drivers, crucial for our understanding of biodiversity organisation in time and space, is still highly limited. Such lack of data is even more apparent in some species-rich tropical regions, especially the Afrotropics. To fill this gap, we are studying pollination networks on Mt. Cameroon, the West African mountain offering the only complete altitudinal gradient of rainforest from lowlands to natural timberline in the whole continent. Simultaneously, it offers an extreme seasonality, being one of the wettest places in the world during its wet season and almost rainless during its dry season. We will present pollination networks from submontane (1450 m asl.) and montane (2200 m asl.) forests sampled in both extreme seasons. At both elevations, we recorded flower visitors of 105 plant species flowering in all vegetation strata from forest understorey to canopy. To cover all plant-pollinator interactions, we recorded flowers by video-cameras for 24-h sessions along six 200m transects per elevation. It allowed us to efficiently cover visitors during entire days and nights, as well as to observe behaviour of individual visitors and thus consider potential pollinators only. Altogether, we analyse a large dataset comprising of 11766 hours of recordings and 16422 individual flower visits. We focus on turnover of individual functional groups of pollinators among seasons and elevations, partly responsible for the networks structuring. Besides the consequent changes of network specialisation, we also focus on other network characterisations, including their modularity, nestedness or connectance. In this contribution, our first comprehensive results will be presented.

The role of floral traits in plant-pollinator interactions in tropical montane forest of Mount Cameroon

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Flowering plants are known to exhibit convergence of various floral traits to attract the same functional group of pollinators, in extreme cases resulting in pollination syndromes. Understanding the role of floral traits has come a long way since the Darwin's and Wallace's first studies on the plant-pollinator co-evolution. Nevertheless, following the recent debates it seems that these convergent floral traits vary in efficiency to attract the predicted flower visitors. However, only little is known about the ecological conditions potentially influencing this predictability of floral Afrotropical pollination networks, as well as about the role of specific traits in attraction of specific pollinators. To gain a better understanding of this understudied area, we study plant-pollinator interactions on the entire community level on Mount Cameroon, West/Central Africa. Our fieldwork was conducted at two different elevations of submontane (1450 m a.s.l.) and montane (2200 m a.s.l.) forests in both wet and dry seasons. 105 plant species flowering in all vegetation strata along six 200m transects were video-recorded for 24-h sessions. This resulted in a large dataset of 16422 interactions with flower visitors

and potential pollinators. Additionally, 25 floral traits (such as shape, symmetry, size, tube width and length, colour and nectar characteristics) were measured in all flowering species. Combining both datasets allows us to analyse the role of specific floral traits in attraction of individual functional groups of visitors, and even test pollination syndromes. In this contribution, we will focus on how these relationships differ among the studied altitudes and seasons.

An automated monitoring system for monitoring individual bumblebees

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Bumblebees are important pollinators at high latitudes. Recent studies have shown that currently, 46% of European bumblebee species have declining populations. This has caused concerns for the sustainability of bumblebee populations and the ecosystem service they provide both in wild plant communities and to entomophilous crops. The aim of this project is to design a monitoring system for bumblebee hives. I operation, the system will register bumblebee workers as they leave and enter the hive, generating data on activity patterns on an individual level. The system consists of a nest box (30cm x 20 cm x 15cm, 2-chamber design) and a dedicated camera box as an entrance/exit. Each worker bumblebee is equipped with a data matrix (bCode, Tim Gernat) on its back. A data matrix, much like a QR-code, is a variation of a two-dimensional barcode. The bCodes are printed on a waterproof paper, 2mm x 2mm in size, and glued on the back of the bumblebee's thorax. A computer with motion detection software controls the system, taking a series of pictures each time it detects motion. Software scans each picture for bCodes and returns a text string containing the ID of the bumblebee and the exact time it left or returned to the hive. The first application of the system, will examine how different sub-lethal doses of the neonicotinoid pesticide clothianidin, affect the duration, and number of foraging bouts on an individual level. We plan to expand the system by adding a weighing scale to the entrance, to estimate the amount of pollen/nectar brought back by workers from a single foraging bout.

Heterogeneity in local density allows a positive evolutionary relationship between self-fertilisation and dispersal

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Despite empirical evidence for a positive relationship between dispersal and self-fertilization (selfing), theoretical work predicts that these traits should always be negatively correlated, and the Good Coloniser Syndrome of high dispersal and selfing (Cf. Baker's Law) should not evolve. Critically, previous work assumes that adult density is spatiotemporally homogeneous, so selfing results in identical offspring production for all patches, eliminating the benefit of dispersal for escaping from local resource competition. We investigate the joint evolution of dispersal and selfing in a demographically structured metapopulation model where local density is spatiotemporally heterogeneous due to extinction-recolonization dynamics. Selfing alleviates outcrossing failure due to low local density (an Allee effect) while dispersal alleviates competition through dispersal of propagules from high- to lowdensity patches. Because local density is spatiotemporally heterogeneous in our model, selfing

does not eliminate heterogeneity in competition, so dispersal remains beneficial even under full selfing. Hence the Good Coloniser Syndrome is evolutionarily stable under a broad range of conditions, and both negative and positive relationships between dispersal and selfing are possible, depending on the environment. Our model thus accommodates positive empirical relationships between dispersal and selfing not predicted by previous theoretical work and provides additional explanations for negative relationships. Heterogeneity in local density allows a positive evolutionary relationship between self-fertilisation and dispersal.

Revisiting the role of petaloid bracts in *Lavandula*: function transfer for pollinator attraction?

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Floral display is supposed to be shaped by pollinators in outcrossing, animal-pollinated angiosperms. Increases in both flower size and flower number would increase pollinator attraction, which would lead to increased pollen transfer and receipt and, eventually, plant fitness. In some cases, a function transfer seems to have occurred, by which non reproductive organs -usually bracts or leaves subtending flowers- become showy, while flowers are inconspicuous. This is the suspected case in *Lavandula* (Lamiaceae) where several species show colourful petaloid bracts on top of the inflorescences. In a classic experiment, Herrera disprooved this hypothesis in *L. stoechas*: neither flower visitation nor seed set decreased after experimental removal of petaloid bracts. Here, we reassess the role of petaloid bracts in *Lavandula*, using two approaches. First, a phylogenetic approach suggests that petaloid bracts evolved twice in the genus. Furthermore, development of petaloid bracts involved an average decrease of 3 mm in corolla length, while calix lenght did not show differences among species with or without petaloid bracts. Second, experimental removal of petaloid bracts in *L. pedunculata* significantly decreased both visitation rate and seed set. Our preliminary results suggest that petaloid bracts are a compelling case of function transfer for pollinator attraction.

9th session

Solitary bee nesting ecology; novel methods and first results

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In the UK, ground nesting solitary bees account for the majority of bee species, but have received little attention in the academic literature. This is particularly true of their nesting ecologies, for which very few empirical data exist. This research gap is largely a result of the logistical barriers and lack of standardised methodologies associated with this type of analysis. We employed a paired methodology in order to overcome these obstacles linking a citizen science approach with traditional field methods. In March 2017, we launched 'The Solitary Bee Project'; a web based citizen science project focussing on four aggregate nesting solitary bee species: *Andrena fulva, Andrena cineraria, Halictus rubicundus* and *Colletes hederae.* Participants were asked to find active nesting aggregations and submit their locations along with some basic information about the ecology of the site. The project received 236 accurate nest site records over an eight month period and facilitated a separate, fine scale study of nesting aggregations, overcoming inherent logistical barriers. The citizen science data demonstrated the capacity of these species to nest in a diverse range of environmental conditions, however the fine scale study indicated that high density nesting occurs within a narrower range of environmental variables. Furthermore, this endeavour demonstrated the efficacy of a linked citizen science and field study approach in surmounting the intrinsic difficulties associated with studying solitary bee nest sites, which are both ephemeral and cryptic structures in the landscape.

An empirical attack tolerance test on real plant-pollinator networks

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Species extinctions might undermine the ecosystem functioning and the among-species interactions. However, field manipulations aimed at investigating this topic are scarce. In the field, we altered plant-pollinator networks by manually removing the most generalist plants from natural species-rich communities. In fact, we performed an attack tolerance test by exploring the ways the system will react after the sudden loss of important species. We tested how the sequential removal of generalists would affect the network structure by testing for changes in network indexes. Furthermore, we focused on the rewiring (i.e. partner switch) by investigating what main driver contributed to pairwise interactions' and network structural re-organization across the sequence of experimental removal (i.e. drivers such as species abundances, nectar resources and morphological match). This empirical attack tolerance test revealed novel insights on the topic of networks stability and on their putative ability to resist to species loss.

Intraspecific variation in floral scent – a meta-analysis

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A major challenge in evolutionary biology is to understand how complex traits of multiple function have diversified and co-diversified across interacting lineages and geographical ranges. We review here the current knowledge about intraspecific variation in floral scent, which is a complex trait of documented importance for mutualistic and antagonistic interactions between plants, pollinators and herbivores. We searched the literature for data on intraspecific, population-level variation in floral scent and found a total of 28 studies (n=33 species) for which we could calculate (i) the number of populations sampled, (ii) the total number of scent compounds emitted across populations, and (iii) the mean number of compounds emitted across populations. We grouped species into pollination system categories, and tried to, albeit with a limited sample size, identify how intraspecific scent divergence was related to pollination system. Finally, we compared the literature-derived patterns of floral scent diversification to the diversity present in our major study system, plants of the genus *Lithophragma*, which are pollinated by specialized pollinating floral parasites of the moth genus *Greya* (Prodoxidae). The results showthat scent diversification in *Lithophragma* is significantly elevated relative to most other plant taxa. We propose that one potential key to understanding floral scent variation in this hypervariable genus is its geographically diverse interactions with the obligate specialized *Greya* moths and, in some species and sites, more generalized co-pollinators.

Measuring, comparing and predicting phenotypic selection on floral traits

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In the event of a community turnover, population decline, or complete disappearance of pollinators, animal-pollinated plants may respond by adapting to novel pollinators or by changing their mating system. A predictive understanding of plant adaptation to changing reproductive environments hinges on a mechanistic understanding of the extent and causes of variation in phenotypic selection on floral traits. Estimating variation in natural selection is difficult due to the complex relationships between phenotypic traits and fitness, and the uncertainty associated with individual estimates of selection. I discuss (i) how explicit consideration of the functional interactions between flowers and pollinators can clarify the relationships between traits and fitness, and (ii) how variation in the ecological context that generates selection can help disentangle true variation from sampling variation. I illustrate these approaches with examples from the literature, and through the analysis of a series of phenotypic-selection studies using the neotropical bee-pollinated vine *Dalechampia scandens*. The insights from *Dalechampia* and other systems are promising, yet illustrate the current lack of empirical data allowing us to predict patterns of phenotypic selection from ecological context.

POSTER PRESENTATION ABSTRACTS

Apis mellifera scutellata (Hymenoptera: Apidae) Beehive Fences influence the pollination services provided to Cow pea (*Vigna unguiculata* L. (Walp)) farms in Sagalla, Kenya

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Previous work conducted by Dr. Lucy King and the Save the Elephants team has found that African Elephants (*Loxodonta africana*) will avoid African honeybees (*Apis mellifera scutellata*). The Beehive Fence project was set up with the intention of finding a natural, farmer-managed solution to reducing the human-elephant conflict caused by crop-raiding elephants in Tsavo, Kenya. The Beehive Fences are naturally occupied by wild African honeybees; however, hive occupancy tends to decrease during the dry season when resources are limited.

Due to its nitrogen-fixing capabilities, Cowpea (*Vigna unguiculata*), is an important source of cheap plant protein for farming communities in Kenya, which can also be sold as grain and fodder, offering a regular source of income to farmers. A study was conducted to determine whether hive occupancy of Beehive fences during the dry season influences the pollination services provided to cowpea farms in Sagalla, Kenya.

A total of 12 farms in Sagalla were visited, each were enclosed by a Langstroth Beehive fence. Hive occupancy was recorded as either; 0,1 or 2 hives. At each farm, cowpea stigma samples were collected, mounted onto a slide and stained with fuschin gel. With a microscope, the total number of pollen grains were counted. Pollen deposition on the cowpea stigmas significantly increased with hive occupancy, suggesting that honeybees occupying Beehive Fences may increase the pollination services provided to the crop.

When hive occupancy is at its maximum, the sale of honey and wax products during the wet season provides financial incentive for farmers to maintain a Beehive Fence. However, the knowledge that crop pollination services could potentially be improved; despite low hive occupancy rates during the dry season, could be added incentive to maintain a Beehive Fence during the dry season. In addition, the high energy and nutritional rewards offered by cowpea flowers could potentially help stabilise honeybee colonies during this season of high environmental stress.

Effects of managed honeybee (*Apis mellifera*) on a local pollinator assemblage in boreal pine forest in North Eastern Poland

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Plant-pollinator networks are useful tool to investigate ecological interactions in various ecosystems. One of the crucial factors influencing the proper functioning of ecosystems is plant reproductive success, and the presence of both specialist and generalist is necessary to achieve proper pollination. Generalists usually visit more plant species, but specialists are better adapted to pollinate plants with more complicated flowers. In recent years more and more researchers proved negative influence of honeybees on local pollinators species. We decided to examine how presence of honeybee influence the functioning of pollination networks in boreal pine forest. Our study was conducted in Wigierski National Park in North-Eastern Poland in 2016-2017 years. Since honeybee is not present in these area,

we could manipulate the presence and size of *A. mellifera* colonies. In 2016 we conducted experiment without presence of honeybee, while in 2017 we added bee hives to six out of nine study sites. We captured floral visitors from previously selected plants and using R software mapped local pollination networks. We found both generalists and specialist among floral visitors, and we detected differences in the strength of interaction between them.

The effect of weather and climate on foraging activity of *Apis mellifera* and *Bombus terrestris*

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Insect pollination is a highly valued ecosystem service that ensures genetic diversity and reproduction among plants and the production of high quality crops. Managed honeybees are a popular agricultural pollinator, but studies have shown that pollination contribution varies between these managed species and bumblebees. It has also been shown that honeybee and bumblebee foraging activity is responsive to environmental factors such as weather, temperature, humidity, solar radiation, and wind speed. However, little has been done to study the differences in responses to these variables by examining the foraging activity of both honeybees and bumblebees in the same places at the same times. By understanding these differences we can estimate the potential pollination contribution distinctions between these species in variable environmental conditions. As annual global temperatures continue to rise these data can be modeled to predict future honeybee and bumblebee activity. In this study the foraging activity of honeybees (*Apis mellifera*) and buff-tailed bumblebees (*Bombus terrestris*) throughout Ireland will be recorded, and the environmental drivers or impediments to this activity identified, so as to understand better the relationship between these pollinators and weather patterns.

Who's the thief? Nectar robbing behaviour by bumblebees on the naturalised Fuchsia in Ireland

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Originating in South America, Fuchsia (Ongaraceae) is an introduced species of flowering plant which has become naturalised across Ireland. In its native range, Fuchsia is typically pollinated by hummingbirds, and the flowers have evolved a shape and colour to facilitate this. However, with no hummingbirds in Ireland, insects such has bumblebees are commonly seen visiting flowers. Some bumblebees legitimately visit flowers, whereas others have been observed to "rob" the flowers and extract nectar without coming into contact with the reproductive parts as accessing nectar can be morphologically difficult. We carried out observations of Fuchsia at 10 sites across the midlands and west of Ireland. We aimed to 1) identify which bumblebee species visit Fuchsia flowers, 2) observe whether they visited both legitimately and/or nectar robbed, and 3) in turn uncover any relationships between bee size and flower morphology and nectar robbing behaviour. Our research will build our understanding of bee morphology and links with nectar robbing behavior, while also helping to understand the relationships between non-native plants and pollinating insects outside their native range.

Effect of land-sparing and land-sharing measures on honeybee nest populations: an individual-based modelling approach

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The intensification of agriculture and the associated decline in biodiversity have an impact on honeybees. The effects on honeybee population development were investigated with landscape scenarios using the models BEESCOUT and BEEHAVE. Based on a typical crop rotation of a region in Brandenburg, Germany (business-as-usual scenario), landscape scenarios with increased diversification under the approach of land-sharing (i.e. catch crops, mix cover crop and the permanent culture of cup plant) and land-sparing (i.e. flower strips) were developed. The influence of different pollen and nectar quality of the catch crops buckwheat and phacelia and the mix cover crop winter rye/hairy vetch as well as their combinations on the number of bee individuals was modeled. Besides the quality of forage supply, variation effects of the proportion of crop or flower strips in the agricultural area were taken into account in the respective scenarios.
The scenarios with the implementation of buckwheat, phacelia and the winter rye/hairy vetch mix cover crop show an increase in the honeybee population over the 12 years, in which the crop rotation was modified. The number of individual bees rises when the cup plant covers 2 % of the agricultural area. However, the honeybee population remains at comparable level even when the percentage cover of cup plant exceeds 8 %. Evenly distributed flower strips with a high pollen and nectar quality lead to an increase of bee population, but a low quality of forage supply results in a negative population development.
Both, land-sparing and land-sharing scenarios had positive impacts on honeybees, whereby it appeared that the quality of the forage supply could have a greater effect than the quantity. In a next step, combined landscape-scale effects of land-sharing and land-sparing measures will be examined.

Geographic variation in pollinator communities and floral scent in the perennial herb *Arabis alpina*

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Divergent natural selection can cause intraspecific variation in plant traits, including floral signals such as flower size and floral scent. A potential cause of divergent selection is variation in local insect communities, where different pollinators and/or herbivores might be responsible for divergent selection on various plant traits. The potential importance of pollinators as agents of selection on floral traits however, might also differ among populations. Specifically, in populations where pollen limitation is low or where plants are self-compatible and potentially selfing, the strength of pollinator-mediated selection could be lower than in pollen limited, self-incompatible populations. As a part of my PhD-studies, I explore variation in floral signalling in different European populations of the arctic-alpine herb *Arabis alpina* (Brassicaceae). Here, we investigate how this variation among populations relate to plant mating system and local pollinator communities. In this way, we can gain an understanding of what conditions in local populations cause divergent selection and generate intraspecific variation.

Tracking patterns of pollen transfer under different plant spatial structures

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Pollen transfer is crucial for sexual reproduction of zoogamous plants. Distances to which pollen is transported may be important, since individuals aggregated in clusters are often close kin. Pollinator visitation behaviour also reflects changing pattern of plant aggregation resulting in variable ratio of within- and among-cluster pollen. The main aim of our study was to investigate distances of pollen transfer from a focal plant under four different spatial distributions of potted individuals of Carthusian Pink (*Dianthus carthusianorum*), a species pollinated mainly by butterflies and hoverflies. The spatial distributions varied factorially in distance of plant individuals within clusters and among them. We tracked pollen transfer by applying fluorescent dye as pollen analogue. In general, more compact clusters (individuals within-clusters close) decreased probability of pollen transfer to other clusters. In future work, we want to compare patterns of pollen transfer under the same experimental conditions but with plant species hosting different dominant pollinator functional groups in order to compare spatial patterns of pollen transfer generated by different pollinator functional groups.

Pollinator Dependence of Plant Reproduction

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An estimated 87.5% of the world's flowering plant species are pollinated by animals but the importance of pollinators for plant reproduction is unclear because many of these plants have some capacity for autonomous pollination. Pollinator exclusion experiments, which allow the contribution of pollinators to plant reproduction to be estimated, have been conducted for many hundreds of plant species. However, this data has not been synthesised to provide a global assessment of the importance of pollinators for the reproduction of wild plants. In a sample of over 1300 species and 1700 separate experiments, we find that over 58% of wild animal-pollinated plants depend on their pollinators for on more than 80% of their fruit and seed production. This implies that pollinator declines could have dramatic impact on extinction rates and community composition.

Reproductive traits affecting pollen limitation of plants in a fragmented landscape

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Pollen limitation is considered as a common phenomenon in majority of plants. Due to ongoing fragmentation and deterioration of natural habitats, plants surviving in small isolated populations may particularly suffer in reproduction from lack of pollinators and compatible mates. We hypothesized that the degree of pollen limitation of plant species will be influenced by (i) type of a breeding system, (ii) floral traits important for pollinator attraction and foraging technique, and (iii) their degree of pollination specialization. We used pollen supplementation technique to evaluate level of pollen limitation in 22 plant species growing on a wet and strongly isolated meadow in fragmented cultural landscape in Central Europe. Our poster will present results from correlation of the pollen limitation of studied plant species (estimated at the level of seed number and weight) with the extent of self-compatibility and autonomous selfing, level of dichogamy, clonality, amount of nectar reward, number of open flowers and number of functional pollinator groups.

Effectiveness of conservation measures for wild bees in agricultural landscapes in Germany

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The dialogue and demonstration project F.R.A.N.Z. (Future Resources, Agriculture & Nature Conservation; http://www.franz-projekt.de/) aims at developing effective nature protection measures that can be integrated into normal farming practice. Within F.R.A.N.Z., researchers and farmers are working together in order to develop and test conservation measures on ten demonstration farms in Germany. These measures should promote biodiversity in general, but at the same time be practicable and economically viable for the farm. Our tasks in F.R.A.N.Z. include the monitoring of bees and their use of plant-pollen resources. Our aim is to find out how combinations of conservation measures, agricultural land use and landscape parameters affect the diversity and abundance of wild bees and how the supply of floral resources is changing through those measures within the landscapes over time. For this, we established matched landscape pairs with one containing the novel conservation measures and one representing the usual land use, respectively. The landscapes comprise areas of 3 km x 3 km and pairs are matched on accordance of land cover and soil type. The landscapes of a matched pair have a distance of at least 3 km to secure independence of sampling areas, considering foraging distances of wild bees (bumblebees in particular). Within the landscape pairs, we use standardized transect walks and trap nests with reed internodes as sampling methods. Transects have a defined length of 1000 m which is subdivided into sections that are proportionally distributed among the major habitat types (including measures) in the agricultural landscape. Transect walks are located in a core area of 1 km x 1 km. Trap nests are only established in the landscapes containing the measures with 5 traps being located neighboring a measure and 5 at a distance of at least 500 m from a measure. From both sampling methods we derive species richness and abundance and we furthermore analyze pollen collected by cavity-nesting bees and also from bumblebees caught along the transects walks. Latter will provide information on whether the pollen supply for wild bees changes over time with the implementation of the measures.

Is bacterial microbiome from the *Polemonium caeruleum* L. (Polemoniaceae) nectar geographically variable?

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Floral nectar is one of the key component influencing interactions between angiosperms and their animal pollinators. Recent studies have focused also on the third party involved in this plant-pollinator interaction that can modify pollination processes, namely microorganisms. Microbial communities inhabiting nectar may affect the reproductive success of plants and elicit ecological and evolutionary responses by plants and flower visitors. *Polemonium caeruleum* reproduces only by seeds, thus proper pollinator service is necessary for sufficient seed production. Pollination system of this plant species may vary geographically and the composition of pollinator assemblages probably influences *P. caeruleum* mating system, leading to the transition from self-incompatible to selfing populations. We analysed bacterial communities inhabiting nectar of this plant in two natural Polish populations and one artificial (at the University of Warsaw Botanic Garden) using 16S rRNA amplicon sequencing (MiSeq, Illumnia). Alpha diversity metrics were defined using Shannon and Chao1 index as well as observed species (OTUs). We found that bacterial communities differed between populations, and that many identified bacterial genera have been found previously in similar circumstances. The work was financially supported by Ministry of Science via Faculty of Biology (DSM grant 501-D114-86-0115000-41)

Somewhere over the rainbow: Linking molecular and ecological drivers of floral colour evolution in the Royal Irises (*Iris* section *Oncocyclus*)

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Floral colour variation is among the most visually prominent phenomena in nature and is often an important floral attractant among animal-pollinated plants. Although much known about the molecular basis of floral colour and the association of colour with pollinator behaviour, selection on flower colour has rarely been studied in association with its underlying molecular genetics. The few studies that have connected ecological interactions with the genetics of pigment synthesis used a relatively narrow range of discrete flower colours. We are testing the extent to which continuous colour variation and extreme dark-coloured flowers in the Royal Irises (*Iris* section *Oncocyclus*) are adaptive traits and whether the genetic basis for these phenotypes is under selection. Anthocyanins are the main pigments responsible for the floral colour variation we observe in nature. We aim to understand the molecular changes that affect anthocyanin production by studying regulatory and structural gene activity in a colour variable sample ranging from light to extreme dark-coloured flowers. Here we present preliminary results of our work quantifying the full path of natural selection on floral colour in two natural *Iris* populations that are highly variable in colour. By connecting genotype to colour phenotype to fitness, our results shed light on the evolutionary trajectory of continuous colour phenotypes and the evolutionary adaptive value of extreme dark flower colour in the Royal Irises. By characterizing the underlying molecular basis for ecological interactions and adaptive traits, our results provide a novel insight to the evolution of flower colour, a key trait in the interaction of plants with their environment.

The importance of wild & managed pollinators to Irish crops: Preliminary results

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Pollinators are important ecosystem service providers and play a role that is vital to the function of ecological communities and sustainable food production. However, the continued availability of these services may be at risk due to the recent global decline of pollinators. Understanding how different pollinator groups contribute to crop pollination, particularly the role of pollinators managed by humans (e.g. honeybees) in comparison to the services provided by wild pollinators, is essential to effectively restoring and preserving a sustainable flow of services for generations to come. In Ireland, relatively nothing is known about the contributions of different pollinator groups to crop pollination. Therefore, to assess the relative contributions of different pollinator groups to Irish crop pollination, we conducted focal observations, transect surveys, body-pollen collection, and pollen limitation experiments in bean (*Vicia faba*) fields and apple (*Malus domestica*) orchards (two of the most widely grown insect-pollinated crops in Ireland). We will use our pollination data, as well as available crop margins, yields, and returns, to conduct an economic valuation to assess the contributions of Irish pollinators to Ireland's natural capital. The results of our research will inform practical solutions for the sustainable management of Ireland's natural capital through wild pollinator conservation and crop production.

Honeybees and stingless bees respond differently to spectral purity and intensity in colours

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Experiments investigating colour vision in Western honeybees started more than 100 years ago. Nowadays, colour vision on honeybees (Apidae, Apini) and bumblebees (Apidae, Bombini) is under research, but the most speciose taxon of eusocial bees, the stingless bees (Apidae, Meliponini), remain largely unexplored. Stingless bees have a predominant role in pollination of flowering plants including crop pollination in tropical and subtropical regions. The colour choice behaviour of bees is known to be influenced by several colour parameters including dominant wavelength, spectral purity, green contrast and colour contrast and potentially also intensity, however, it could not be clarified which of these parameters dominates the bees' colour preferences. In our study the colour preferences for spectral purity and intensity were tested by offering colour stimuli providing either four different levels of spectral purity or four different levels of intensity to freely flying experienced workers of *Apis mellifera* and the sugarbag bee, *Tetragonula carbonaria*, an Australian stingless bee. Each bee was tested twice, as each test based on precedent reciprocal training, i.e. each bee was initially trained to forage on colour stimuli providing either low or high spectral purity, respectively low or high intensity, followed by the first test and was then reciprocally trained with the respective opposite level of the same parameter, followed by the second test. The experimental setting was kept as similar as possible for Western honeybees tested in Düsseldorf, Germany and sugarbag bees tested in Brisbane, Australia. *A. mellifera* workers showed a distinct preference for high spectral purity of colours and did not respond to intensity of colours, both confirming the findings of previous studies. However, the observed colour choices indicate that *A. mellifera* workers are able to discriminate and learn intensity differences of colour stimuli. *T. carbonaria* workers did not show any preference neither concerning spectral purity nor intensity, indicating that their colour choices are not driven by these colour parameters. Another experiment showed an innate preference in *T. carbonaria* for colours

simultaneously providing high spectral purity and high green contrast, suggesting that their colour choice behaviour is influenced by a combination of different colour parameters.

Fitness costs of delayed pollination in a mixed-mating plant

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Unreliable pollination environments may select for delayed autonomous selfing as a mechanism of reproductive assurance. To fully predict the evolutionary consequences of pollinator declines, we need to estimate the costs associated with an increasing level of selfing but also those that may result from the delayed pollination and the senescence of the flower. We studied these costs in populations of the mixed-mating vine *Dalechampia scandens*, by testing whether floral longevity responds plastically to delayed pollination. We then assessed costs of delayed selfing in terms of seed number and seed size, explicitly separating costs of inbreeding depression from those resulting from floral senescence. In general, non-pollinated blossoms increased their longevity, but seed quantity and quality strongly decreased with increasing delay of pollination, independently of inbreeding depression. These results confirm that delayed pollination may carry costs associated with the senescence of the blossoms. These costs may select for both greater autofertility and more rapid selfing under reduced pollination reliability.

Perception of floral symmetry in the bumblebee *Bombus terrestris*

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Bumblebees are one of the most important pollinator groups in Europe. Not only do they have a high ecological value as a diverse and effective pollinator group, they also play an important role in human economy, as they are used for pollination of cultivated plants in greenhouses. Therefore, the efficiency in handling and pollinating flowers is crucial to bumblebees as well as to humans. In the coevolution between plants and pollinators two factors determine the interaction between flowers and bumblebees in pollination: effective and time-saving collection of pollen and nectar is the key to the bumblebees' survival. For plants, however, the perfect pollen placement and removal is essential for their sexual reproduction. Based on these facts, we derived the assumption, that in the course of evolution, bumblebees likely experienced high selective pressure for identifying the most efficient way to get to the source of pollen or nectar on a flower by estimating access to the floral reward location with the help of the flower's shape and colour pattern. Horizontally displayed polysymmetrical flowers look similar from all directions and can be accessed from all directions. By contrast, vertically displayed monosymmetrical flowers look different from all directions and can be accessed from one direction only. We tested the hypothesis, whether bumblebees use the flowers' vertical axis of symmetry to start the approach for landing. Naïve workers of the Buff-tailed bumblebee (*Bombus terrestris*) were tested on their approaches to symmetrical and asymmetrical artificial flowers. We evaluated the angle of their approach as well as the location of a landing site on the artificial flower. According to our current evaluation of the data, the bumblebees tend to approach the middle of symmetrical flowers. The manipulation of the artificial flowers' symmetry will provide further insight to the bumblebees' perception and use of flower symmetry.

Quantum dots and scopal pollen – *Heriades truncorum* as a pollinator of Asteraceae

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Heriades truncorum (Megachilidae) is an oligolectic bee collecting pollen only on flowers of Asteraceae. Female *H. truncorum* bees have a ventral scopa on the abdomen and collects pollen by abdominal drumming, through which pollen grains are placed directly in the ventral scopa. In contrast to pollen collected by corbiculate bees which is compacted together with regurgitated nectar in pollen pellets and is lost for pollination, the scopal pollen of *H. truncorum* might still be valid for pollination. The aim of this study is to examine *H. truncorum* as a pollen vector of two Asteraceae species, *Pulicaria dysenteriaca* and *Inula ensifolia*. We tested pollen transfer by *H. truncorum* by labeling pollen-presenting florets with quantum dots, fluorescent nanoparticles that bind to pollenkitt (Minnaar & Anderson, unpublished). On average, 2.7 pollen grains were transferred to receptive styles (41% of all pollen grains deposited on the flower head) per single visit in *P. dysenterica.* In comparison, in *I. ensifolia* 12.1 pollen grains (39% of total) were deposited by a single visit. Video footage suggests that pollen transfer is dependent on the surface structure of a flower head, leading to different collection behavior on the different plant species. While scopal pollen is evidently deposited on receptive stigmas by *H. truncorum*, pollen grains adhering to the legs might also be involved in pollination. Additionally, pollen is not only transferred during abdominal drumming, but also already while landing on the flower. This study shows that *H. truncorum* serves as an effective pollinator and provides first evidence that pollen stored in a bee´s scopa can achieve pollination.

The Ecology and monitoring of the rare bumblebee *Bombus sylvarum* in Ireland

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Bumblebees are one of the most important wild pollinating insect groups in the northern hemisphere, and contribute to the pollination of both wild flowers and commercially important crops such as Oilseed Rape. However bumblebees have suffered rapid declines as a result of agricultural intensification, pesticide use and climate change. In response to this, Ireland was the first country to develop and implement a bumblebee monitoring scheme which has been highly successful in recording trends in abundances of common bumblebee species over time, as well as promoting public interest in bumblebees. However, rarer bumblebee species such as *Bombus sylvarum* (Shrill Carder Bee) are not effectively monitored by such large-scale schemes. *B. sylvarum* populations have suffered declines across Northern Europe, and the Burren region in Ireland is now a hotspot for the species in both Ireland and the UK. The aim of this study was to collaborate with the National Biodiversity Data Centre to develop effective species-specific monitoring strategy for the rare *Bombus sylvarum*. Through a series of field sampling and surveys across nine sites in the Burren using transects from April to October, we aimed to determine the optimal sampling intensity needed to accurately record *B. sylvarum* abundance and any population trends over time. This study will also provide insights into the ecology of *B. sylvarum* including their floral associations and preferences, and nesting behaviour. The results of this study will be used in the development of a specific monitoring scheme for *B. sylvarum*, aid in the understanding of the ecology of this rare bumblebee and provide recommendations on their conservation management.

Is the association between floral and nectar traits in *Digitalis purpurea* perceived by pollinators?

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Correlation between floral traits and nectar production is thought to be used by pollinators to decide which flowers to visit to optimise foraging. In flowers that remain open for several days, nectar can be produced continuously, but it is unclear if the association between floral traits and nectar remains constant, whether it changes with time, and the level to which pollinators perceive this variation. In the present study, we investigated the pollination ecology of *Digitalis purpurea* to describe the association between flower size, nectar guides and nectar production during the life-time of flowers, and inferred the implications for plant fitness. We studied nectar production and concentration in newly open flowers, in flowers before stigmatic lobe opening at the end of the male phase and two days after stigmatic lobe opening in the hermaphrodite phase. We measured flower tube width, flower tube length and nectar guides to investigate the association of these traits with nectar production and the response of pollinators using pollen load on the stigmas as measure of pollinator activity. Nectar was produced continuously, with a substantial increase during the hermaphrodite period compare to the male phase. Floral traits did not show differences between the male phase and hermaphrodite phase, with the exception of the amount of nectar guides, which were more abundant in the latter phase. The correlation of flower tube width and length remained similar between phases. In contrast, the number of nectar guides showed a positive association with flower tube length only in the male phase, whereas volume of nectar was showed a positive correlation with flower tube width only in the hermaphrodite phase. Surprisingly, there was not an association between nectar guides and volume of nectar produced. The main floral visitor in the population studied was the long-tongued *Bombus hortorum*, who usually inspected flowers before visiting. The analyses of pollen load on the stigma revealed a positive association with flower tube width, and negative with flower tube length and nectar guides. Our results suggest the association between flower tube width and nectar production could be perceived as an honest signal for *B. hortorum*. Alternatively, the association between pollen load on the stigma and flower tube width and length could also reflect selection to increase mechanical fit between flowers and pollinators. Further work requires to investigate if the nectar guides or volume increase male fitness.

Can managed grasslands enhance pollinators in intensively farmed areas?

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Wild flower strips is a common agri-environmental scheme used by farmers and land managers in order to improve biodiversity of pollinators. However, managed grasslands may also provide flower resources for flower visiting insects in agricultural landscapes. Botanically diverse grasslands on arable farms may support a range of wild pollinators, enhancing pollination services of crops. Intensively managed leys, on the other hand, typically contain only a few high-yielding, competitively strong species. One of the aims of the Multiplant project (2014-2018) was to test perennial seed mixtures targeted for bio-energy, feed protein and biodiversity, in order to develop multi-functional seed mixtures for grasslands. In the current study, we specifically investigated if yield (biomass production) and floral resources for pollinators could be simultaneously optimized by varying botanical composition of mixtures and cutting frequency. We tested four different perennial seed mixtures (3-, 5-, 11- and 13-species mixtures) at three sites varying in surrounding environment using three cutting

strategies (no cutting, two cuts per year, four cuts per year). We measured flower production during the season, composition of flower-visitors (in functional groups), and biomass production of all plant species in the seed mixtures. The 11- and 13-species mixtures, which were designed to enhance pollinators, produced similar or higher yield than the 3- and 5- species mixtures under certain cutting regimes. The 3- and 5- species mixtures had a high accumulated flower abundance due to excessive flowering of lucerne under the two-cut strategy and white clover under the four-cut strategy. However, the 11- and 13 species mixtures presented a higher diversity of flowers during the flowering season. Interestingly, accumulated flower abundance was not significantly reduced under the two-cut strategy compared to no cut. Pollinator profiles (visits by different functional groups of insects) were plant-species specific, i.e. at all sites, plant species attracted similar types of insects. Legume species mainly attracted large bees (honey bees and bumblebees), while herbs attracted other insect groups, in particular syrphids and other flies. Our results suggest that multi-species grassland mixtures can be designed to support a higher diversity of pollinators without compromising herbage yield. In particular, adding forbs to the grass-legume mixtures and using a two-cut strategy rather than four cuts per year, may increase flower resources available for a larger range of wild pollinators.