SCAPE 2020

34th Annual Meeting of the Scandinavian Association for Pollination Ecology

6 – 8 November 2020

Virtual Conference
University of Northampton
UK

University of Northampton
Faculty of Arts, Science & Technology

PELAGIC PUBLISHING

Welcome to SCAPE 2020!

This is the 34th annual meeting of the Scandinavian Association for Pollination Ecology. Or is it the Scandinavian Association of Pollination Ecologists…..? No one really knows, for the roots of SCAPE are shrouded in the mists of timeless Nordic mythology. What we do know is that it's the world's longest-running annual conference devoted to pollinators and plant reproduction. It was also the first international conference that I ever attended, as a young PhD researcher back in 1991. Since then I've gone to as many SCAPEs as possible, watched it grow in size and geographical spread, and it remains my favourite conference. That's because SCAPE is characterised by its hospitable and friendly atmosphere, and by the high quality of the science that is presented. What more could you wish for from a conference?

For the first time in its history SCAPE is being hosted in the UK, what I like to think of as "Wider Scandinavia". You don't need me to tell you what a challenging year 2020 has been. So I won't. Suffice to say that the conference couldn't be face-to-face as originally intended, and over the summer the decision was made to go virtual. This has presented its own problems, but one of the advantages is that we can support many more attendees from a much wider range of countries.

All the information that you need to access the SCAPE conference each day is provided below. I'd like to say thanks to the people who have helped make SCAPE 2020 possible: Yannick Klomberg for his work on developing the SCAPE website and supporting the conference registrations; to Paul Egan for staffing the SCAPE Twitter account; all of the colleagues who have stepped up to chair sessions and discussions; Lynn and Scott for agreeing to be our excellent keynote speakers; the University of Northampton for its support, especially our technical crew (Rob Farmer, Cleo Cameron, Liane Robinson and Rob Howe); Pelagic Publishing for supplying gifts for the keynotes and prizes for the student competition; my wife Karin Blak for her inspired ideas and help with putting together the programme; and last but not least, to all the participants for making SCAPE what it is. And remember: once a SCAPEr, always a SCAPEr.

If you are tweeting about the conference please use the hashtag #SCAPE2020 and tag in @SCAPE_Poll_Ecol

I hope that you enjoy the great science that will be on show over the three days of the conference!

Stay safe and stay healthy,

Jeff Ollerton

Joining SCAPE

Important: we recommend that you join the sessions using an up-to-date version of the Chrome browser: https://www.google.com/chrome/update/

If you have any technical issues please email our support crew (not Jeff!): scape.pollination.2020@gmail.com

Links are not shown in this online version. Check the version send to you by email.

Please do not share these links with anyone: we will be checking attendees and removing anyone who has not registered.

The SCAPE virtual rooms will be open from 08.00 GMT each day and will persist until 23.59. If you click on them before this time, they will give a message telling you when the room will be open.

Some presenters have videos associated with their talks and they can be viewed here: https://scape-pollination.org/scape-2020/presentation-extra/

Journal announcements

Casper van der Kooi and colleagues are organising a special issue of *Frontiers in Ecology and Evolution* on the Sensory Ecology of Plant-Pollinator Interactions, aimed at elucidating the role of signals and perception in different facets of plant-pollinator interactions. More details are available here: https://fro.ntiers.in/SensoryEcology

Alice Claßen and Jonas Kuppler are currently co-editing a special issue of *Frontiers in Ecology and Evolution* on the effects of anthropogenic stressors on plant-pollinator and plant-frugivore interactions - and the consequences for pollination and seed dispersal. The editors are particularly interested in bringing together experts on both fields to try to gain new insights by contrasting similarities and differences between these two processes. If you're interested follow this link: http://fro.ntiers.in/AnthStressors or email Alice: alice.classen@uni-wuerzburg.de

Brief update from the *Journal of Pollination Ecology*

The *Journal of Pollination Ecology* (*JPE*) was founded following discussions at SCAPE some years ago and has gone from strength to strength. The end of October finds considerable activity at *JPE*. Editor-in-Chief James Thomson is primarily focused on overseeing the review process for the eight submissions under consideration for the upcoming joint Special Issue with the *Nordic Journal of Botany* (*NJB*) derived from last year's SCAPE meeting. He has opted to act as handling editor for all of them, to reduce the chance of the issue being delayed by one or more lagging manuscripts. The submission that was received first is already back with the authors for revision. Reviewers have been solicited for all manuscripts, but some have not yet replied. As invited reviewers decline, James is attempting to issue new requests within a day.

At *NJB*, the joint SCAPE Special Issue is edited by Anders Nielsen, Amy Parachnowitsch and Stefan Andersson. They have sent the submitted manuscripts to reviewers. For unforeseen reasons, one manuscript was not submitted. The first submitted manuscript is ready for Editor's decision. The joint Special Issues are planned to be published in spring 2021 and advertised in tandem with covers reflecting pollination ecology. We have an agreement with the *NJB* publishers that all published SCAPE manuscripts in the Special Issue will be freely available for a period after publication.

Meanwhile, Carolin Mayer and Peter Kevan have been working to raise *JPE*'s profile by applying for listings at Scopus and Clarivate (formerly ISI). This follows our recent upgrading to provide DOI numbers for *JPE* papers. These efforts should increase the visibility of our authors' publications, and help to distinguish *JPE* from for-profit vanity journals. We are also seeking to upgrade our aging editorial management software, with anticipated funding from the International Commission for Plant-Pollinator Relationships (ICPPR). More information at: www.pollinationecology.org

SCAPE programme and protocol for attendees

The programme of talks is presented below. Talk types are:

K = Keynote
ST = Standard (10 minutes talk + 5 minutes for questions)
F = Flash talk (5 minutes, no questions)

- This virtual SCAPE is using the Collaborate platform for all sessions which works best using the latest version of Chrome. **If you have technical problems email our support crew (not Jeff!):** scape.pollination.2020@gmail.com

- Chairs have been asked to keep presenters strictly to time. Please be ready in good time to give your talk.

- Presentations will be uploaded in advance, however speakers will have control over their own presentations and be able to move from slide to slide as they wish.

- All talk times are approximate. If for technical reasons a presenter is unable to give their talk we will go immediately to the next speaker. If time permits, we will go back to any "missing" speakers at the end of the session. Therefore, please attend for the whole session in which you are speaking.

- All attendees will be muted except for presenters, chairs and moderators. For the standard talks, questions can be asked using the chat function. The chair will then select questions to ask according to how much time is left.

- When you join the session please use your full name. Any anonymous or unregistered participants will be asked to leave.

- Details of the themed discussions and poster session will be released later in the week. If you wish to host a themed discussion, please let us know.

- If anyone requires a receipt for the fee or a certificate of attendance, email Jeff Ollerton after Monday 9th November: jeff.ollerton@gmail.com

Prizes for student poster and presentations

If you are an undergraduate, Master's or doctoral student you are eligible to be considered for the prize of best poster, flash talk or standard talk at SCAPE. The prize will be any book from Pelagic Publishing's catalogue (https://pelagicpublishing.com/), plus a copy of Jeff Ollerton's new book *Pollinators & Pollination: Nature and Society*. If you wish to be considered for a prize, send your name and category (standard or flash talk, or poster) to Yannick Klomberg (yannickklomberg@gmail.com) by Sunday 8th November. Voting will be by SCAPE participants and will open on Monday 9th November.

Friday 6th November - all timings are GMT (London) time

Timing	Type	Name	Title	Ref
09.00 – 09.15		**Jeff Ollerton**	**Welcome to SCAPE 2020 and announcements**	
09.15 – 10.15	K	Lynn Dicks	Understanding the risks to human well-being from pollinator decline	K.01
10.15 – 10.30		Comfort break		
Session 1		**Chair: Jeff Ollerton**	**Agriculture - 1**	
10.30 – 10.45	ST	Ke Chen	Indirect and additive effects of arbuscular mycorrhizal fungi on insect pollination and crop yield of raspberry under different fertilizer levels	1.01
10.45 – 11.00	ST	Julia Osterman	Enhancing mason bee populations for sweet cherry pollination	1.02
11.00 – 11.15	ST	Idan Kahnonitch	Viral distributions in bee communities: associations to honeybee density and flower visitation frequency	1.03
11.15 – 11.30	ST	Anna Birgitte Milford	Who takes responsibility for the bees?	1.04
11.30 – 11.45	ST	Emma Gardner	Boundary features increase and stabilise bee populations and the pollination of mass-flowering crops in rotational systems	1.05
11.45 – 12.00	ST	Stephanie Maher	Evaluating the quantity and quality of resources for pollinators on Irish farms	1.06
12.00 – 12.05	F	Thomas Timberlake	Pollinators and human nutrition in rural Nepal: experiences of remote data collection during a global pandemic	1.07
12.05 – 12.15		Comfort break		
Session 2		**Chair: Jane Stout**	**Agriculture - 2**	
12.15 – 12.30	ST	Michael Image	The impact of agri-environment schemes on crop pollination services at national scale	2.01
12.30 – 12.45	ST	Nicola Tommasi	Plant - pollinator interactions in sub-Saharan agroecosystems	2.02
12.45 – 13.00	ST	Tal Shapira	The combined effects of resource-landscape and herbivory on pollination services in agro-ecosystems	2.03
13.00 – 13.15	ST	Márcia Motta Maués	Despite the megadiversity of flower visitors, native bees are essential to açai palm (*Euterpe oleracea* Mart.) pollination at the Amazon estuary	2.04
13.15 – 13.30	ST	Sabrina Rondeau	Quantifying exposure of bumblebee queens to pesticide residues when hibernating in agricultural soils	2.05
13.30 – 13.35	F	Maxime Eeraerts	Landscapes with high amounts of mass-flowering fruit crops reduce the reproduction of two solitary bees	2.06
13.35 – 13.40	F	Patricia Nunes-Silva	Crop domestication, flower characteristics and interaction with pollinators: the case of *Cucurbita pepo* (Cucurbitaceae)	2.07
13.40 – 14.30		Lunch break		
Session 3		**Chair: Mariano Devoto**	**Networks and communities**	
14.30 – 14.45	ST	Kit Prendergast	Plant-pollinator networks in Australian urban bushland remnants are not structurally equivalent to those in residential gardens	3.01
14.45 – 14.50	F	Kavya Mohan	Structure of plant-visitor networks in a seasonal southern Indian habitat	3.02
14.50 – 14.55	F	Opeyemi Adedoja	Asynchrony among insect pollinator groups and flowering plants with elevation	3.03

14.55 – 15.10	ST	Yael Mandelik	Rangeland sharing by cattle and bees: moderate grazing does not impair bee communities and resource availability	3.04
15.10 – 15.25	ST	Felipe Torres-Vanegas	Landscape change reduces pollen quality indirectly by shifting the functional composition of pollinator communities	3.05
15.25 – 15.40	ST	Isabela Vilella-Arnizaut	Quantifying plant-pollinator interactions in the Prairie Coteau	3.06
15.40 – 15.55		Comfort break		
Session 4		**Chair: Nina Sletvold**	**Conservation perspectives - 1**	
15.55 – 16.10	ST	Lise Ropars	Seasonal dynamics of competition between honeybees and wild bees in a protected Mediterranean scrubland	4.01
16.10 – 16.25	ST	Philip Donkersley	A One-Health model for reversing honeybee (*Apis mellifera* L.) decline	4.02
16.25 – 16.40	ST	Nicholas Tew	Nectar supply in gardens: spatial and temporal variation	4.03
16.40 – 16.55	ST	Peter Graystock	The effects of environmental toxicants on the health of bumble bees and their microbiomes	4.04
16.55 – 17.10	ST	Hauke Koch	Flagellum removal by a heather nectar metabolite inhibits infectivity of a bumblebee parasite	4.05
17.10 – 17.25		Comfort break		
Session 5		**Chair: Anders Nielsen**	**Conservation perspectives - 2**	
17.25 – 17.40	ST	Miranda Bane	Pollinators on Guernsey and a Pesticide-free Plan	5.01
17.40 – 17.55	ST	Jamie Wildman	Reintroducing *Carterocephalus palaemon* to England: using the legacy of a locally extinct butterfly as a (morpho)metric of future success	5.02
17.55 – 18.10	ST	Sjirk Geerts	Invasive alien Proteaceae lure some, but not other nectar feeding bird pollinators away from native Proteaceae in South African fynbos	5.03
18.10 – 18.25	ST	Sissi Lozada Gobilard	Habitat quality and connectivity in kettle holes enhance bee diversity in agricultural landscapes	5.04
18.25 – 18.45		Comfort break		
18.45 – 23.59		Themed discussion rooms open		

Saturday 7th November - all timings are GMT (London) time

Timing	Type	Name	Title	Ref
08.55 – 09.00		**Jeff Ollerton**	**Reminders and announcements**	
Session 6		**Chair: Jeff Ollerton**	**Conservation perspectives - 3**	
09.00 – 09.15	ST	Paolo Biella	The effects of landscape composition and climatic variables on pollinator abundances and foraging along a gradient of increasing urbanization	6.01
09.15 – 09.30	ST	James Rodger	Potential impacts of pollinator declines on plant seed production and population viability	6.02
09.30 – 09.45	ST	Emilie Ellis	Moth assemblages within urban domestic gardens respond positively to habitat complexity, but only at a scale that extends beyond the garden boundary	6.03
09.45 – 10.00	ST	Samuel Boff	Novel pesticide class impact foraging behaviour in wild bees	6.04
10.00 – 10.15		Comfort break		
Session 7		**Chair: Jon Agren**	**Conservation perspectives - 4**	
10.15 – 10.20	F	Maisie Brett	The impacts of invasive Acacias on the pollination networks of South African Fynbos habitats	7.01
10.20 – 10.25	F	Joseph Millard	Global effects of land-use intensity on local pollinator biodiversity	7.02
10.25 – 10.30	F	Susanne Butschkau	How does land-use affect the mutualistic outcomes of bee-plant interactions?	7.03
10.30 – 10.35	F	Elżbieta Rożej-Pabijan	Impact of wet meadow translocation on species composition of bees (Hymenoptera: Apoidea: Apiformes)	7.04
10.35 – 10.40	F	Lorenzo Guzzetti	May urbanization affect the quality of pollinators diet? A case-study from Milan, Italy.	7.05
10.40 – 10.45	F	Emiliano Pioltelli	Functional traits variation in two bumblebee species along a gradient of landscape anthropization	7.06
10.45 – 11.00		Comfort break		
Session 8		**Chair: Marcos Mendez**	**Pollinator behaviour - 1**	
11.00 – 11.15	ST	Hema Somanathan	Foraging on left-overs: comparative resource use in diurnal and nocturnal bees	8.01
11.15 – 11.30	ST	Sajesh Vijayan	To leave or to stay? Answers from migratory waggle dances in *Apis dorsata*	8.02
11.30 – 11.45	ST	G.S. Balamurali	Decision making in the Asian honeybee *Apis cerana* is influenced by innate sensory biases and associative learning at different spatial scales	8.03
11.45 – 12.00	ST	Gemma Villagomez	Resource intake of stingless bee colonies in a tropical ecosystem in Ecuador	8.04
12.00 – 12.15	ST	Ola Olsson	Pollen analysis using deep learning – better, stronger, faster	8.05
12.15 – 13.00		Lunch break		
Session 9		**Chair: Magne Friberg**	**Pollinator behaviour - 2**	
13.00 – 13.15	ST	Shuxuan Jing	'Interviewing' pollinators in the red clover field: foraging behaviour	9.01
13.15 – 13.30	ST	Océane Bartholomée	How to eat in the shade? Bumblebees' behavior in partially shaded flower strips	9.02

13.30 – 13.45	ST	Manuela Giovanetti	*Megachile sculpturalis:* insights on the nesting activity of an alien bee species	9.03
13.45 – 14.00	ST	Zahra Moradinour	The allometry of sensory system in the butterfly *Pieris napi*	9.04
14.00 – 14.05	F	Pierre Tichit	New insights into the visual ecology of bees	9.05
14.05 – 14.10	F	Fabian Ruedenauer	Does pollinator dependence correlate with the nutritional profile of pollen in plants?	9.06
14.10 – 14.15	F	Hannah Burger	Floral signals involved in host finding by nectar-foraging social wasps	9.07
14.15 – 14.30		Comfort break		
Session 10		**Chair: Amy Parachnowitsch**	**Floral scent**	
14.30 – 14.45	ST	Herbert Braunschmid	Does the rarity of a flower´s scent phenotype in a deceptive orchid explain its pollination success?	10.01
14.45 – 15.00	ST	Yedra García	Ecology and evolution of spatial variation in scent emission within flowers	10.02
15.00 – 15.15	ST	Manoj Kaushalya Rathnayake	Floral scent evolution across the penstemons: does scent change with pollination system?	10.03
15.15 – 15.20	F	Hanna Thosteman	The chemical landscape of *Arabis alpina*	10.04
15.20 – 15.25	F	Laura S. Hildesheim	Patterns of floral scent composition in species providing resin pollinator rewards	10.05
15.25 – 15.30	F	Christine Rose-Smyth	Does *Myrmecophila thomsoniana* (Orchidaceae) use uncoupled mimicry to obtain pollination?	10.06
15.30 – 15.45		Comfort break		
Session 11		**Chair: Renate Wesselingh**	**Pollination ecology and floral evolution - 1**	
15.45 – 16.00	ST	Rachel Spigler	Adaptive plasticity of floral display and its limits	11.01
16.00 – 16.15	ST	Wendy Semski	Individual flowering schedules and floral display size in monkeyflower: a common garden study	11.02
16.15 – 16.30	ST	Carlos Martel	Specialization for tachinid fly pollination and the evolutionary divergence between varieties of the orchid *Neotinea ustulata*	11.03
16.30 – 16.45	ST	Marcela Moré	Different points of view in a changing world: The tobacco tree flowers through the eyes of its pollinators in native and non-native ranges	11.04
16.45 – 17.00		Comfort break		
17.00 – 18.00		Poster discussion rooms open	A chance to talk with the authors of the posters	
18.00 – 23.59		Themed discussion rooms open		

Sunday 8th November - all timings are GMT (London) time

Timing	Type	Name	Title	Ref
08.55 – 09.00		**Jeff Ollerton**	**Reminders and announcements**	
09.00 – 10.00	K	Scott Armbruster	Pollination accuracy explains the evolution of floral movements	K.02
10.00 - 10.15		Comfort break		
Session 12		**Chair: Jeff Ollerton**	**Pollination ecology and floral evolution - 2**	
10.15 – 10.30	ST	Kazuharu Ohashi	Three options are better than two: complementary nature of different pollination modes in *Salix caprea*	12.01
10.30 – 10.45	ST	James Cook	Why size matters in fig-pollinator mutualisms	12.02
10.45 – 11.00	ST	Yuval Sapir	Within-population flower colour variation: beyond pollinator-mediated selection	12.03
11.00 – 11.15	ST	Henninge Torp Bie	Flower visitation of the Sticky catchfly (*Viscaria vulgaris*) on isles within isle.	12.04
11.15 – 11.30		Comfort break		
Session 13		**Chair: Yuval Sapir**	**Pollination ecology and floral evolution - 3**	
11.30 – 11.45	ST	Jonas Kuppler	Impacts of drought on floral traits, plant-pollinator interactions and plant reproductive success – a meta-analysis	13.01
11.45 – 12.00	ST	Carmen Villacañas de Castro	Cost/benefit ratio of a nursery pollination system in natural populations: a model application	13.02
12.00 – 12.15	ST	Anna E-Vojtkó	Floral and reproductive plant functional traits as an independent axis of plant ecological strategies	13.03
12.15 – 12.30	ST	Camille Cornet	Role of pollinators in prezygotic isolation between calcicolous and silicicolous ecotypes of *Silene nutans*	13.04
12.30 – 12.45	ST	Courtney Gorman	Phenological and pollinator-mediated isolation among selfing and outcrossing *Arabidopsis lyrata* populations	13.05
12.45 – 13.45		Lunch break		
Session 14		**Chair: Rocio Barrales**	**Pollination ecology and floral evolution - 4**	
13.45 – 14.00	ST	Danae Laina	Geographic differences in pollinator availability in the habitats shape the degree of pollinator specialization in the deceptive *Arum maculatum* L. (Araceae)	14.01
14.00 – 14.15	ST	Eva Gfrerer	Is the inflorescence scent of *Arum maculatum* L. (Araceae) in populations north vs. south of the Alps locally adapted to a variable pollinator climate?	14.02
14.15 – 14.30	ST	Kelsey Byers	Pollinators and visitors to *Gymnadenia* orchids: historical and modern data reveal associations between insect proboscis and floral nectar spur length	14.03
14.30 – 14.45	ST	Nina Jirgal	Orientation matters: effect of floral symmetry and orientation on pollinator entry angle	14.04
14.45 – 15.00	ST	Alice Fairnie	Understanding the development, evolution and function of the bullseye pigmentation pattern in *Hibiscus trionum*	14.05
15.00 – 15.15		Comfort break		

Session 15		**Chair: Maria Clara Castellanos**	**Pollination ecology and floral evolution - 5**	
15.15 – 15.30	ST	Jon Ågren	On the measurement and meaning of pollinator-mediated selection	15.01
15.30 – 15.45	ST	Katarzyna Roguz	Plants taking charge: Autonomous self-pollination as response to plants-pollinator mismatch in *Fritillaria persica*	15.02
15.45 – 16.00	ST	Mario Vallejo-Marin	Bees vs flies: Comparison of non-flight vibrations and implications for buzz pollination	15.03
16.00 – 16.15	ST	Agnes Dellinger	Linking flower morphology to pollen-release dynamics: buzz-pollination in Melastomataceae	15.04
16.15 – 16.30	ST	Lucy Nevard	Are bees and flowers tuned to each other? Variation in the natural frequency of buzz-pollinated flowers.	15.05
16.30 – 16.35	F	Gabriel Chagas Lanes	An investigation of pollen movement and release by poricidal anthers using mathematical billiards	15.06
16.35 – 16.40	F	Rebecca Höfer	The magnitude of water stress and high soil nitrogen decreases plants reproductive success	15.07
16.40 – 16.45	F	Marta Barberis	May ecotonal plants attract less efficient pollinators to stay on the safe side?	15.08
16.45 – 17.00		Comfort break		
Session 16		**Chair: Agnes Dellinger**	**Pollination ecology and floral evolution - 6**	
17.00 – 17.15	ST	Gabriela Doria	Petal cell shape and flower-pollinator interaction in Nicotiana	16.01
17.15 – 17.30	ST	Nathan Muchhala	The long stems characteristic of bat-pollinated flowers greatly reduce bat search times while foraging	16.02
17.30 – 17.35	F	Juan Isaac Moreira-Hernández	Differential tolerance to heterospecific pollen deposition in sympatric species of bat-pollinated *Burmeistera* (Campanulaceae: Lobelioideae)	16.03
17.35 – 17.40	F	Juan José Domínguez-Delgado	Does autopolyploidy shape plant-pollinator interactions?	16.04
17.40 – 17.45	F	Caio Simões Ballarin	How many animal-pollinated plants are nectar-producing?	16.05
17.45 – 17.50	F	Ana Clara Ibañez	Concerted evolution between flower phenotype and pollinators in *Salpichroa* (Solanaceae)	16.06
17.50 – 18.00		**Jeff Ollerton**	**Final announcements, conference handover and close.**	

Posters – grouped into broad themes

https://scape-pollination.org/scape-2020/posters/

Agriculture

Manoela Lencino Sant Anna, Patrícia Nunes-Silva & Marcelo Zagonel-Oliveira
The effect of bee behavior during floral resource collection on blueberry pollination (*Vaccinium ashei* Reade)

Pau Capera Aragones
Wild bee pollination services predicted by a PIDE model

Muhammad Amjad Bashir
The role of pollinators in yield and nutrition of tomatoes

Leila Bendifallah, Djamila Abdellaoui, Faiza Touatioui, Nicolas Leclercq & Nicolas J. Vereecken
Contribution to the knowledge of apple pollinators (Rosaceae) in the region of Northern Algeria

Jordan Chetcuti
Bumblebee agricultural risk assessment using ALMaSS framework individual-based modelling

Tara Dirilgen, Saoirse R. Tracy & Dara A. Stanley
From Roots to Pollinators: How above- and below-ground organisms interact through plants

Shelby Gibson
Determining the plant-pollinator network in an Indigenous Three Sisters garden

Sajad Hussain Mir & Palatty Allesh Sinu
Interruption and exploitation competition exerted by floral ants on foraging behaviour of pollinators in pumpkin, *Cucurbita maxima*

Francesca Laurini, Fabio Sgolastra, Laura Bortolotti, Marino Quaranta, Nicolas Leclercq, Nicolas Vereecken, Denis Michez & Marta Galloni
Assessment of pollination service in four apple orchards in Emilia-Romagna region (Italy)

Tania P. Palacios, Pedro M. Tognetti, Natacha P. Chacoff & Mariano Devoto
Dependence of soybean yield on insect pollination: a critical review of the evidence

Adara Pardo & Paulo A.V. Borges
Worldwide importance of insect pollination in apple orchards: A review

Jenna M. Walters & Rufus Isaacs
Determination of upper threshold temperatures of pollen germination and pollen tube growth in northern highbush blueberry (*Vaccinium corymbosum*: Ericaceae)

Conservation perspectives

Hannah Brazeau

Manipulation of a floral landscape did not alter pollen transfer

Marika Brown

Effect of Glyphosate-based herbicide use on flowering plant and pollinator communities in managed forests

Katherine Burns

Oh, honey! Potential effects of managed honeybee presence on bumblebee survival in Irish heathlands

Manuela Giovanetti, Marino Quaranta, Emanuele Carpana, Piotr Medrzycki, Antonio Nanetti, Gennaro Di Prisco & Laura Bortolotti

The Italian BeeNet project for the managed honeybee and the wild bees

Zachary Nolen

Assessing the impacts of changes in land use on the genetic diversity and adaptive potential of pollinator species

Leticia De Santis & Mario Balzan

Local and landscape habitat variables influencing bee diversity

Tom Sloan, Jeff Ollerton & Gavin Ballantyne

Assessment of management cutting cycles on nectar sources in the Old Sulehay nature reserve, Northamptonshire

Florian Straub & Markus Birkenbach

Effects of land use intensity on pollinator health and pollination services

Clara Stuligross

Larval pesticide exposure reduces adult wild bee reproduction

Linzi Jay Thompson

Effects of colony level exposure to a fungicide or herbicide on the bumblebee *Bombus terrestris*: preliminary results

Diana Tixi

Do wild bees' physiological or ecological traits influence their response (abundance and diversity changes) to conservation strategies? A meta-analysis

Julia Weber

Preserving mobile insects in semi-natural grasslands - minding the Matrix

Theresia Widhalm, Veronica Hederström & Yann Clough

Pollination and herbivory in grassland plant communities along a landscape-scale land use intensity gradient

Pollination ecology, networks, pollinator behaviour, floral evolution, and scent

Ellen Baker

How does the nutritional content of pollen affect bee foraging choices?

Christine Coppinger & Dara A. Stanley

Are pollinators important for the reproduction of miombo woodland trees?

Pactli F. Ortega González

Pollinators of *Pilostyles thurberi* (Apodanthaceae). An awesome endoparasitic plant!

Roni Heliczer

Physical models of heat reward in *Oncocyclus* irises

Judit Linka

How does caffeine influence the robbing behaviour of Bombus terrestris, the buff-tailed bumble bee?

Klaus Lunau

The backside of flowers - UV-absorbing properties differ between adaxial and abaxial side of petals

Amy Parachnowitsch

Floral scent in a hybrid zone

Carolin Plos, Niklas Stelbrink, Christoph Rosche, Isabell Hensen, Tiffany Knight & Christine Römermann

The effect of temperature on nectar production and pollinator visitation rates in four herbaceous species

Zubair Ahmad Rather

Structure of flower visitation web of Kashmir Himalaya

Justyna Ryniewicz

Geographic variation in nectar composition and its implications for insect visitors: the case of a rare plant *Polemonium caeruleum* L.

Ruby E. Stephens

Functional biogeography of floral traits in Australia

James Thomson

A 30-year study of lily demography: pollination, costs of fruiting, and size dependent mortality

Gayathri Venkatraman & Shivani Krishna

Capturing the Buzz: Characterising buzz pollinated plant species in the Indian Subcontinent

Wujian Xiong, Jeff Ollerton, Sigrid Liede-Schumann, Wanyi Zhao, Qiancai Jiang, Hongmei Sun, Wenbo Liao & Wenhui You

Specialized cockroach pollination in the rare and endangered plant *Vincetoxicum hainanense* in China

SCAPE 2020 abstracts

Abstracts are arranged by type (Keynote Talks, Flash Talks, Posters, Standard Talks) then alphabetically by surname of the presenter. To find a particular abstract search by name or title of the presentation.

Keynote Talks

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Understanding the risks to human well-being from pollinator decline

Pollinator decline has attracted global attention, largely because of the relative ease with which a subset of pollinators can be allocated monetary value, for their services to crop production. These small animals are worth hundreds of billions of dollars, worldwide, we are told. Without them, we would face terrifying consequences, like ‘no more chocolate’ or perhaps a third of our food supply dramatically restricted. As a result, substantial efforts are underway to reverse pollinator decline around the world, through national pollinator strategies and action plans. In the talk, I will provide an update on what is known about pollinator decline, and consider what it really means for humanity, in terms of risks to human well-being. I will report results of a global risk assessment exercise, in which we considered how the risks from pollinator decline differ among regions. Overall, perceived risks were substantially higher in the Global South. Despite extensive, research on pollinator decline, our analysis reveals considerable scientific uncertainty about what this means for human society.

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Pollination accuracy explains the evolution of floral movements

The theory of adaptive accuracy relates within-population variation in (multivariate) morphology to variation in reproductive fitness based on estimated or calculated fitness functions, where deviation from maximal population fitness (phenotypic “load”) comprises two components: i) departure of the population mean from the optimum, and ii) imprecision (variance) in the population. This approach can be used effectively to understand the relationship between floral morphology and pollination fitness. I will focus on how various movements of flowers and floral parts, during the life of a flower, act to improve pollination accuracy and thereby fitness. Movements examined include secondary pollen presentation, progressive movements of styles and stamens, and corrective reorientation of flowers and flower parts after floral accidents.

Flash Talks

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Asynchrony among insect pollinator groups and flowering plants with elevation

Mountains influence species distribution through differing climate variables associated with increasing elevation, however, how varying environmental conditions across elevation differentially influence the phenology of various insect groups is largely unknown. We assess here how species composition and seasonal peaks in abundance among different insect pollinator groups (bees, wasps, beetles and flies) and flowering plants differ across four floristically distinct elevation zones. In terms of abundance, beetles were the dominant group across the three lower zones, but declined in the summit, where flies and bees were more abundant. Bee abundance peaked earlier than other groups across all elevation zones. Bee abundance peaked earlier than flowering plants at the middle zone and slightly later than flowering plants at the base zone, suggesting a mismatch. We conclude that, while elevation shapes species distribution, it also differentially influences species phenology. This may be of significance in long-term assessment of species distribution in mountain ecosystems.

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How many animal-pollinated plants are nectar-producing?

Many studies claim that "nectar is the main floral resource offered by plants to pollinators". However, we have no information on how many flowering plants are nectar-producing, neither their global distribution. To answer these questions we estimated the number of animal-pollinated plants and tested whether latitude influences their global distribution. For this, we evaluated 7,136 species (ca. 2% of zoophilic angiosperms), distributed in 324 families, and 135 plant communities in different ecosystems over the world. Altogether, 76.65% of zoophilic angiosperms offer nectar to floral visitors, emphasizing the importance of this reward for plant-pollinator interactions. Latitude affected the global distribution of nectar-producing plants (R^2 1,135 = 0.285, p <0.0001) so that low latitude plant communities presented a lower proportion of nectariferous zoophilic species than that of higher latitudes. We suggest that the higher functional diversity of flowers observed in the tropics are directly related to such a latitudinal trend.

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May ecotonal plants attract less efficient pollinators to stay on the safe side?

The main alimentary resource offered by the ecotonal plant *Buglossoides purpurocaerulea* to visitors is a hexose-dominant nectar, known to be preferred by dipterans and short-tongued bees. In this study, we investigated (i) the reproductive strategies of the species and (ii) the spectrum and efficiency as pollinators of the visitors in a population close to Bologna. *B. purpurocaerulea* resulted to be a self-incompatible species relying on pollinators for its sexual reproduction. According to the sugar nectar composition, *Bombylius* represented one of the most frequent genus, along with hymenopterans of the genus *Eucera*. Nevertheless, *Bombylius* spp. performed significantly less cross-movements among flowers and carried on body a significantly lower number of total and conspecific pollen grains than hymenopterans, contributing less efficiently to cross-pollination. We can hypothesize that the plant, adapted to transitional habitats and used to vegetative propagation, may benefit more from a mixed reproductive system than from a highly efficient crossing.

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The impacts of invasive *Acacia*s on the pollination networks of South African Fynbos habitats

Invasive Australian *Acacia*s are a primary threat to the biodiversity and economies of the Fynbos biome of South Africa, a biodiversity hotspot renowned for its floral diversity and endemism. Their impact on insect communities and pollination of local plants remains largely unknown, however. This study explores the impact of *Acacia*s on local plant-pollinator networks and insect communities through a combination of direct observation, passive trapping and study of local seed sets. It was found that whilst overall insect visitation to local plants increases at *Acacia*-invaded sites, seed set and pollinator diversity to certain plants decreases. Coleoptera are the primary pollinators of invasive *Acacia*s and are particularly susceptible to change in local abundance due to *Acacia* invasion. Fynbos pollination networks in general are grossly understudied, and this project presents the first comprehensive networks for three endangered Fynbos vegetation types.

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Floral signals involved in host finding by nectar-foraging social wasps

Social vespid wasps forage on flowers with easily accessible nectar. Among such plants are species with a generalist pollination system. The aim of this study was to investigate the role of olfactory and visual floral signals of *Hedera helix* (Araliaceae) and *Heracleum sphondylium* (Apiaceae), both frequently visited by vespid wasps to collect nectar. Our behavioural experiments showed that olfactory cues are key in attracting vespine wasps to the inflorescences of both species. Visual traits increase the attractiveness of olfactory signals. Most abundant floral compounds were 4-oxoisophorone, linalool and (E)-linalool oxide furanoid, floral compounds known from plants with various pollination systems. Wasps seem to be attracted to the studied plants by floral volatiles that are also attractants for other flower visitors. We show for the first time, that those compounds are also involved in communication between wasps and their host plants.

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How does land-use affect the mutualistic outcomes of bee-plant interactions?

The decline of wild bee populations and other insects is a very contemporary issue and threatens the pollination of animal-pollinated plant species. Bees need pollen and nectar as food source and many plant species depend on pollination to reproduce. The stability of this mutualistic relationship requires both a diverse plant and a diverse bee community. Using established experimental plots of different land-use intensities within the framework of the German Biodiversity Exploratories, we study the effects of land-use and landscape components on plant and bee biodiversity and their reproductive success. Using pollen DNA-metabarcoding we gain insight into differences of pollen-based plant-pollinator networks between grassland habitats differing in land-use intensity. This project will help us to better understand how pollination interaction networks respond to land-use intensity in terms of stability and possibly predict the probability of survival of plant and pollinator species.

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Does autopolyploidy shape plant-pollinator interactions?

Polyploidy has mayor implications in plant evolution. The genetic, physiological and morphological shifts that occur after polyploidization may alter the chemical communication between plant and pollinators. In this regard, our study in *Dianthus broteri* provide new insights into how the divergence in pollinator spectra might have been triggered by autopolyploidization. This Iberian carnation polyploid complex encompasses four cytotypes (2x, 4x, 6x and 12x). Gas chromatography–mass spectrometry analyses revealed that each cytotype shows a distinctive volatile emission. In addition, field observations suggest changes in the pollinator spectrum. Although pollinator behaviour tests in mixed populations are needed, coupled gas chromatography-electroantennographic detection trials demonstrated that two of these pollinators (*Autographa gamma* and *Macroglossum stellatarum*) can discriminate among scent bouquets of polyploids. These results point out that pollinator-mediated selection could play a key role in the establishment and divergence of autopolyploids.

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Landscapes with high amounts of mass-flowering fruit crops reduce the reproduction of two solitary bees

Recent studies in mass-flowering oilseed crops show that mass-flowering crops reduce the offspring reproduction of bees after mass-flowering. In our study we quantified the reproductive output of two solitary bee species (*Osmia* spp.) during and after mass-flowering of fruit crops (MFFC). Ten trap nests were placed in landscapes with independent gradients of semi-natural habitat and MFFC in the proximity. We also identified the composition of the collected pollen. For both bee species, we found that the number of constructed brood cells after mass-flowering significantly decreased with increasing proportions of mass-flowering fruit crops within 200 m of the surrounding landscape. During mass-flowering no effects were found, probably because *O. cornuta* collects significant amount of Prunus spp. and Pyrus spp. pollen and because O. bicornis collects Malus spp. pollen. The negative effect is clearly detrimental to *O. bicornis*, as well as for other pollinators that are active in late spring or summer.

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May urbanization affect the quality of pollinators diet? A case-study from Milan, Italy.

Flowers provide trophic rewards to pollinators for fulfilling their metabolic needs. However, little is known on how landscape modifications and habitat alteration affect the quality of flowers rewards. In this study, the production of sugars in nectars from different flowering species was evaluated in about 40 sites distributed in semi-natural, agricultural or urban areas around the city of Milan, Italy. Species-specific patterns were identified for the content of sugars in nectars. For instance, the cinquefoil *Potentilla reptans* L. nectary sugars were found to be negatively affected by the level of urbanization, while the opposite trend was identified for the clover *Trifolium pratense* L. Further investigations were implemented on pollen grains hand-collected from the anthers, which also showed the impact of landscape type on the nutraceutical properties of pollen. Our research deals with key aspects of

pollinator nutritional ecology and will evaluate which land use type provides the best opportunities to contrast anthropogenic activities and stressors in pollinators.

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Patterns of floral scent composition in species providing resin pollinator rewards

Floral scent can serve as a pollinator attractant or reward and evolve in response to shifts in pollinator communities. Small changes in the floral scent profile can lead to the attraction of a set of different pollinators. In the genus *Dalechampia* (Euphorbiaceae) flowers are pollinated mainly by Euglossine bees, which collect resin- and scent rewards. Pollinator shifts from resin-collecting female Euglossine bees to scent-collecting male bees have occurred 3 to 4 times independently. The scent rewards may have evolved by modifying scent advertisements produced in different floral tissues. I study how the pollinator shifts and the evolution of scent rewards occurred in this genus by quantifying variation in floral scent composition in a greenhouse common garden and mapping it onto a phylogeny of the genus. Starting with species providing resin rewards and using scent as an attractant, I study scent variation among species, populations, individuals, and floral tissues.

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The magnitude of water stress and high soil nitrogen decreases plants reproductive success

Reduced precipitation and drought events can alter floral traits with cascading effects on flower-visitor interactions and plant fitness. Generally, soil nitrogen can reduce plants' drought stress but in high concentrations amplify this stress. However, the interplay of magnitudes of water stress and soil nutrient on floral traits, interactions and reproductive success are poorly understood. In a field experiment, we tested how reduced mean precipitation and prolonged dry periods, modulated by nitrogen, affect floral morphology, phenology, scent, colour, flower-visitor interactions and seed set. We found, that the effects on floral traits were dependent on strength of drought stress, as with decreasing soil humidity, e.g. the plants grew smaller and had lesser siliques. However, flower number, floral

size and number of visits were not affected. Further, nitrogen treatment additionally increased the influence of drought stress. Overall, drought stress had negative effects on plants' reproductive success with high soil nitrogen amplifying this effect.

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Concerted evolution between flower phenotype and pollinators in *Salpichroa* (Solanaceae)

Available comparative results are ambiguous about the association between variable sets of floral traits and specific groups of pollinators. Here, we tested whether interspecific variation in floral traits is associated with concerted changes in pollination modes using both analytic and comparative approaches in *Salpichroa* (Solanaceae) a small Andean genus with a remarkable variation in floral phenotype and mainly pollinated by hummingbirds or moths. We quantified five floral traits (shape, size, fragrance, corolla reflectance, and nectar) relevant to the attraction of and functional fit with pollinators. Phylogenetic comparative analyses revealed significant association between floral traits and pollination mode. Overall flower variation showed two distinct groups, one comprised by the hummingbird-pollinated species, and another by moth-pollinated species. Ancestral reconstructions of floral traits and pollination modes suggest that ornithophilous syndrome would have evolved recently. Our results suggest that floral diversification in the genus *Salpichroa* is mainly concomitant with an adaptation to different pollinators groups.

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An investigation of pollen movement and release by poricidal anthers using mathematical billiards

Although the interaction between vibrating bees and pollen flowers in buzz pollination is well known, little is said about how such vibrations affect the pollen movement within anthers as well as its release. Using a dynamical system known as a billiard, our goal was to

create and validate a mathematical model that reproduces the vibration of poricidal anthers and the movement and release of pollen grains. Such a model represents the anther as a rectangular billiard with a pore in its tip, and the pollen grains as a set of non-interacting particles. Using this model, we study the pollen escape rate after applying an orthogonal perturbation to the anther. We retrieve some previously published empirical results that show the influence of vibration properties like frequency and amplitude on the pollen release. With this model, we hope to generate new insights in pollen movement and release by poricidal anthers.

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Global effects of land-use intensity on local pollinator biodiversity

Pollinating species are reported to be in decline globally, with land use an important driver. However, most of the evidence on which these claims are made is patchy, and generally based on studies with low taxonomic and geographic representativeness. Further research incorporating a broader spectrum of taxa and geographies is required. Here, we model the effect of land-use type and intensity on global pollinator biodiversity, using a database of local-scale biodiversity covering 340 studies, 12,968 sites, and 5,151 likely pollinating species. We show that differences in pollinator biodiversity among land-use types are relatively small. However, increasing land-use intensity was associated with an overall decrease in pollinator species richness and total abundance, across all anthropogenic land-use types. Our findings confirm widespread loss of pollinator biodiversity, most significantly in the tropics, where land use is predicted to change rapidly in the coming decades.

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Structure of plant-visitor networks in a seasonal southern Indian habitat

Studies on community plant-flower visitor interactions are poorly represented from the Asian tropics except for a few locations. In a tropical dry deciduous community in the Eastern

Ghats, India, we studied factors structuring these interaction networks. We built quantitative plant - visitor group interaction networks for 189 plant species and examined seasonal changes in network topology. We examined correlations between visitor taxa and traits such as floral morphometry, nectar volume and colour. Preliminary results suggest highly generalised interactions with multiple visitor groups including ants, bees, butterflies, birds, beetles, bugs, flies, moths, wasps and squirrels. Bees, especially social species significantly dominated interactions across seasons. Data are currently being analysed examining seasonal changes in network structure and the similarity of interactions in plants with multiple, sub-annual flowering events.

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Differential tolerance to heterospecific pollen deposition in sympatric species of bat-pollinated *Burmeistera* (Campanulaceae: Lobelioideae)

Nectar-feeding bats often carry pollen from many species on their fur and thus some bat-pollinated flowers commonly experience heterospecific pollen deposition (HPD). Closely related sympatric species frequently exposed to each other's pollen may evolve tolerance to its negative effects on fruit and seed production. We investigated the relative impact of increasing HPD on female reproduction on sympatric species of bat-pollinated *Burmeistera* bellflowers (Campanulaceae: Lobelioideae) that experience pollen transfer between them by their shared bat pollinators in Ecuador's cloud forests. We found asymmetric impacts on female reproduction between the study species, with the species that most commonly receives foreign pollen exhibiting greater tolerance to HPD. Ongoing work is exploring how different isolation mechanisms contribute to this differential tolerance to HPD. We further hypothesize that tolerance to heterospecific pollen deposition may be a common response among sympatric closely related plant species pollinated by bats and other low-fidelity pollinators.

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Crop domestication, flower characteristics and interaction with pollinators: the case of *Cucurbita pepo* (Cucurbitaceae)

The development of new crop cultivars can alter flower characteristics, impacting plant-pollinator interactions. *Cucurbita pepo* presents flowers of several sizes and forms. We investigated if floral traits (petal length; tube width and length; nectar volume and concentration) influence the bee visitation rate (number of bees per number of observed flowers) on four C. pepo cultivars, 'Black Beauty', 'Celebration', 'Pik-a-Pie' and 'Spaghetti Squash'. Flower traits differed among cultivars (MANOVA; $P<0.001$). Flower visitation was best explained by cultivars ($F_{2,189} = 7.902$, $P<0.001$), bee species ($F_{3,316} = 8.824$, $P<0.001$), and time interval ($F_{2,93} = 3.915$, $P=0.02$). ‘Celebration’ received more visits than ‘Black Beauty’ and ‘Pik-a-Pie’, but not ‘Spaghetti Squash’ ($P<0,001$). This may be explained by the higher nectar concentration in ‘Celebration’ and ‘Spaghetti Squash' and their shallower corollas. This indicates that the agronomic development of new cultivars can lead to changes in flower traits and, consequently, flower visitation rates.

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Functional traits variation in two bumblebee species along a gradient of landscape anthropization

Landscape anthropization represents the principal cause of natural habitats loss and fragmentation with intensive agriculture and urbanization as the major drivers of land-use changes. The effects of urban habitats on species functional traits are still poorly understood. Through a geometric morphometric approach we assessed the impacts of environmental conditions, associated to land-use change and temperature, on both body size and shape and size asymmetry of front wings in two model species of bumblebees (*Bombus terrestris* and *B. pascuorum*) sampled at 47 sites along a gradient of landscape anthropization within the metropolitan area of Milan. Results show a species-specific response, with higher

temperatures in cities determining a phenotypic shift towards smaller size in *B. pascuorum* and higher asymmetry in *B. terrestris*. These shifts could indicate an impaired dispersal capability of these two pollinator species that could negatively affect the service of pollination in urbanized areas.

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Does *Myrmecophila thomsoniana* (Orchidaceae) use uncoupled mimicry to obtain pollination?

Orchids are renowned for obtaining pollination services via food reward, food deception, and sexual deception. The Australia genus *Caledenia* is considered unique in that its members exhibit all three mechanisms. Further, some *Caledenia* deceive with “uncoupled mimicry”, luring male wasps with semiochemicals but completing pollination by engaging food seeking behaviour in the insect. *Myrmecophila thomsoniana* (Laeliinae) is a Cayman Islands endemic epiphyte. Direct and camera trap observation of the array of visitors to its flowers suggest that all three attraction mechanisms are in play. Unusually, it is pollinated principally by native and non-native flower beetles (Cetoniinae), and honeybees. Pollination by three other beetle species and pollinia removal by an endemic anole lizard, a flower-piercing bird, and a Centris bee have also been recorded. These results lay the foundation for testing uncoupled mimicry in *M. thomsoniana* through analysis of its intermittent floral scent, extrafloral nectar, and semiochemical activity.

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Impact of wet meadow translocation on species composition of bees (Hymenoptera: Apoidea: Apiformes)

The study was carried out on wet meadows translocated seven years ago from the area of Katowice-Pyrzowice airport to the Silesian Botanical Garden in Radzionków. Relocation was undertaken to protect the valuable ecosystem of wet meadows, which would be destroyed as a result of the enlargement of the airport. The aim of the study was to compare the species composition of bees on meadows near the airport and relocated ones.

Most bee species (20) were found on relocated meadows. The second in species richness was the vicinity of the botanical garden. The lowest species diversity was recorded near the airport - seven species. The results indicate that relocation helped to maintain high species diversity on wet meadows, however the inflow of bee species from the vicinity of the botanical garden is noticeable. Further research on the effectiveness of translocation as a protection method is needed.

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Does pollinator dependence correlate with the nutritional profile of pollen in plants?

Pollinator dependence differs between different plant species. Some plant species do not at all depend on pollinators, while others exclusively rely on them for reproduction. Pollinator dependent plant species typically try to attract pollinators by offering a reward, mostly nectar. However, in particular bees, a highly important pollinator group, also rely on pollen to raise offspring, as pollen provides nutrients lacking in nectar, e.g. lipids or sterols. Offering nectar as only reward may thus not be sufficient to attract bee pollinators. In theory, plants may increase visitation rates by pollinators through offering pollen of suitable quality. We investigated pollen nutritional profiles in relation to pollinator dependence in 139 local and introduced plant species. We found that protein, polypeptide and free amino acid contents were much higher in plants that depend on pollinators than on pollinator-independent plant species. Moreover, more nutrients correlated with other nutrients or nutrient groups in pollinator-dependent plants, potentially facilitating nutritional quality assessment by pollinators. We therefore suggest that pollinators can influence the nutrient content of pollen, potentially exerting a selection pressure on those plants that rely on them for their reproduction.

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Pollinators and human nutrition in rural Nepal: experiences of remote data collection during a global pandemic

Nepal is on the front line of climate change, placing both its people and its pollinators at risk. Declines in pollinators are predicted to have negative impacts on human health as key dietary micro-nutrients in insect pollinated crops such as vitamin A and folate are lost from the diet. With no viable alternatives to home-grown foods and limited access to vitamin supplements, rural Nepali communities cannot afford to lose their pollinators. Our team of ecologists, climate modelers and nutritionists are working to understand the links between pollinators and human health in Nepal and mitigate the long-term effects of climate change. But 2020 has taken overseas travel off the menu, so we are adapting to some novel methods of remote fieldwork. Data collection apps, training videos and talented local assistants are the new order of the day and we discover some unexpected benefits, which could make this the new normal.

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The chemical landscape of *Arabis alpina*

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

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New insights into the visual ecology of bees

Bees are key pollinators that rely heavily on vision to fly, navigate and locate flowers. Thus, the visual abilities of pollinators represent a fundamental property that constrains a bee's ability to exploit floral resources in different habitats. Nonetheless, the relationship between the visual abilities of bees and their pollination ecology remains mostly unexplored. To start to bridge this knowledge gap and unravel what information bees can extract from the visual world, I established together with my collaborators a high throughput method based on advanced X-ray micro-tomography and optical analysis. This method enables to swiftly measure visual parameters over the entire field of view of bees, and thus to understand how the visual perception of objects such as flowers may differ between species. In this presentation, I will explain how I have applied this promising method to study the visual ecology of two important groups of pollinators: stingless bees and bumblebees.

Posters

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Wild bee pollination services predicted by a PIDE model

Bumblebees provide valuable pollination services to crops around the world. However, bumblebees and the pollination services they provide have declined in several regions. Here we develop a partial integro-differential equation model to predict the spatial distribution of foraging wild bees in dynamic heterogeneous landscapes. The foraging population is divided into two subpopulations engaged in intensive search mode (modelled by diffusion) and extensive search mode (modelled by advection) respectively. Our model considers the effects of resource-dependent transition rates between movement modes, resource depletion, central-place foraging behaviour and the effects of memory in the spatial distribution of foraging bees. We use the model to study the benefits that planting wildflowers adjacent to a crop can have on crop's pollination services and use it to quantify the benefits as a function of the location, quantity and type of the planted wildflowers.

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How does the nutritional content of pollen affect bee foraging choices?

Pollen is a key nutritional resource for bees however there is considerable variability in its composition between floral species. As a result, foragers may exhibit preferences for particular flowers and can fail to develop properly if supplied with unsuitable pollen. Sterols, constitute a key nutritional component of pollen, supporting important biochemical processes including the production of key hormones. Early work has shown sterol content and requirements to be variable between floral and bee species respectively, posing the question of whether this influences foraging choices. My PhD project seeks to investigate this question by quantifying the sterol content of a range of UK wildflowers and the requirements of select UK bee species. I hope to analyse this data in the context of different planting schemes and distributional data to better understand the pollen nutritional landscape for bees.

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The role of pollinators in yield and nutrition of tomatoes

No abstract available.

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Contribution to the knowledge of apple pollinators (Rosaceae) in the region of Northern Algeria

The present work consists in carrying out a census of the useful species of insects associated with the apple tree in the region of Boumerdes and Tizi Ouzou. We investigated the insect communities visiting apple orchards during the blooming period using three common survey methods: coloured pan traps (yellow, blue and white), netting, and direct contact captures. Our results indicate the presence of pollinators with greater abundance in the two study areas. The number of individuals (ni) collected with pan traps was higher compared to other types of traps (ni = 518). Furthermore, we recorded a total of 78 species divided into 7 taxonomic orders and 17 families. The Hymenoptera showed the highest number of individuals collected with a relative abundance of 60.45. Also, the honey bee *Apis mellifera* ssp. *intermissa* was the most frequent species in apple orchards.

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Manipulation of a floral landscape did not alter pollen transfer

The diversity of floral landscapes can play an important role in the pollination of individual species. Evidence is accumulating for both competitive and facilitative effects, with the experimental removal or addition of co-flowering species being a common approach to understanding these dynamics. However, these experiments may not always produce the intended effect and may be complicated by the spatial scales of pollinator foraging. Here, we present data on the quantity of conspecific and heterospecific pollen deposited on stigmas in an artificial community of Chamerion angustifolium. We used a blocked design in conjunction

with hand and open pollination treatments and found that neither the presence or absence of co-flowering neighbours or pollination treatment produced any appreciable differences in conspecific or heterospecific pollen loads. Our results suggest that neighbour removal/addition experiments may be complicated by the spatial scales at which pollinators forage, particularly when a generalist plant is the focal species.

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Effect of Glyphosate-based herbicide use on flowering plant and pollinator communities in managed forests

Land management can have unintended effects on non-target organisms. A branch of non-target research is concerned with evaluating the potential indirect effects on non-target organisms from changes within the target communities. Within managed forests, vegetation management objectives are met through silviculture techniques with the focus being on improving conditions for the harvestable lumber. The most common technique in promoting softwood production in North America is the application of a Glyphosate-based herbicide (GBH) which targets competitive vegetation. The suppression of competitive species helps to promote optimal growing conditions for planted coniferous species that are of higher value to the forestry industry. However, the suppression of competitive species shifts the natural regeneration pattern of disturbed forests which can dramatically change the plant communities. I am evaluating what effect GBH use has on managed forest ecosystems over a 15 year period in New Brunswick, Canada. Specifically, I will address what effect GBH use has on flowering plant communities and the potential indirect effects this could have on native pollinators. I have surveyed 37 harvest blocks that were either sprayed (22N) or not sprayed (15N) and will present the preliminary findings on the pollinator communities found within each forest practice. My preliminary data suggests that it is beneficial to have a mosaic of management practices within managed forests to support native pollinators throughout their foraging season.

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Oh, honey! Potential effects of managed honeybee presence on bumblebee survival in Irish heathlands

In European heathlands, late-blooming ericaceous species provide vital foraging resources for wild bumblebees, as well as the managed honeybees that are brought to heathlands in late summer for heather honey production. However, given the limited floral diversity and increased honeybee activity in these habitats in late summer, there is potential for niche overlap and competition between honeybees and bumblebees, which may have negative impacts on local bumblebee survival. To assess the potential effects of honeybee presence on bumblebee survival, we conducted a study in the Wicklow Mountains, Ireland to determine the effect of distance (250m and 1000m) and density (0-35 hive gradient) of honeybee hives on (i) honeybee abundance, (ii) bumblebee diversity and abundance, (iii) honeybee and bumblebee foraging preferences, (iv) nectar availability, and (v) bumblebee worker size. The results of our study will inform future management initiatives to both conserve wild insect pollinator populations and maintain profitable honey production.

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Bumblebee agricultural risk assessment using ALMaSS framework individual-based modelling

The Animal, Landscape and Man Simulation System (ALMaSS) agent-based model, has been used to look at the risk from pesticides and agricultural practice on insects, such as beetles and spiders, which provide pest controlling ecosystem services. We are now extending the framework to include bee species, which supply pollinator services, to perform an agricultural risk assessment and analyse bee health. Agent-based models can range from the simplistic to the complex, tailored to the complexity or generalisability of questions. The final model aims to then integrate multiple stressors, including explicit incorporation of pesticide-related effects to predict impacts of changed agricultural management on bumblebees. Our findings will help to ensure the safe use of pesticides while protecting wildlife, health, and the environment internationally. Additionally, we hope to gain insights into the biology of bumblebees through the parameterising analysis.

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Are pollinators important for the reproduction of miombo woodland trees?

Miombo woodland is the most widespread dry forest type in southern-central Africa, covering an area of ca2.7 million km2 and spanning seven countries. Despite being a globally significant carbon sink and centre of plant biodiversity, which supports over 65 million livelihoods and provides vital ecosystem goods and services, the ecology of miombo woodlands is relatively poorly understood. Although genetic studies have found miombo species to harbour considerable diversity, promoting resilience to disturbance, almost nothing is known of the importance of pollinators for miombo tree reproduction and therefore the maintenance of this diversity. The breeding systems of two miombo species were studied as a first step towards addressing this research gap. Flower abortion rate, seed set, and seed and fruit weight were compared between three experimental groups: open-pollinated flowers; manually self-pollinated flowers; and manually cross-pollinated flowers. Information on the role of pollinators for maintaining miombo woodlands will affect future conservation practices.

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

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

investigate soil-plant-pollinator interactions (i) in a multi- species setting, (ii) incorporate the plant root system and (iii) in a pesticide contamination context.

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Determining the plant-pollinator network in an Indigenous Three Sisters garden

Studying the basic biology of culturally significant Indigenous food and medicine plants is an important step towards ensuring the persistence of these plants on the landscape. This is linked to Indigenous food sovereignty and the use of traditional medicines. This study examines the plant-pollinator network in an Indigenous polyculture practice using beans, corn, and squash, referred to as a Three Sisters garden. This method of growing is part of a refugia of sustainable agriculture practices and knowledge, that may become increasingly more important in the future as conventional agriculture becomes destabilized. Data from 2019 and 2020 show both *Eucera* and *Bombus* as being key pollinator genera within this system. Baseline data on the important and required pollinators in the Three Sisters garden will be useful in ensuring successful pollination into the future on a changing landscape. These data will also lend support to the conservation efforts of various pollinator species.

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Pollinators of *Pilostyles thurberi* (Apodanthaceae). An awesome endoparasitic plant!

Pilostyles thurberi (Apodanthaceae) is an endoparasitic plant that lacks a visible or defined vegetative body but have an endophytic system that is embedded inside the stems of *Dalea* species (Fabaceae). Generally, the sexual system of *P. thurberi* is dioicous and its flowers break the host bark to emerge and perform its reproduction once a year. The dioecy as a sexual system implies a dependence on pollinators for pollen transport, in order to fertilize and thus, produce seeds. After two years of monitoring various Mexican populations, its registered small bees of *Augochlora* and *Lasioglossum* (Halictidae), as well as potter wasps (Eumeninae) as pollinators. Unlike other floral visitors, these insects actively forage

the flowers touching the sexual structures of male and female flowers. Besides, they move among flowers or nearby individuals. This research shows the importance of *P. thurberi* for these hymenopteran insects which play a vital role in their reproduction.

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The Italian BeeNet project for the managed honeybee and the wild bees

A current bottleneck in addressing the decline of insect pollinators in the EU regards monitoring data on pollinators status, diversity and trend. BeeNet is an Italian project funded under FEASR 2014-2020 (Rete Rurale Nazionale 2014-2020) that CREA Research Centre for Agriculture and Environment will implement in the following years. BeeNet will employ monitoring techniques to correlate environmental quality to bee occurrence, abundance, diversity, population trends and health. The project will differently tackle the complexity of situations of the managed honeybee and the wild bees, but it will be based on an environmental common denominator that will help to highlight differences and similarities: i.e., geographical proximity to intensely farmed - or protected areas. On honeybees, environmental features will also include: the influence of agrochemicals and hive pathogens, employing high-tech hives. On wild bees, BeeNet will advance taxonomic validation of wild bee specimens and the implementation of 3-years data for population estimates.

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Pollination and herbivory in grassland plant communities along a landscape-scale land use intensity gradient

Pollinator declines in response to land-use intensification have raised concerns about the persistence of plant species dependent on insect pollination for their reproduction. Recent studies show that reduced pollinator abundance decreases seedling densities of insect-pollinated plants, which could potentially change the composition of grassland plant communities. To which extent and under which conditions this is the case, and which cascading effects on ecosystem functioning this may have, is yet unexplored. We investigate

the effects of pollinator declines on grassland plant communities and ecosystem functions using a long-term experimental setup consisting of 18 sites along a land-use intensity gradient.

Here, we report:

1. Criteria used to select sites on the land-use intensity gradient
2. How this gradient correlates with pollinator abundance, diversity and activity as well as flower resource cover and herbivory in the selected sites
3. Effects of exclusion cages compared to control plots on pollination and herbivory

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Physical models of heat reward in *Oncocyclus* irises

Flowers of the *Oncocyclus* irises are nectarless and are utilized as night-sheltering “motel” for their pollinators, solitary male bees. The reward to the pollinators is heat. The tunnels are getting warmer faster than the environment after sunrise, enabling the bees to fly earlier. The heating process is passive - based on direct sunlight, yet it is unclear how sun radiation is translated and transformed into the pollination tunnels. We hypothesize that the black patch on the tunnel’s entrance was evolved to facilitate the heating process. We propose a few (not mutually exclusive) physical models regarding the patch's role, based on texture, optics, heat flow and tunnel's structure. We will test the theoretical models on flowers in the wild, using optical methods and manipulations of floral parts, in order to partition between the possible mechanisms. The study will enable to understand the evolution of this unique pollination system.

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Assessment of pollination service in four apple orchards in Emilia-Romagna region (Italy)

Apple production is one of the most important fruit crops globally. Its cultivation entails a high use of pesticides which has a negative effect on pollinator diversity with possible consequences on pollination service. In the framework of an international project, CliPS (Climate change and its effects on Pollination Services), we assessed the pollination service and pollinator community in four apple orchards in Emilia-Romagna region (Italy) characterized by different cultivars and management practices. Despite the lack of pollination deficit in the four monitored fields we found important variations in pollinator contribution and diversity. These variations can mainly be explained by different apple variety, farming practices (e.g. pest management and colony renting) and landscape diversity. In conclusion, we highlight the importance to assess pollination deficit as routinely tool for a sustainable farming system in the IPPM (Integrated Pest and Pollinator Management) framework.

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How does caffeine influence the robbing behaviour of *Bombus terrestris*, the buff-tailed bumble bee?

Alkaloids are commonly present in the nectar of flowering plants and can influence the behaviour of the flower visitors which are feeding on the nectar. The research focuses on the primary robbing behaviour of caffeinated vs. non-caffeinated *Bombus terrestris* bees. Data will be presented from experiments from two years, the first year using 2 hives and the second year 6 hives to control for any hive effect. Data was analysed for when first primary robbing occurred caffeinated vs. non-caffeinated bees. Preliminary analyses suggest that caffeine had no effect on primary robbing behaviour. Further analysis will look at all robbing behaviours occurring during observations.

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The backside of flowers - UV-absorbing properties differ between adaxial and abaxial side of petals

Studies of the signalling and protective functions of flower colours along an altitudinal gradient ranging from 2700m to 4200m in the Hengduan Mountains revealed a yet largely unexplored phenomenon: In many flowers the abaxial side of petals forming the outermost layer of flower buds is absorbing ultraviolet light even in flowers known to reflect UV-light for pollinator attraction. UV-photography of flower buds and adaxial as well as abaxial sides of petals of open flowers show permanently different-coloured petals rather than a floral colour change. The following hypotheses are discussed: 1. Signalling for pollinators to enable discrimination of open flowers and flower buds. 2. Camouflage to hide vulnerable flower buds from herbivores. 3. Protection of pollen and reproductive organs against UV-radiation.

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Interruption and exploitation competition exerted by floral ants on foraging behaviour of pollinators in pumpkin, *Cucurbita maxima*

Pumpkin is a honey bee-mediated cross-pollinated monoecious plant that produces disproportionately very few pistillate flowers. Pumpkin plants set fruit only if pollinated by honeybees, and fruit quality is enhanced by intensive pollinator activity. Male flowers produce nectar and pollen, while female flowers offer higher quantities of nectar but no pollen. The presence of invasive ants in pumpkin flowers has negative effects such as pollinator harassment or flower avoidance by pollinators. We compared the duration of visits of pollinators between the staminate and pistillate flowers, and there seems to be no significant variation in the visit duration. The time spent by the honey bees in antless flowers was significantly higher compared to the flowers with ants. Of those pumpkin plants that had ants in flowers, the native and invasive ants were more abundant in pistillate flowers (77%) compared to staminate flowers (46%). The visitation frequency by honey bees was significantly lower in antless flowers as compared to the flowers infested by ants. This

indicates that the floral visitors have a strong preference for the antless flowers compared to the ant flowers. The visitation frequency was significantly affected by the number of ants too. The results revealed that both native and invasive ants in the flowers can affect the visitation rate and foraging time of honey bees in the flowers, the fruit set in pumpkins, and can exert predatory pressure on the honey bees if the bees linger in ant-colonized flowers.

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Assessing the impacts of changes in land use on the genetic diversity and adaptive potential of pollinator species

Many insect species are undergoing rapid population decline in due to anthropogenic changes to natural landscapes. Pollinator declines in particular have far reaching effects due to the services these species provide to plant communities. Here, I outline how I plan to examine the evolutionary consequences of decline in a generalist pollinator, the Common Blue Butterfly. Using museum specimens, I will establish a baseline measure of genetic diversity before the onset of large-scale agriculture in Sweden and compare this to modern levels of diversity. By mapping this data to an annotated reference genome, I will be able to determine if the prevalence of deleterious mutations has increased over time. Using phenotypic measurements, I will establish a measure of current adaptive potential, and compare this between populations in habitats with varying levels of fragmentation. These results can then help to inform on the effects for similar, but more specialized species.

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Dependence of soybean yield on insect pollination: a critical review of the evidence

Soybean [*Glycine max* (L.) Merr.] has been traditionally considered an autogamous crop. However, several recent studies reported that insect pollination can increase its yield, and thus the issue remains unresolved. Our objective was to critically review the evidence published on the matter. We assessed the quality (design and execution of the experiment that minimize bias and inferential error) and generality (extent to which the conclusions can

be extrapolated to different contexts) of 19 papers that encompass a diverse array of experimental approaches to study soybean dependence. Although most studies claim that soybean yield increases with insect pollination, many failed in key items thus limiting the validity of the conclusions. In light of this, it is necessary to apply standard robust protocols that facilitate the synthesis of results which in turn lead to reliable management recommendations.

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Floral scent in a hybrid zone

Hybrid species pose an excellent natural study system to understand ecological and evolutionary processes. While many aspects of floral traits have been studied across hybrid zones, the patterns that floral scent plays in distinguishing species are poorly understood. Here we examine the floral scent of two *Penstemon* species that have overlapping but different pollinator communities. These species form a hybrid zone in the Sierra Nevada mountains where *P. davidsonii* (low altitude) and *P. newberryi* (high altitude) meet at mid-altitudes. We show that although distinct species, these two closely related species show strong overlap in their scent profiles. However, scent does differ between the species and hybrids appear to have intermediate phenotypes. Our work show that scent alone is unlikely to keep these two species evolutionarily distinct and adds to our understanding of the effects of hybridization on floral scent.

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Worldwide importance of insect pollination in apple orchards: A review

Apple (*Malus domestica*) is one of the most important fruit crops globally, and it depends greatly on insect pollination. We review the published research on the contribution of insects to apple pollination, addressing the following questions: i) Are there gaps in data availability across regions and research topics? ii) What is the importance of insect pollination for yield and fruit quality? iii) What is the contribution of wild insects vs. honeybees? iv) What is the influence of landscape and v) of agricultural management? Results showed that there were gaps across regions and research topics. Substantial evidence proves that insect pollination is essential for ensuring both yields and fruit quality, and a significant proportion of studies demonstrated that wild pollinators are abundant and frequently more effective than honeybees. Current findings suggest a critical role of semi-natural habitats to sustain healthy pollinator communities, while the effect of local management was less consistent.

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The effect of temperature on nectar production and pollinator visitation rates in four herbaceous species

Understanding how plant-pollinator interactions respond to changing temperature is essential when aiming to predict effects of climate changes on biodiversity. Here, we focus on the relationship between nectar production, pollinator visitation rates and temperature. More specifically, we ask if both parameters respond in the same way to temperature and if we find consistent patterns across different plant species. In an observational case study, we measured nectar production and, in parallel, observed flower visiting pollinators on four plant species (*Dictamnus albus*, *Lamium album*, *Salvia officinalis* and *Vincetoxicum hirundinaria*). We could show that for two out of the four species, nectar production significantly decreased,

and pollinator visitation rates significantly increased with increasing temperature. However, there was no correlation between nectar production and visitation rates in these species. We concluded that plant-pollinator interactions are determined by temperature in a species-specific way, eventually leading to shifts in plant communities with ongoing climate changes.

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Structure of flower visitation web of Kashmir Himalaya

Current study presents structure of flower visitation web of Kashmir Himalaya by analyzing diversity, modularity and functional roles of native and non-native pollinator and forage plant species, and the way non-native forage plant species integrate into the native web. A total of 302 interacting species were recorded including 227 forage plant species and 75 flower-visitor species, resulting in 1940 species-species links in the web.64.8% forage plant and 98.7% flower-visitor species are native where 35.2% and 1.3% are non-native respectively. Trifolium pratense and Malus domestica formed strongest network hubs in native and non-native forage plant species respectively whereas Apis cerana (native) and A. mellifera (non-native) were the strongest network hub visitors. Ten native visitor species (Vespidae and Meloidae) served as peripherals in the native web. Out of seven strongly defined modules, module 5 was the largest containing a mix of bees, hoverflies and other Diptera, whereas module 6 was the smallest and dominated by two large carpenter bees.

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Geographic variation in nectar composition and its implications for insect visitors: the case of a rare plant *Polemonium caeruleum* L.

Floral nectar is a key factor in shaping plant–pollinator interactions, however little is known about the variability in nectar traits, which could potentially affect pollinators and the reproduction of the species. To investigate this issue, we analyzed nectar traits in 14 populations of a Red-listed plant species *Polemonium caeruleum*. In 2018 we collected nectar samples from populations of *P. caeruleum* involved in our study. Using HPLC, we

determined the nectar sugar and amino acid composition and concentration. For each population we also recorded some basic habitat parameters, and in seven selected populations, we investigated the taxonomic composition of the insects visiting flowers. Our observations revealed that nectar production was male-biased, and there is significant interpopulation variability in nectar traits in *P. caeruleum* caused by environmental factors. The studied nectar characters, however, had little effect on insects visiting flowers.

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The effect of bee behaviour during floral resource collection on blueberry pollination (*Vaccinium ashei* Reade)

Blueberry flowers have bell-shaped corolla; thus nectar is inaccessible to some visitors, which may obtain this resource through perforations on the corolla (thefts). We compared the bee behaviour during floral resource collection among six blueberry cultivars (Climax, Bluegem, Bluebell, Powerblue, Britteblue and Woodard) that present differences in corolla traits. For that, we counted the number of thefts and legitimate collections for one minute per bush (n=3/cultivar) at 11am, 1pm and 3pm for three days. The number of pollen grains deposited on the stigma was compared between robbed and non-robbed flowers (with/without perforation). The frequency of theft was similar between cultivars (p=0.238). Perforated flowers showed a higher number of pollen grains on the stigma (p=0.01), except Bluegem, which presented more pollen grains on non-robbed flowers (p=0.07). The results indicate that theft does not prevent pollination but improves it.

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Local and landscape habitat variables influencing bee diversity

This study assesses the impacts of local and landscape habitat composition on wild and managed bee abundance in the Maltese Islands. A total of 78 transect walks were carried out during spring 2019, and a total of 2532 flower visits recorded covering 71 plant species. The highest wild bee abundance was recorded in agricultural habitats but there was

substantial variation between different functional groups, when categorised according to nesting, pollen transport and body size functional traits. Wild bee abundance was negatively associated with honeybee abundance. At the landscape scale, wild bee abundance was positively associated with agricultural habitats whilst for *A. mellifera* agricultural, garrigue, urban and woodland cover was significantly associated with increased abundance. A negative association between landscape diversity and bee abundance was recorded. These results provide first evidence of potential interspecific competition arising from high honeybee density in Malta and are used to identify potential conservation measures.

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Assessing the impact of roadside vegetation management on nectar resources

Roadside margins are well known to have a significant ecological impact on flora and fauna, with studies commonly reporting their negative effect. However, they have the potential to be important habitats for flowering plant species, thus supporting pollinating-insects. This study aimed to ascertain how cutting regimes impact nectar sources along such margins, with the main ride through the Old Sulehay forest cut back on a 1-year, 2-year and 4-year basis for the duration of the study. This was to identify which management cycle produced the greatest and highest quality nectar resources. Preliminary results indicate that there was no significant difference in abundance, richness or diversity of flowering plants under different management cycles, contrary to what was expected - yearly cutting providing the greater nectar resources. Assessment of the quality of nectar sources is ongoing, where it is expected that sites cut yearly will have the greatest overall nectar sugar content.

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Functional biogeography of floral traits in Australia

Floral traits affect plant reproductive success and the interaction of flowering plants with pollinators. Despite this, floral traits have rarely been considered in studies of trait variation along environmental gradients, or functional biogeography. Our project examines how floral traits vary across the Australian landscape by targeting two key floral traits: (i)

duration of flowering; and (ii) flower symmetry. We combine plant composition and abundance data from sites across Australia with data on species symmetry and flowering duration. We then assess whether environmental variables such as temperature, rainfall and soil impact the distribution of floral traits in Australia. We predict a relationship between site productivity, which may affect the availability of pollinators in the landscape, and flowering duration. Further, we hypothesise a functional relationship between flowering duration and symmetry, whereby bilaterally symmetric flowers, which typically experience more efficient pollen transfer, may open for a shorter duration than less specialised flowers.

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Effects of land use intensity on pollinator health and pollination services

Pollinators provide essential ecosystem services and are currently threatened by a variety of anthropogenic influences and changing environmental conditions. In intensively used agricultural areas, pollinators suffer from resource limitation, exposure to pesticides and habitat loss. These stressors could affect pollinator health (e.g. increased pathogen loads, developmental changes), which might in return result in a loss of pollination services (e.g. decreased foraging activity, change of behaviour), posing a severe threat to pollinators and pollination. We aim to understand the links between land use intensity, pollinator health and pollination services to help preserving ecosystem functioning in land-use intensive areas. To achieve this, we will investigate pollinator health indicators (viral loads, pheromone composition, fluctuating asymmetry) and foraging behaviour of two common pollinator species (*Bombus lapidarius* & *Episyrphus balteatus*) in 150 grasslands with varying land use intensity and management regimes embedded in an agricultural landscape.

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Larval pesticide exposure reduces adult wild bee reproduction

Bees experience stressors across landscapes, such as pesticides, as they forage for pollen and nectar. Determining the consequences of persistent or variable stressors is critical for understanding the long-term potential effects on populations. We investigated the effects

of larval and adult pesticide exposure on the foraging and reproduction of the solitary bee, *Osmia lignaria*. We established nesting females in field cages containing wildflowers treated with or without imidacloprid. As larvae, these parent bees were reared on provisions containing imidacloprid or controls. Larval and adult pesticide exposure directly affected bee nesting activity. Bees exposed to pesticides as adults were less likely to start nesting and produced fewer offspring. Additionally, larval pesticide exposure reduced offspring production regardless of adult pesticide exposure. Our research provides experimental evidence of the effects of pesticide exposure on solitary bees across multiple life stages, a critical step in understanding mechanisms underlying pollinator health.

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A 30-year study of lily demography: pollination, costs of fruiting, and size dependent mortality

By late summer, the spring-blooming *Erythronium grandiflorum* retracts into a dormant corm that can be exhumed, measured, and replanted. Since 1991, I have performed annual exhumations of ca. 250 plants in an outdoor garden where they are protected from gopher predation. In conjunction with recently published experiments on pollination sufficiency, I have placed the demographic records in a public archive. The primary findings are: flower and fruit production scale with corm size; plants regulate their corm size by fruit production and occasional splitting; mortality is rare, and is concentrated in the smallest and largest size classes. Evidence for senescence is scant.

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Effects of colony level exposure to a fungicide or herbicide on the bumblebee *Bombus terrestris* preliminary results

Fungicides and herbicides are pesticides designed to target non-insect pests, such as fungal diseases and competing plants. They are commonly applied in both agroecosystems and urban landscaping and are some of the most applied pesticides globally. However, increasing research suggests that these pesticides may have harmful effects on bees, but more research is required to understand the risks these pesticides pose and is necessary for

ensuring future sustainable pesticide use. In this study, commercial *Bombus terrestris* colonies received a field realistic chronic dose of either the fungicide prothioconazole or the herbicide glyphosate. Colonies were then placed outside and allowed to forage freely, with their growth and activity levels monitored over a 4-week period. Here we show the preliminary results, including observed trends in colony level foraging activity, colony production, and reproductive output.

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Do wild bees' physiological or ecological traits influence their response (abundance and diversity changes) to conservation strategies? A meta-analysis

Some pollinators' physical or ecological traits confer higher robustness against habitat changes and inputs such as pesticides, while others have traits that render them more sensitive (Williams et al. 2010). If such traits commonly predict species' responses to disturbances, then we predicted that some physical or ecological traits in different species of wild bees are predictive of their likelihood of responding to conservation and habitat restoration. Here we use meta-analysis to synthesise the literature, following standard protocols, to identify published studies of wild bees' responses to conservation as it varies according to those bees' traits. We searched Web of Science, GreenFILE, ProQuest and SciELO, covering the time from 1st of January 2001 to 31st of August 2019 in English and Spanish for studies evaluating the impact of conservation measures on bee groups with specified or inferred traits. Preliminary analysis indicates that groups of bees with particular traits respond more strongly to conservation strategies than others.

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Capturing the Buzz: Characterising buzz pollinated plant species in the Indian Subcontinent

Bees are known to extract pollen from flowers that have specialised morphologies such as poricidal anthers by repeated vibrations and the resultant pollination is known as buzz pollination. Poricidal anthers occur in approximately 65 plant families which represent

about 6-8% of angiosperms. India is a megadiverse country with 18,000 species of angiosperms across diverse habitats and rich bee fauna. However, little is known about the distribution of buzz pollinated species and their associated characteristics in Indian subcontinent. As a first step towards understanding this, we use literature review and plant databases to characterize the species of angiosperms relying either exclusively on or to varying degrees on buzz pollination, their morphologies and their distribution. Our preliminary analysis shows that majority of these species were of Solanaceae family, white or pink coloured and prevalent in the Western and Eastern Himalayas, and the Southern Western Ghats region.

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Determination of upper threshold temperatures of pollen germination and pollen tube growth in northern highbush blueberry (*Vaccinium corymbosum*: Ericaceae)

Climate change is increasing the intensity and frequency of extreme heat events, such as heat waves. A short period of extreme heat during blueberry bloom in Michigan during 2018 led to 30% yield reduction, prompting this investigation. We sought to answer the following questions: (1) how does blueberry pollen germination and growth respond to temperature?, and (2) what are the upper threshold temperatures inhibiting pollen germination and growth? To answer these questions, we plated blueberry pollen from four common highbush blueberry cultivars (Bluecrop, Elliott, Jersey, and Liberty) on a nutrient medium and exposed them to 10, 20, 30, or 40°C conditions and measured the germination and growth at 4 and 24 hours after exposure. We found that blueberry pollen germination and growth were completely inhibited at 40°C. To determine the threshold for this inhibition, we exposed the same cultivars to 30, 32.5, 35, 37.5, or 40°C and measured germination and growth. We determined the upper inhibition threshold for pollen germination and growth occurs at 37.5°C in all cultivars.

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Preserving mobile insects in semi-natural grasslands - minding the Matrix

To mitigate loss of farmland biodiversity, including insect pollinators, much effort has been spent on preserving semi-natural grasslands. However, already lost grasslands are difficult to restore and costly to manage for increased benefits to biodiversity. Previously often mowed semi-natural grasslands are today mostly managed by grazing, resulting in a lack critical floral resources for many insects during summer. I therefore take an alternative approach and investigate if proper management of the surrounding landscape can enhance the conservation value of grasslands for flower-visiting mobile insects. I will present the outlines of my first study design, focusing on measures that create complementary/supplementary food resources, particularly late in the season when grasslands are often heavily grazed, and thereby potentially reduce extinction risks and enhance population sizes of pollinating insects in semi-natural grasslands. I focus on consequences of availability and management of leys that produce nectar and pollen resources.

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Specialized cockroach pollination in the rare and endangered plant *Vincetoxicum hainanense* in China

Species of Apocynaceae are pollinated by a diverse assemblage of animals. Here we report the first record of specialized cockroach pollination in the family, involving an endangered climbing vine species, *Vincetoxicum hainanense* in China. Experiments were designed to provide direct proof of cockroach pollination and compare the effectiveness of other flower visitors. Globally, only 11 plant species are known to be cockroach-pollinated. Because their range of floral features encompass similarities and differences, defining a

“cockroach pollination syndrome” is difficult. One commonality is that flowers are often visited by insects other than cockroaches, such as beetles, that vary in their significance as pollinators. Cockroach pollination is undoubtedly more widespread than previously thought and requires further attention. For a summary of the published study see: https://jeffollerton.co.uk/2020/10/27/cockroaches-as-pollinators-a-new-example-just-published/

Standard talks

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On the measurement and meaning of pollinator-mediated selection

Understanding the agents and targets of selection and how they vary among populations remains a central problem in evolutionary biology and is required for informed predictions regarding the evolutionary consequences of global change. Several studies have by now demonstrated current pollinator-mediated selection on floral traits by comparing phenotypic selection among open-pollinated control plants and among plants receiving supplemental hand-pollination. When pollinator-mediated selection has been detected, this has been attributed to trait effects on attraction of pollinators and pollen transfer efficiency at each visit, or effects on capacity for autonomous self-pollination. However, we here argue that also indirect effects of mean pollen limitation on opportunity for selection, costs of floral traits, and interactions with antagonists may influence this measure of pollinator-mediated selection and should be critically evaluated. We will outline how the relative importance of these mechanisms can be assessed experimentally.

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Pollinators on Guernsey and a Pesticide-free Plan

The Guernsey Pollinator Project is working with the States of Guernsey government to implement a 'Pesticide Free Island' plan. The aim is to stop the commercial and personal use of pesticides, herbicides and fungicides, through legislation and encouraging ecologically

safe alternatives. This creates a unique opportunity to study the effect of a 'pesticide-free' transition on pollinators at island-scale. We are currently collecting the baseline data for this study, sampling pollinator communities on 4 of the Channel Islands: Guernsey, Jersey, Alderney and Sark. Baseline data does not exist for the Channel Islands which in itself should prove interesting as the islands are known to host a subset of both UK and continental species. Here we present our initial findings and outline our future plans to launch the project and encourage research interest in the Channel Islands.

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How to eat in the shade? Bumblebees' behaviour in partially shaded flower strips

Many studies have worked on crepuscular pollinators' activity in relation to light conditions, but little have been done to test the effects of light variations on diurnal pollinators' activity. In this context, we tried to answer: how does the daily variation in light-shade conditions impact the behaviour of bumblebees? We worked on flower strips (Skåne, Sweden) had similar plant communities but could vary in light conditions. Our field design consisted on transect pairs: one shaded part of the day and one "control" always on the sunlight. Each pair was visited five times. At each visit, both transects were observed in three or four conditions combining: both transects in the sun or one shaded and the other in the sun with low or high light intensities. First results showed that bumblebee abundance was higher under high light conditions independently from the shade condition, but it was also higher for control transect.

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Novel pesticide class impact foraging behaviour in wild bees

Sulfoxaflor is a competitive modulator of nicotinic acetylcholine receptors (nAChR) in insects. Despite structural differences to the worldwide commonly used neonicotinoids, both substances bind to nAChR and seems to similarly affect negatively foraging in wild bees. During Scape 2020 I aim to present how effects of field realistic dose of this novel pesticide impact bee foraging behaviour at indoor and outdoor settings. Different doses of sulfoxaflor reduces the outcome of foraging and flight performance. The observed disruption in foraging

behaviour may impair important features for fruit and seed production of cross-pollinated plant species and colony development.

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Flower visitation of the Sticky catchfly (*Viscaria vulgaris*) on isles within isle

Island biogeography explains how size and distance to land affect island ecosystems. Today, McArthur &Wilson's theory can be applied both to oceanic islands and to fragmented terrestrial systems. The latter, human induced habitat fragmentation, is one of the greatest threats to biodiversity and ecosystem function. Pollination is found to be affected by habitat fragmentation. As pollination is crucial for both human welfare and ecosystem function, understanding these effects is of great interest. Eløen is a volcanic island in the outer Oslofiord. Its flora and avian fauna have been extensively mapped, but its pollination systems and insect fauna remain understudied. This summer, I assessed flower visitation of *Viscaria vulgaris* in continuous and patchy populations on Eløen. Flower visitations were recorded and resulting seed set was counted. Species of Hymenoptera were caught by net and pan traps for identification. On SCAPE2020, I will present my methods and some preliminary results and reflections.

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The effects of landscape composition and climatic variables on pollinator abundances and foraging along a gradient of increasing urbanization.

Urbanization is growing steadily all over the world and pollinators are suffering from population decline. Therefore, it is relevant to explore how urbanization and landscape modification impact pollinators, in order to provide suggestions aimed at reaching sustainability. In this study, we surveyed pollinator abundances with passive trapping and plant-pollinator interactions with netting and HTS DNA metabarcoding of pollen in about 35 sites along a gradient from seminatural to urbanized habitats in Northern Italy. The results indicate linear and nonlinear dependencies to the landscape structure and to the climatic

variables in wild bees and hoverflies abundances. Furthermore, urbanization altered plant-pollinator networks in ways indicating more simple networks of pollinators converging on fewer flowers in highly urbanized areas than in areas with less cementification. Overall, this research highlights how habitat alteration and particularly the process of urbanization are impacting both the foraging dynamics and the population size of wild pollinators.

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Does the rarity of a flower´s scent phenotype in a deceptive orchid explain its pollination success?

In deceptive plants, variation in traits involved in pollinator attraction is assumed to be maintained by negative frequency-dependent selection. This has been tested in floral color traits, but so far not in the multivariate and/or continuous characteristics of floral scent bouquets. We investigated in the deceptive orchid *Cypripedium calceolus* whether flowers with rare scent phenotypes are more likely to produce a fruit than those with more common ones. Scent of single flowers was collected in two natural populations, and from the same flowers it was recorded whether they set fruits. We introduced a measure of rarity for the scent phenotype of single flowers. We found that the rarity of floral scent phenotypes greatly varied among flowers but was not a predictor of whether flowers set fruits in neither of the populations. Our approach to calculate the rarity of single phenotypes is also applicable to other univariate and multivariate traits.

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Pollinators and visitors to *Gymnadenia* orchids: historical and modern data reveal associations between insect proboscis and floral nectar spur length

Assessing pollination systems takes detailed fieldwork, and distinguishing floral visitors from effective pollinators even more so, yet both are critical to understanding the role of pollination in floral evolution. The orchid genus *Gymandenia* contains species in two main morphotypes. Using historical data, I show that average proboscis length differs between visitors to long-spurred *G. conopsea* and to short-spurred *G. rhellicani*. However, these data

are largely based on visitation observations rather than verified carriage of pollinia. To gather modern data and assess verified pollinator identity, we collected pollinators of both species, showing that the major pollinators are Lepidoptera for *G. conopsea* and Lepidoptera and Hymenoptera for *G. rhellicani.* Pollinia are carried in different positions on the proboscis between the two species, and proboscis length of effective pollinators differs between species. These results demonstrate the validity of historical data in assessing proboscis: nectar spur associations, while also demonstrating the importance of validating visitor effectiveness.

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Cost/benefit ratio of a nursery pollination system in natural populations: a model application

Nursery pollination systems are a type of mutualism in which pollinating insects also use the host plant to reproduce. The *S. latifolia–H. bicruris* system fluctuates along a gradient between mutualism and antagonism, depending on the ecological context. Our aim is to understand the origin of such conditionality. We analysed pollination behaviour of *H. bicruris* moths, collected field data and analysed pollination, infestation rates, and parasitism rate by a natural enemy. Then we applied a theoretical model to determine interaction outcomes. Our results show that male pollination benefits are essential for the stability of the system. Pollination, infestation and parasitism rates vary between fields, although some of the factors causing such variability remain unclear. The amount of co-pollination is a good predictor for the outcome of the system. Overall, third parties associated to the system —specially co-pollinators and natural enemies— play an important role modifying the outcome of the interaction.

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Indirect and additive effects of arbuscular mycorrhizal fungi on insect pollination and crop yield of raspberry under different fertilizer levels

Insect pollinators and arbuscular mycorrhizal fungi (AMF) can provide vital ecosystem services for crop production, but it remains unknown whether their effects interact and how their effects are influenced by fertilizer availability. To test the combined effects of pollination, AMF and fertilizer inputs, we conducted a pot-field experiment on raspberry (*Rubus idaeus* L.), adopting a full-factorial randomized block design with two levels of pollination (open pollination vs pollinator exclusion) and two levels of AMF treatments (AMF inoculated vs non-mycorrhizal treatment), receiving four levels of fertilizer. We found that AMF inoculation increased yield with 43%, and additionally increased yield indirectly by increasing insect pollination rates. Insect pollination increased crop yield on average 55%, and these effects were stronger (up to 90%) with increasing fertiliser levels. Our results indicate that AMF inoculation can be a novel agricultural management practice that increases raspberry crop yield directly, and indirectly through increasing insect visitation rate.

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Why size matters in fig-pollinator mutualisms

The mutualisms between fig trees (*Ficus*) and their pollinator wasps (Agaonidae) are a classic case of coevolution. The wasps are the only pollen vectors for figs; which, in turn provide the only sites where wasp offspring develop. However, this highlights a conflict – wasp offspring eat fig seeds, so how do figs protect seed production? Previous studies on different fig-wasp systems suggest multiple possible mechanisms. A potential general explanation incorporates and reconciles these mechanisms through allometric scaling relationships and predicts that foundress wasps in Ficus species with small figs introduce more pollinator wasp eggs per flower, leading to higher plant/pollinator conflict. We analysed data from 23 monoecious fig tree-fig wasp mutualisms and found that the potential for pollinator wasp exploitation of their hosts is indeed a negative function of fig size. These

results suggest a greater importance of physical and/or chemical barriers to oviposition in *Ficus* species with smaller figs.

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Role of pollinators in prezygotic isolation between calcicolous and silicicolous ecotypes of *Silene nutans*

The moth-pollinated *Silene nutans* (Caryophyllaceae) consists of a cryptic species complex, including two strongly differentiated eastern (E1) and western (W1) genetic lineages. Several barriers to reproduction between them have been demonstrated, including strong hybrid inviability. In southern Belgium, the E1 and W1 lineages come into secondary contact and form a calcicolous and a silicicolous ecotype, respectively. Given possible mating costs (pollen loss and inviable progeny) involved in inter-ecotypic pollination, pollinator isolation might have evolved between ecotypes. To determine if pollinator isolation represents a barrier to reproduction between the two ecotypes of S. nutans, pollen dispersal between populations was studied using fluorescent powdered dyes as pollen analogues, and nocturnal moth pollinators were observed using infrared cameras. Overall, no evidence of pollinator isolation was found, since intra- and inter-ecotypic pollen flows were similar. Moreover, *Hadena albimacula*, a nursery pollinator specialized on *S. nutans* in Belgium, visited both ecotypes.

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Linking flower morphology to pollen-release dynamics: buzz-pollination in Melastomataceae

Buzz-pollination is a functionally specialized pollination strategy where bees remove pollen from flowers through vibrations. Although buzz-pollination occurs in ca. 8% of angiosperms and has been associated with high evolutionary success, its functionality and evolution remain poorly understood. Melastomataceae represent the largest radiation of buzz-pollinated flowers, with a tremendous diversity in floral morphology. In this talk, I explore the idea that flowers of different sizes and architectures are adapted to exploiting different bee-buzz-pollination niches, and that small flowers are tuned to release pollen at

lower amplitudes (produced by small bees) than larger flowers. I applied artificial vibrations across a range of amplitudes and frequencies to 11 Melastomataceae species with contrasting floral architectures. Against expectation, most pollen was released at high amplitudes and frequencies around 200 Hz, regardless of flower size and architecture. I discuss these findings in the light of empirical observations of pollinator behaviour and outline future experiments.

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A One-Health model for reversing honeybee (*Apis mellifera* L.) decline

Global insect decline impacts ecosystems resilience; pollinators such as honeybees (*Apis mellifera* L.) have suffered extensive losses over the last decade, threatening food security. Research has focused discretely on in-hive threats (e.g. *Nosema* and *Varroa destructor*) and broader external causes of decline (e.g. agrochemicals, habitat loss). This has notably failed to translate into successful reversal of bee declines. Working at the interdisciplinary nexus of entomological, social and ecological research, we posit that veterinary research needs to adopt a “One-Health” approach to address the scope of crises facing pollinators. We demonstrate that reversing declines will require [1] integration of hive-specific solutions, [2] a reappraisal of engagement with the many stakeholders whose actions affect bee health and [3] recontextualising both of these within landscape scale efforts.

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Petal cell shape and flower-pollinator interaction in *Nicotiana*

Petal epidermal cell shape has been shown to affect pollination success in flowering plants. Conical epidermal cells may increase grip for insect pollinators and enhance flower colouration compared to non-conical cells. *Nicotiana* presents a diverse range of petal cell shapes. Interestingly, sister species in at least two phylogenetically distinct clades of the genus have contrasting petal epidermal cell shapes (conical vs. non-conical). This provides a unique opportunity to explore the evolution of conical cells. Using a combination of

molecular, morphological and behavioural ecology tools I studied the development, evolution and function of petal cell shape in *Nicotiana*. Differential expression of candidate regulatory genes rather than amino acid sequence differences in the proteins, might explain contrasting cell shapes between sister species. Flower choice experiments with bumblebees, using biomimetic replicates of petals, indicate that the bumblebees can discriminate flowers of contrasting texture using visual cues alone as well as tactile cues alone.

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Moth assemblages within urban domestic gardens respond positively to habitat complexity, but only at a scale that extends beyond the garden boundary

This study uses light-trapping to examine the response of moth assemblages to domestic gardens that are assessed in terms of their habitat complexity (simple and complex) both within the garden and extending out to a 30m radius that includes surrounding habitats. The results clearly show that moth assemblages were influenced by complex habitats, but only at a scale that extended beyond the garden boundary to include the surrounding area. In other words, neither the complexity of the habitat within the garden or the size of the garden had any influence on the abundance or diversity of the moth assemblage. These results have implications garden management– if domestic gardens are to be a useful component of strategies to reduce biodiversity loss within the urban environment then they should provide good habitat quality and be managed as a network of interconnected patches rather than as individual units.

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Floral and reproductive plant functional traits as an independent axis of plant ecological strategies

The search for the set of traits capturing most of the variation in plant forms and related ecological functions is still ongoing. A global study has found that the majority of trait variation can be described by two main axes: plant size and the leaf economic spectrum, using only a limited array of plant traits. Therefore, we ask whether i) less frequently studied

i.e. clonal and bud bank, floral and sexual reproduction traits explain a unique part of the variation, ii) these patterns are universal by using three different datasets and iii) phylogeny explains part of this variation. We confirmed the most important axes based on vegetative traits found before. Moreover, we found that floral traits explain a unique part in plant form and function, which was consistent in the three datasets. However, floral traits tend to be more dependent of phylogenetic relationships among species compared to other traits.

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Understanding the development, evolution and function of the bullseye pigmentation pattern in *Hibiscus trionum*

Colourful petal patterns act in pollinator interactions but their formation and evolution is not well understood. *Hibiscus trionum* has a bullseye pattern produced by restricting production of pigmented tabular cells with a striated surface to the petal base. Variation in bullseye size between *H. trionum* relatives results mostly from differences in pigmentation restriction. My PhD aims to characterise the gene regulatory network restricting pigment production to the bottom of the petal and how alterations to this network lead to bullseye size variation during evolution. My results indicate that differences in the expression patterns of two MYB genes could account for the strong bullseye reduction observed in *H. richardsonii*, the sister-species of *H. trionum*. My PhD also investigates pollinators' ability to perceive differences in bullseye patterning and I am currently characterising bumblebees' response to artificial flowers of varying bullseye size.

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Ecology and evolution of spatial variation in scent emission within flowers

Floral scent is an important long-distance signal that attracts pollinators, but also has been suggested to function at shorter distances such as within-flower nectar guides. To support the theory of functions within the flower, in some species, the floral scent emission is

compartmentalized as certain compounds are exclusively emitted from certain tissues. Whereas other species emit scent evenly from the entire flower. We summarize the current evidence on floral scent compartmentalization by combining a literature review with data from 17 species. Results show that floral scent compartmentalization is frequent, occurring in species from distant groups. We report varying levels of compartmentalization involving tissue-specific emissions and/or variation in the proportions of volatile compound groups in different floral parts. We discuss adaptive and non-adaptive hypotheses underlying floral scent compartmentalization. Our synthesis provides a foundation for future studies on the functional ecology of floral scent and reinforces the idea of high complexity in floral chemical signals.

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Boundary features increase and stabilise bee populations and the pollination of mass-flowering crops in rotational systems

Pollinators experience large spatio-temporal fluctuations in resource availability when mass-flowering crops are rotated with resource-poor cereal crops. Yet, few studies have considered the effect this has on pollinator population stability, nor how this might be mitigated to maintain consistent crop pollination services. We use a state-of-the-art, process-based pollinator model to assess the potential of boundary features (field margins and hedgerows) to support and stabilise bee populations and pollination service in agricultural landscapes under crop rotation. Using a sample of 117 study landscapes in England, we show the stabilising effect of boundary features on bee populations strongly depends on bee life-history and mobility. Despite this, predicted visitation rates to field bean and oilseed rape were still significantly more stable with boundary features present than absent (up to 25% reduction in predicted variability in some landscapes). Based on our findings, we recommend ways to maximise the stabilising benefits of boundary features.

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Phenological and pollinator-mediated isolation among selfing and outcrossing *Arabidopsis lyrata* populations

Transitions from outcrossing to selfing have been a frequent evolutionary shift in plants and clearly play a role in species divergence. However, many questions remain about the initial mechanistic basis of reproductive isolation during the evolution of selfing. For instance, how important are pre-pollination mechanisms (e.g. changes in phenology and pollinator visitation) in maintaining reproductive isolation between newly arisen selfing populations and their outcrossing ancestors? To test whether changes in phenology and pollinator visitation isolate selfing populations of *Arabidopsis lyrata* from outcrossing populations, we conducted a common-garden experiment with plants from selfing and outcrossing populations as well as their between-population hybrids. Specifically, we asked whether there was isolation between outcrossing and selfing plants and their hybrids through differences in 1) the timing or intensity of flowering; and/or 2) pollinator visitation. We found that phenology largely overlapped between plants from outcrossing and selfing populations. There were also no differences in pollinator preference related to mating system. Additionally, pollinators preferred to visit flowers on the same plant rather than exploring nearby plants, creating a large opportunity for self-fertilization. Overall, this suggests that pre-pollination mechanisms do not strongly reproductively isolate plants from selfing and outcrossing populations of *Arabidopsis lyrata*.

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Invasive alien Proteaceae lure some, but not other nectar feeding bird pollinators away from native Proteaceae in South African fynbos

Invasive alien plants can lure pollinators away from and reduce the reproductive output of native plant species. This is well studied for insect pollinated species, but whether the same is true for bird pollinated species is largely unknown. Here, we address this by considering the impact of an invasive alien plant species (*Banksia speciosa*, Proteaceae) on visitation rates of nectar-feeding bird pollinators to the native *Protea compacta* in the Cape Floristic Region of South Africa. We quantified pollination rates to *B. speciosa* and *P. compacta* in areas of co-occurrence and compared this with a control site. Sugarbird visitation to *P. compacta* was significantly lower in the presence of *B. speciosa*, whilst sunbirds mostly avoided *B. speciosa*. Despite this, there was no reduction in seed set in *P. compacta*. The long-term effect of reduced pollinator visitation may reduce fitness in *P. compacta* whilst pollinators enhance the invasive potential of *B. speciosa* by increasing seed set.

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Is the inflorescence scent of *Arum maculatum* L. (Araceae) in populations north vs. south of the Alps locally adapted to a variable pollinator climate?

Local adaptation can arise from differing environmental conditions among populations through divergent selection pressures. In a recent study, we found that the inflorescence scent of brood-site-deceptive *Arum maculatum* shows signatures of region-specific phenotypic selection between populations north vs. south of the Alps, potentially reflecting the geographic pattern in pollinator availability and their different scent preferences. Here, we

ask if scent in *A. maculatum* is locally adapted to the different pollinators north vs. south of the Alps. To address this question, we reciprocally transplanted plants between and within regions and tested if the visiting pollinator composition, fruit set, and olfactory attractiveness to pollinators differed between plants “local vs. foreign”. We show whether local plants attracted pollinators more effectively and had a higher fruit set. Our study provides novel insights into ecological effects of intraspecific trait variation and fosters our understanding of local adaptation in deceptive plants.

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Megachile sculpturalis: insights on the nesting activity of an alien bee species

The giant resin bee, *Megachile sculpturalis* (Megachilidae), is a species alien to Europe that easily adopts bee hotels in city gardens. In Italy, we are carrying out a monitoring project at CREA bee hotel. Starting in 2016, we monitored emergence and defined nest structure and pollen; estimated the number of nests completed by each female, and recorded nesting activity. Males emerge first, the second half of June, and quickly disperse in a couple of weeks. Dominant pollen in the cells belong to *Sophora japonica* (Fabaceae), abundant in parks of Bologna. Females resulted highly philopatric (only the 5% possibly dispersed). They used and re-used drilled cavities in woody blocks or reeds, moving in and out material and gathering pollen, and using more than a cavity along the season. Present data point in the direction of nesting flexibility that can partly justify the quick spread of the species in Europe.

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The effects of environmental toxicants on the health of bumble bees and their microbiomes

Bumble bees (*Bombus* spp.) are important and widespread insect pollinators, but the act of foraging on flowers can expose them to harmful pesticides and chemicals such as oxidizers and heavy metals. These toxicants in floral nectar and pollen take many forms yet how they influence pollinator health not fully understood. Here we explore how bee health may be influenced by exposure to cadmium, copper, selenate, the neonicotinoid pesticide imidacloprid, and hydrogen peroxide – all of which have all been identified in floral nectar and pollen. We look at their direct toxicity, their influence on the bee gut microbiome and the potential for the microbiome to detoxify these toxicants.

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The impact of agri-environment schemes on crop pollination services at national scale

Agri-environment schemes are contractual agreements between landholders and governments that create and maintain semi-natural habitat within agricultural landscapes. Previous work has shown that individual agri-environment features can provide floral and nesting resources for wild pollinators, thus indirectly supporting visitation to nearby crops. However, the effect of an entire scheme on this ecosystem service at national scale has never previously been studied. We use a state-of-the-art, process-based pollinator model to examine if the current uptake of agri-environment agreements in England has enhanced pollinator abundance and visitation rates to four pollinator-dependent crops. Results show significant increases in pollinator populations and some localised areas of significant crop visitation increase. However, the overall change in crop pollination at national scale was not significant. Analysis suggests that current schemes provide adequate floral resources but insufficient nesting resources in key locations. Implications for future scheme design and targeting are discussed.

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‘Interviewing’ pollinators in the red clover field: foraging behaviour

Monitoring foraging behaviour of pollinators in flowering red clover is difficult under field condition. In this study, we succeeded in ‘interviewing’ pollinators by using portable camera and fresh cut flowers to explore the correlation of the foraging behaviour (number of florets visited per flower head) between the 1st and the 2nd visiting bee. We interviewed 240 bee individuals during the peak flowering time (late-June to mid-July, 2020). We found that the discrimination behaviour of the 2nd bee was positively related to the flower head exploitation rate of the 1st bee. Further, we found a negative correlation of the flower head exploitation rate between the 1st and 2nd visiting bee, indicating scent marks left by the 1st bee may negatively influence the foraging behaviour of the 2nd bee. Foraging behaviour also differed among pollinator species when offering a new flower head, where *B. pascuorum*, *B. terrestris*, *B. hortorum*, and *B. muscorum* visited relatively higher number of florets per flower head compared to *B. lapidarius* and A. *mellifera*.

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Orientation matters: effect of floral symmetry and orientation on pollinator entry angle

Sprengel (1793) observed that flowers with one plane of symmetry seemed to restrict pollinator approach, allowing for more precise pollen placement onto the pollinator’s body. Other researchers have suggested that horizontal flowers could have a similar effect. However, little is known about the relative importance of floral symmetry and orientation, as well as their interactions on the stabilisation of pollinator entry angle. In a laboratory study, we compared the variance in entry angle of *Bombus ignitus* workers foraging on artificial flowers with nine different combinations of floral symmetry (radial/bilateral/dissymmetry) and orientation (upward/horizontal/downward). Our results show that horizontal orientation significantly reduced variance in entry angle, while floral symmetry did not. Floral symmetry also has no significant interaction with orientation. These results may contradict the traditional view on the evolutionary advantage of bilaterally symmetric flowers.

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Viral distributions in bee communities: associations to honeybee density and flower visitation frequency

Viruses infect a wide range of bee species and spread within and between wild and managed bee communities, with shared flowers as a probable site of interspecific transmission. The aim of this study is to characterize factors that are associated with the spread of viruses in bee communities. We conducted a field survey across 8 sites with varying densities of honeybee foragers and flower diversity. The presence and abundance of select viruses (DWV, BQCV, SBV and LSV) were assessed in individual honeybees and Andrena bees. Using a model selection framework, we determined that the occurrence of the monitored viruses in Andrena bees was positively related to the density of total and infected honeybees and flower visitation frequency, thus supporting the hypothesized importance of flowers in the interspecific virus transmission.

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Flagellum removal by a heather nectar metabolite inhibits infectivity of a bumblebee parasite

Parasites can threaten pollinators, either by themselves as emergent pathogens, or in combination with other anthropogenic stressors like habitat destruction and pesticides. Anti-parasitic metabolites in pollen or nectar could reduce the impact of parasites, but so far little is known on which plants could serve this role for pollinators, and through which mechanism they could do so. We here present results of a novel screening method to identify antimicrobial nectar compounds from 17 major bee foraging plants in Europe. We describe

callunene, a metabolite from heather (*Calluna vulgaris*) nectar, with strong activity against the common bumblebee gut parasite *Crithidia bombi* (Trypanosomatida). We show that callune can reduce the likelihood of bumblebees becoming infected, likely by inducing the loss of the flagellum, used by the parasite for locomotion and attachment in the host. Widespread loss of heath lands in Europe may thus reduce the availability of a major anti-parasitic pollinator ""medicine"".

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Impacts of drought on floral traits, plant-pollinator interactions and plant reproductive success – a meta-analysis

Climate change-induced alterations in precipitation will decrease water availability in many regions across the globe. This reduced water availability, i.e. drought, can cause physiological stress in plants which can affect floral development leading to changes in floral morphology, production of resources or scent; traits that mediate interactions with pollinators. As pollinators can detect small changes in trait expressions, it is likely that drought-induced changes in floral traits affect visitation patterns of pollinators. These effects on plant-pollinator interactions are mediated by various abiotic and biotic factors, such drought severity, soil conditions or species identity. To summarise our current knowledge and highlight future research directions, I conducted a meta-analysis of primary studies exploring the effects of experimental drought on floral traits, plant-pollinator interactions and plant reproductive success. Thus, this study provides an up-to-date assessment and summary on the sign and magnitude of drought effects on the floral phenotype and plant-pollinator interactions.

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Geographic differences in pollinator availability in the habitats shape the degree of pollinator specialization in the deceptive *Arum maculatum* L. (Araceae)

Most flowering plants are pollinated by animals, with pollinator abundance, pollinator composition, and degrees of specialization often varying among sites within plant species. It remains unclear whether geographic differences in pollinator spectra result from site-specific strategies of plants and/or merely mirror differences in pollinator availability in the habitats. We address these questions in *Arum maculatum*, which exhibits different compositions and abundances of visiting pollinator taxa (Psychodidae, Diptera) north vs. south of the Alps. We also explore how pollinator spectra affect the fruit set between the two regions. Our findings show that differences in pollinator availability explain most of the variability in pollinator spectra. Specialized interactions towards one psychodid species were observed when its availability in the habitats was high, whereas a low pollinator availability resulted in more generalized interactions, including other dipteran families. Fruit set increased with increasing pollinator abundance, but random patterns appeared when the latter was too high.

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Seasonal dynamics of competition between honeybees and wild bees in a protected Mediterranean scrubland

Many conservation measures focused only on honeybees, leading to an increase in the installation of hives in natural areas. In this context, within a Mediterranean protected area, Calanques National Park, we studied the impact of honeybees within plant-pollinator networks. On 17 sites and over 2 years, we counted the number of visits realized by honeybees and wild bees within a scrubland habitat. We observed a competition for floral

resources induced by honeybees especially in early spring. This competition results in a competitive exclusion of large wild bees (body size >1cm). Likewise, the presence of honeybees also leads to a modification of wild bee foraging behaviour and floral diet. This study highlights the need to mitigate the establishment of honeybee colonies in protected areas such as national parks, in particular to release the pressure of competition between large wild bees and honeybees.

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Habitat quality and connectivity in kettle holes enhance bee diversity in agricultural landscapes

The decline of wild bees endangers pollination services worldwide. In this study, we evaluate wild bee diversity in wetland habitats (kettle holes) embedded in agricultural landscapes and study the relationship of area, isolation, and habitat diversity. We sampled 36 kettle holes using color traps and identified 77 species. Our results showed that the combination of kettle-hole area and density of neighboring kettle holes enhanced bee diversity. Habitat quality (i.e. higher flower availability) within the kettle holes positively influenced bee diversity; while dense vegetation and presence of trees were negatively associated with bee-species richness. Wild bee community responded differently to the environment according their functional traits and was mainly represented by solitary, polylectic, belowground species. Area and isolation did not affect eusocial diversity while surrounding habitat diversity was negatively correlated with solitary bee abundances only. Body size was not associated with any environmental condition. Our study stresses the need for a combination of large quality habitats within the kettle holes providing with a high availability of insect pollinated flowers and a high density kettle-hole network to enhance wild bee diversity in these intensive agricultural landscapes.

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Evaluating the quantity and quality of resources for pollinators on Irish farms

The aim of this project was to evaluate empirically the quantity and quality of natural resources for pollinators (bees and hoverflies) on Irish farms. Data were collected from two geographical regions, Sligo in the West of Ireland and Wexford in the Southeast, and from a mix of farm types. Between May and August 2019, fifteen farms in each region were surveyed five times to establish pollinator abundance, species richness and diversity (via pan trapping and transects) and floral resource availability. Preliminary results show that the availability of both floral and nesting resources on the farm was important for pollinators. Stonewalls, ditches and earth banks provided useful nesting habitat for wild bees, and hedgerows were heavily utilised for forage. However, the quality of these habitat features varied significantly between farms. In short, both the quantity and quality of habitats for pollinators needs to be monitored, improved and incentivised on Irish farms.

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Rangeland sharing by cattle and bees: moderate grazing does not impair bee communities and resource availability

Rangelands are a main driver of natural habitat loss worldwide. Land sharing, the integration of agricultural production and biodiversity conservation, may provide a platform for managing rangelands to fulfil multiple ecosystem services. We investigated the effect of cattle grazing on bee communities and their resources in Mediterranean rangelands. The availability of floral and nesting resources for bees was unaffected or positively affected by

grazing. Similarly, wild bee abundance, species richness and composition were not affected by grazing, nor was honeybee activity level impaired by grazing. Moreover, our results indicate the potentially important role of ungrazed patches in increasing nectar and pollen diversity and availability in rangelands for both honeybees and wild bees in the spring. Our findings support the notion of rangeland sharing by cattle and bees in Mediterranean ecosystems under moderate grazing intensities, mimicking the coexistence of honeybees, wild bees and cattle in Mediterranean ecosystems on an evolutionary timescale.

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Specialization for tachinid fly pollination and the evolutionary divergence between varieties of the orchid *Neotinea ustulata*

The European orchid *Neotinea ustulata* has been known to consist of two phenologically divergent varieties (var. *ustulata* and var. *aestivalis*), from which detailed studies of their reproductive biology have been lacking. This study aimed to characterize the floral traits (i.e. morphology, colour and scent chemistry) and reproductive biology of *N. ustulata* varieties. *Neotinea ustulata* varieties differ in their floral traits and pollinator assemblages; var. *ustulata* appears to be pollinated mainly by both bees and flies, whereas var. *aestivalis* is pollinated almost entirely by tachinid flies and only very occasionally by bees. Tachinids were also found to be much more effective than bees in removing pollinaria, and they use the modified dark inflorescence top as a cue for approaching inflorescences. *Neotinea ustulata* varieties seem to represent a transition from functional generalization to more specialized dependence on tachinids for pollination. This may be driven by spatial and temporal pollinator availability and effectiveness.

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Despite the megadiversity of flower visitors, native bees are essential to açai palm (*Euterpe oleracea* Mart.) pollination at the Amazon estuary

Açai palm (*Euterpe oleracea*) is a non-timber forest product and the most important native crop in the Amazon estuary. Its inflorescences are visited by a megadiversity of insects. Understanding the functional roles of different pollinators is crucial to the development of sustainable farming practices in pollinator-dependent crops. We assessed the pollen loads of insect visitors from pistillate inflorescences at eight sites, four managed floodplain forests and four plantations. Pollinator Importance Value Index (PIVI) and Relative Importance (RI) scores were calculated for common visitor taxa (≥ 10 individuals) using sum visit frequencies and median pollen loads. Pollen load analyses revealed that over seventy species, including bees, flies, beetles, wasps and ants, were effective pollen vectors. Native bees were the most efficient ones, with median pollen loads at least eight times higher than the others, thus essential to açaí pollination and should be the primary focus of pollinator management in açaí production systems.

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Who takes responsibility for the bees?

The worldwide decline in bees and other pollinating insects is a threat to biodiversity and food security, and it is urgent to take action. One of the causes for insect decline is the use of harmful pesticides in agriculture. In the presented study we use Norwegian apple production as a case-study to investigate which of the three groups: farmers, consumers and public authorities, have the most responsibility for protecting bees against harmful pesticides. The questions are investigated empirically with qualitative data material from Norwegian apple farmers, consumers and public authorities, and survey data from consumers and farmers. Our results indicate that consumers see public authorities and farmers as equally responsible for protecting the bees, while farmers are inclined to see themselves as more responsible. Neither groups consider consumers to have any large responsibility. Among the consumers there is also a high level of trust in both farmers and public authorities.

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Decision making in the Asian honeybee *Apis cerana* is influenced by innate sensory biases and associative learning at different spatial scales

Visual detection and discrimination of flowers against complex backgrounds is challenging for insect pollinators due to the limited resolution of their compound eyes. Bees use either achromatic or both chromatic and achromatic cues to detect flowers at different spatial scales. Knowledge of these thresholds of detection, which are species-specific, is important in understanding the visual ecology of insect pollinators. We estimated single object target detection thresholds in the Asian honeybee *Apis cerana* and conducted behavioural experiments in the laboratory to validate field observations of honeybee decision making and pollination success in a floral colour changing tree (*Catunaregum spinosa*) in the Western Ghats, India. Our results demonstrate that the bees rely on innate biases and learned associations at different spatial scales. The tree exploits the sensory bias of the bees through colour change to attract them from a distance and at close proximity the tree honestly signals reward availability to increase its fitness.

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The allometry of sensory system in the butterfly *Pieris napi*

Habitat destruction is one of the main issues attributed to the population decline of pollinators over the last decades. The proper function of sensory systems and their adaptation to the modified habitat determine the foraging success and, thus, the survival of the pollinators in that environment. The size of the sensory traits is one of the factors that play an essential role in the adaptation of sensory traits for perceiving necessary sensory cues for foraging activity. To better understand how the size of the sensory traits change with body size, we studied the allometry of sensory systems in the butterfly (*Pieris napi*). Our results from both sexes didn't show any significant increase or decrease of the sensory organs in relation to body size; however, proboscis length had an increase trend with body size in females. We also found males notably own larger eyes compare to females, regardless of body size.

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Different points of view in a changing world: The tobacco tree flowers through the eyes of its pollinators in native and non-native ranges.

Different pollinators show distinct visual and cognitive abilities that can influence floral colour evolution. *Nicotiana glauca* is a South American hummingbird-pollinated plant that has become a significant invasive of semi-arid parts of the world, where it is visited by local animals like sunbirds in South Africa or diurnal hawkmoths in Spain. We measured corolla reflectance spectra from native and non-native populations encompassing the different pollination contexts. Flower colour loci were represented in the visual space of tetrachromatic birds and trichromatic hawkmoths. Variation in corolla reflectance spectra was revealed, both across pollination contexts and among populations. From the pollinators' point of view (hummingbirds, sunbirds and hawkmoths), flowers from native populations were, in general, significantly discriminated from those of the non-native populations, which mostly were not discriminated as different from each other. We discuss our findings under the hypothesis of pollinator-mediated colour selection and alternative evolutionary processes that may occur during invasions.

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The long stems characteristic of bat-pollinated flowers greatly reduce bat search times while foraging

Botanists have long noted that bat-adapted flowers tend to be particularly well-exposed, with long stems that position them away from other foliage. The selective advantage of this trait, however, has remained obscure. We captured nectar-feeding bats in cloud forests of Colombia and held them in flight cages to test the effects of floral exposure on foraging time (to find flowers of *Burmeistera succulenta*). Ten bats were exposed to four treatments: long or short floral stems, in either simple or complex backgrounds (i.e., surrounded by foliage). In simple backgrounds, bats showed no difference for long vs. short stems, while in complex backgrounds, bats took twice as long to locate short-stemmed

flowers. This suggests that increased flower exposure allows bat echolocation to better distinguish floral echoes from background clutter echoes. This, in turn, would favour the evolution of long stems to ensure flowers are discovered by bats and thus can successfully reproduce.

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Are bees and flowers tuned to each other? Variation in the natural frequency of buzz-pollinated flowers

Bees use vibrations to remove pollen from buzz-pollinated flowers. Vibrations at the natural frequency of stamens are amplified through resonance, resulting in higher amplitudes. Because pollen release depends on vibration amplitude, bees could increase pollen removal by vibrating at the natural frequency. Few studies have characterized the natural frequencies of stamens and compared them to bee vibration frequencies. We use laser vibrometry to characterise stamen natural frequency of six morphologically diverse, heterantherous *Solanum*. We also compare the frequency of bumblebee buzzes produced on two Solanum species with different natural frequencies. Stamen morphology and plant identity explain variation in natural frequencies, which fall between 45-295 Hz with most species <190 Hz, only partly overlapping bee vibrations. Our bumblebees buzz at 345 Hz, without changing frequency to match the stamen natural frequency. Our results suggest that pollen release induced by vibrations at stamen natural frequencies is not key to most buzz-pollination interactions.

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Three options are better than two: complementary nature of different pollination modes in *Salix caprea*

We studied four field populations of a dioecious willow, *Salix caprea*, which employs three different pollen vectors, i.e., wind, diurnal bees, and nocturnal moths. By comparing seed set among six bagging treatments, we found wind pollination was most strongly limited

by the distance to the nearest mate, as well as by the directional diversity of nearby mates. Nocturnal pollination was much less effective than diurnal pollination but significantly increased total seed set in populations where wind pollination was ineffective. The onset of flower anthesis peaked at sunset, which may be considered an adaptation to prioritize the visits by nocturnal moths over pollen wasting bees. Thus, *S. caprea* could reduce the risk of reproductive failure by combining the complementary pollination modes, while at the same time minimizing potential conflicts among them by opening flowers at dusk. The possible roles of such "adaptive generalization" in floral evolution deserve more attention.

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Pollen analysis using deep learning – better, stronger, faster

We present a new high throughput, automated method for pollen analysis, based on deep learning (convolutional neural networks, CNN). We have tested the method in a series of experiments, and performance of the CNN models is high with up to 98% accuracy for a model with 83 species. We have also validated the method using samples collected from bumblebees (which is a more challenging kind of test), and then obtained accuracies up to 8 % for 29 pollen types (species grouped based on how humans can separate them). Our digital pollen reference library, of fuchsine stained fresh pollen on scanned microscope slides, currently consists of over 100 plant species, with at least 1000 labelled pollen grains per species. Our system, if operated by a single person, can readily analyse (from slide preparation to data) up to 100 samples per day.

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Enhancing mason bee populations for sweet cherry pollination

Pollination services are provided by a mix of wild and managed pollinators. The most prominent managed pollinator, the Western honeybee, still faces high colony winter mortalities and in addition it might not be the most suitable pollinator across all crops. Sweet cherry (*Prunus avium*) is an economically important crop, but the early flowering period often with inclement weather conditions, is threatening sufficient pollination services by

honeybees. Mason bees have been shown to be efficient pollinators of sweet cherry flowers, are easy to manage and are active during lower temperatures compared to honeybees. However, little is known about how the active management of a mason bee species, *Osmia cornuta*, is affecting sweet cherry yield. Our preliminary results show that by providing artificial nesting material, mason bees are more frequently visiting sweet cherry flowers. However, we could not detect an effect of their abundance on pollination service provisioning in sweet cherry orchards.

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Plant-pollinator networks in Australian urban bushland remnants are not structurally equivalent to those in residential gardens

Urbanisation may disrupt the interactions between pollinators such as bees and the flowering plants that they visit. We used a network approach, which goes beyond simple metrics of abundance and species richness, to understand how the structure of plant-pollinator communities were affected by urbanisation. We compared pollination networks between seven native vegetation (bushland) remnants and seven residential gardens in the urbanised southwest Australian biodiversity hotspot. Extinction slope, network robustness and nestedness were higher for bushland remnants, suggesting these networks had greater integrity, but if disrupted, more cascading extinctions could occur. Pollinator-level niche overlap was higher in residential gardens, suggesting greater competition for resources. The only species-level property that differed between habitats, normalised degree, was higher in bushland remnants. In conclusion, pollination networks in managed residential gardens are not structurally equivalent with those in bushland remnants. Removal of remnant native vegetation for residential development may disrupt the integrity of plant-pollinator assemblages.

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

A classic view of bird and insect pollination is that floral scent plays little role in bird pollination but is important for insect pollination. However, few studies have directly measured floral scents across these pollination syndromes. Therefore, we set out to test the hypotheses that the floral scent bouquets, as an attractive trait to pollinators, reflect their pollinators. Here we analyse floral scent bouquets of 29 species of the genus *Penstemon* that differ in whether they are pollinated by insects (mainly bees) or hummingbirds. Initial results showed that total scent did not dramatically differ between pollinator syndromes, but the devil is in the details. Here we tested whether there is a direct association between individual scent compounds and scent compound classes with pollinator syndromes. Our results show that floral scent bouquets do not necessarily follow simple predictions for pollination syndromes and suggest these simple hypotheses may need revisiting.

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Potential impacts of pollinator declines on plant seed production and population viability

Widespread declines in the abundance and diversity of pollinating animals may threaten plant diversity and ecosystem function, yet the impact of pollinator decline is not clear because some plants can produce seeds without pollinators by self-fertilisation and declines in plant reproduction do not necessarily translate into declines in population size. We compiled a global dataset quantifying seed production in the presence and absence of animal pollinators for 1174 animal-pollinated plants to assess the contribution of animal pollinators to plant seed production. This dataset showed that in the absence of animal pollinators, a third of flowering plant species would not reproduce by seed at all and half would have 80% less seed production. In addition, we explore impacts on population growth rate and population viability during recovery from disturbances (transient dynamics). Despite considerable impacts of reduced reproduction on transient phase population growth rates,

reduced reproduction exacerbates extinction risk more strongly through asymptotic than transient dynamics.

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Plants taking charge: Autonomous self-pollination as response to plants-pollinator mismatch in *Fritillaria persica*

Floral colour is a visual cue to pollinators and of great importance in shaping plant-pollinator interactions. Directional selection creates uniformity of floral colour, but rare cases of colour variation are important to study the evolution of floral colours. In the geophyte *Fritillaria persica*, both cream-greenish and purple floral colour morphs were described. We tested the hypothesis that existence of both colour morphs is maintained through differential pollinator spectrum and visitation rate, due to differences in colour perception and nectar properties (sugar and amino acids). We propose also increased autonomous self-pollination is response to seasonal mismatch between flowering and pollinator emergence, and/or to differences in the pollination efficiency, which is hypothesized to vary between colour morphs.

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Quantifying exposure of bumblebee queens to pesticide residues when hibernating in agricultural soils

In temperate regions, bumblebee (*Bombus* spp.) queens hibernate underground for several months, potentially putting them at high risk of exposure to soil contaminants. To generate field pesticide exposure estimates for overwintering bumblebee queens, we sampled soils adjacent to agricultural fields, corresponding to likely hibernation sites, from 19 diversified farms and apple orchards throughout Southern Ontario (Canada) in early autumn 2019. Multi-pesticide residue analyses (UPLC-MS/MS) detected pesticide residues in all 36 soil samples: herbicides were the most frequently detected (92% of samples), followed by insecticides (86%), and fungicides (67%). Residue levels were highest in orchard soil samples, and our results suggest bumblebee queens hibernating in agricultural areas may

be at a high risk of exposure to low-moderate levels of a broad range of pesticide residues in soil. The exposure estimates generated in our study will be used to design realistic experiments to investigate the potential effects of such exposure for bumblebees.

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Within-population flower colour variation: beyond pollinator-mediated selection

Flower colour is among the most conspicuous and highly diverse traits in nature. Most flowering plant populations have uniform floral colours, but a minority exhibit within-population flower colour variation, either discrete (polymorphic) or continuous. We discuss the evolutionary drivers that create and maintain within-population flower colour variation. Colour variation most commonly is maintained by balancing selection through multiple pollinators, contrasting biotic and abiotic selection regimes, or fluctuating selection. Variation can be also maintained by heterozygote advantage and frequency-dependent selection. Neutral processes, or lack of selection, may maintain variation, although this remains largely untested. We suggest several prospective research directions in the area of flower colour evolution and propose that such work may provide insight into the evolutionary theory regarding drivers of variation and its maintenance in nature.

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

Flowering phenology is crucial to reproductive success. However, most studies examine singular components of flowering phenology in natural populations, such as date of onset or flower abundance, and fail to account for individual variation in flowering schedule. Additionally, studies of among-plant variation in patterns of flower deployment can provide important insights concerning mating patterns. In this study, we raised plants from 9 populations of *Mimulus ringens* in a common garden. Flowers in this species last for a single morning. We recorded the daily floral display for the duration of the flowering period, and quantified components of flowering phenology, including date of initiation, total abundance,

duration, and synchrony. Individual flowering schedules vary widely within and among populations. Plants that flower early also flower for longer and therefore have greater fecundity. Within populations, flowering synchrony varies markedly and may influence mate diversity and effective population size.

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The combined effects of resource-landscape and herbivory on pollination services in agro-ecosystems

Distribution of foraging resources across habitats in agricultural landscapes is expected to shape the activity of ecosystem service providers. However, little is known about the role of resource-landscape on pollination services and how it is affected by herbivory. Here we combined empirical and statistical neighbourhood modelling to explore the effect of flower cover and aphid herbivory on pollination in agricultural landscapes. In each of 25 Mediterranean landscapes, spanning a gradient of land-use intensity, we established a pair of arrays of potted model plants that were either aphid-infested or aphid-free. In each array, we recorded insect flower visitor activity and seed-set. Simultaneously, we recorded flower density 1 km around each array. Neighbourhood analyses revealed a negative (competitive) effect of flower cover on pollinators activity and seed set of model plants, but this effect was stronger on aphid-infested than aphid-free plants. Our results highlight the importance of resource-landscape for mapping pollination services.

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Foraging on left-overs: comparative resource use in diurnal and nocturnal bees

Some bees have evolved adaptations for a nocturnal lifestyle, representing a poorly understood and recent niche. Sustenance within this niche was studied by examining flower-use in a nocturnal carpenter bee (*Xylocopa tranquebarica*) in comparison to diurnal congenerics. Flower observations and body pollen loads indicate that *X. tranquebarica* is

opportunistic on residual resources from day-opening flowers and substantially overlaps with diurnal bees. The greater pollen load diversity on individual foragers indicates lower floral constancy in *X. tranquebarica* compared to diurnal species. Reduced foraging on darker moon phases suggests constraints despite well-known visual adaptations. The salience of nocturnal bees as night-time pollinators is not fully understood, however these results suggest a role in the reproductive assurance of plants with nocturnal and even diurnal anthesis.

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Adaptive plasticity of floral display and its limits

Floral longevity, the amount of time a flower remains open and receptive, is thought to be shaped by selection, with the outcome hinging on the rate and shape of fitness gain curves balanced by floral maintenance costs. In variable pollination environments, plasticity of floral longevity in response to pollination could enable plants to respond to shifting gain curves and thus track shifting optimal longevity. We experimentally demonstrated how plasticity in floral longevity can be adaptive in a wild biennial plant. Plants under reduced pollinator visitation had slower rates of pollen accumulation but longer-lived flowers that ultimately arrived at similar total pollen loads and seed set as plants under high pollinator visitation. However, we also illustrate a decline in the ability to maintain longer floral lifespans across the season and costs of delayed fertilization, which together place strong limits to achieving optimal longevity.

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Nectar supply in gardens: spatial and temporal variation

Residential gardens are a valuable habitat for insect pollinators and cover a substantial area in aggregate, approximately a fifth to a third of UK cities and 3.5% of England. We repeatedly surveyed 59 urban gardens in Bristol, UK, to investigate how nectar supply varies in space and time. We found substantial variation in nectar production among gardens and only a relatively weak temporal effect, with production peaking in summer.

However, despite strong variation among gardens, nectar supply was relatively stable through time at a landscape scale due to the 'portfolio effect', in which fluctuations among gardens tend to 'average out' at aggregated scales. Turnover in species composition among gardens drives the extremely high flowering plant richness found in urban landscapes and we also identified important differences the species composition of the nectar supply through the year. Our results help us develop evidence-based management recommendations for conserving pollinators in urban areas.

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Plant-pollinator interactions in sub-Saharan agroecosystems

The global awareness about the pollinator insects decline is enhancing the need for a deeper comprehension of the effects related to human activities, especially in those areas facing rapid changes of natural landscapes. In the present study we combined field observation with GIS-landscape description and DNA-based approaches to analyse how urban and peri-urban agriculture affect plant-pollinator community composition and interactions in 26 farms in the district of Arusha, north Tanzania. Our results highlight that pollinator-plant communities' composition and interactions are affected by the level of urbanization around farmland, with fewer insects and higher overlap in the collected resources in highly urbanized farms. Plant resource density and richness were also found to positively affect the presence of pollinators and, indirectly, the overall stability of interaction networks. Overall, we offered new insights for the conservation of pollinator insects in a country where the awareness about the importance of pollinators in agriculture is starting to grow.

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Landscape change reduces pollen quality indirectly by shifting the functional composition of pollinator communities

Landscape change can reduce plant reproductive success by limiting pollen quality. These effects may be direct, when landscape change reduces the availability of pollen donors, or indirect, when decreased pollen quality results from shifts in the composition of the pollinator community. We quantified the direct, pollen-donor-mediated and indirect, pollinator-mediated effects of landscape change on pollen quality in *Heliconia tortuosa*, a tropical herb pollinated by low- and high-mobility hummingbirds. Although we did not detect any significant direct, pollen-donor-mediated effects of landscape change on pollen quality, reductions in forest cover and patch size resulted in functional shifts that filtered out high-mobility hummingbirds from the pollinator community, thereby reducing pollen quality indirectly. Our results indicate that pollen quality strongly depends on the functional composition of the pollinator community. Functional shifts that filter out highly mobile pollinators reduce the transfer of genetically diverse pollen loads from unrelated plants.

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Bees vs flies: Comparison of non-flight vibrations and implications for buzz pollination

Buzz pollination, a pollination syndrome involving flowers with specialised morphology and insects that use vibrations to remove pollen from anthers, is widespread across angiosperms. The ability to buzz-pollinate is almost entirely restricted to female bees. Flies, despite being important flower visitors are not usually known to apply vibrations for pollen removal. Here we compare the non-flight thoracic vibrations produced by different species of bees (Hymenoptera) and hoverflies (Diptera: Syrphidae) and determine their capacity to achieve peak acceleration magnitudes previously shown to elicit pollen release from buzz-pollinated flowers. We discuss hypotheses to explain why flies, and some bees, do not buzz pollinate.

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Quantifying plant-pollinator interactions in the Prairie Coteau

Community structure contributes to ecosystem persistence and stability. To understand the mechanisms underlying pollination and community stability in a human influenced landscape, a reliable understanding of the interaction patterns between plants and pollinators in disturbed landscapes is needed. The Northern Great Plains still retain tracts of remnant northern tall grass prairie habitat within a matrix of varying land-uses. We used a network-based approach to quantify how prairie attributes and landscape heterogeneity influence plant-pollinator community structure. We also quantified pollinator diversity, abundance, and floral diversity to assess the functional role of prairie attributes and the surrounding landscape on the plant-pollinator community. We found that the amount of local plant sugar and increased proportions of certain land-uses contribute to pollinator diversity that in turn influences the structure of interactions between plants and pollinators. Understanding the factors contributing to plant-pollinator networks can benefit management decisions resulting in resilient plant-pollinator communities and conserve the stability of pollination services.

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Resource intake of stingless bee colonies in a tropical ecosystem in Ecuador

Stingless bees (Apidae: Meliponini) represent one major pollinator group in tropical forests. Tropical forests are undergoing extreme habitat changes and losses, which affect floral communities and put at risk biodiversity and associated ecosystem services, such as pollination provided by stingless bees. Even though, stingless bees pollinate a large spectrum of tropical plant species, we often know little about their foraging behaviour and resource intake. A better understanding of species-specific differences in resource intake is

essential for unravelling their role in tropical plant-pollinator interaction networks, and to improve conservation programs aimed at supporting these pollinators in altered ecosystems. Here we show how foraging strategy (group or solitary) and percentage of collected resin can influence the foraging activity, pollen and nectar intake, and richness of floral sources visited (obtained from collected pollen via DNA-metabarcoding) by eleven stingless bee colonies (seven different species) in two nature reserves in the Esmeraldas Province, Ecuador.

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To leave or to stay? Answers from migratory waggle dances in *Apis dorsata*

Honeybees use waggle dances to transfer spatial information about resource availability to hive-mates. Previous studies have shown that nest movement in artificially induced swarms are preceded by waggle dances in which waggle runs show high variation in the distance signalled and have been termed as migratory dances. Earlier studies on this behaviour have employed artificially generated swarms during which colonies had no choice but to migrate immediately. We revisit migration by decoding dances in colonies of the giant honeybee *Apis dorsata* across two Indian habitats. We show here that 'migratory dances' are not a sufficient indicator of ensuing migration. We conclude that migratory dances may serve more than one purpose and may be part of a larger response of honeybee colonies towards environmental stress, and presence of floral resources all year round, such as in urban green spaces, can potentially delay migration in *A. dorsata*.

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Reintroducing *Carterocephalus palaemon* to England: using the legacy of a locally extinct butterfly as a (morpho)metric of future success

Reintroduced to Rockingham Forest in 2018 as part of the Butterfly Conservation-led Back from the Brink project 'Roots of Rockingham', the chequered skipper butterfly *Carterocephalus palaemon* has returned to its former English stronghold in Northamptonshire for the first time in 42 years after the translocation of adult stock from Belgium. Causes of the native English butterfly's decline and eventual extirpation in 1976 are

poorly understood however and researching the history and ecology of a locally extinct species that existed exclusively in a pre-digital age is challenging. An interdisciplinary approach to data collection is required to assess how abundance and distribution was influenced by environmental factors over centuries. Novel methods are utilised, including analysis of the external morphology of generations of digitally catalogued specimens using landmarking to identify variations in taxonomic features between (meta)populations. Findings will explain why local extinction occurred and help to predict the likelihood of reestablishment in England.

See you in 2021 for the 35th annual SCAPE meeting!