Welcome to SCAPE 2008

The 22nd meeting of the Scandinavian Association of Pollination Ecologists

Kaupanger, Norway, 17-19 October 2008

The Programme

Programme for SCAPE 2008

Overview

Friday

16.00-	Arrival and Registration
18.00-20.00	Dinner
20.15	Welcome to SCAPE 2008 (practical information: Stein J.Hegland)
20.20	Poster session (chaired by Anders Nielsen)
21.15-	Social interactions in the bar (pollination-quiz by quizmaster Prof. Ørjan)

Saturday

8.00-9.00	Breakfast
9.00	Welcome to SCAPE 2008 II
9.15-10.15	Session 1
10.15-10.30	Coffee break
10.30-11.30	Session 2
11.30-11.45	Fruit Break
11.45-12.45	Session 3
12.45-15.00	Lunch
15.00-16.00	Session 4
16.00-16.30	Coffee break
16.30-17.30	Session 5
19.00	Dinner
20.30-	Social interactions in party cabin (music: Dj Nielsen, SCAPE-bar, and sauna!)

Sunday

9.00-10.00	Breakfast
10.00-11.00	Session 6
11.00-11.15	Coffee break
11.15-12.15	Session 7
12.15-12.30	Farewell/SCAPE 2009
12.30	Lunch

Busses leaving to Oslo and Bergen: ca. 14.30 (or 11.30)
Airport coach at 13.10 or 17.00, Airplanes to Oslo or Bergen at 14.30 or 18.15

Excursion leaves at ca.13.30 for culture and nature experiences.

Detailed scientific programme

Poster session
Friday

Time: 20.20-21.15
Chair:
Posters will be presented in order of appearance in the seminar-room.
Presentation time 5 minutes per poster, please leave ca. 2 of these for questions

Talks

20 minutes per presentation, please leave ca. 5 minutes for questions.

Saturday

Session 1: Sex, sense and attraction
Time: 9.00-10.15
Chair: Stein Joar Hegland
Talks:
1) Klaus Lunau: Colour preferences of pollen eating insects
2) Robert R. Junker: Scents as floral filters: the challenge to attract *and* defend
3) Knut Rydgren: Population growth rate in the clonal moss *Hylocomium splendens* as a function of sporophyte frequency and sex ratio

(Coffee break)

Session 2: Pollination networks
Time: 10.30-11.30
Chair: Jens Olesen
Talks:
1) Martina Stang: Size-specific interaction patterns and size matching in plant-pollinator interaction webs
2) Christopher N. Kaiser-Bunbury: How does habitat degradation modify the structure of pollination webs of Seychelles inselbergs?
3) Yoko L. Dupont: Spatial and temporal robustness of modular structure and network keystone species in Danish heathland pollination networks

(Fruit Break)

Session 3: Environmental impacts on plant-pollinator interactions
Time: 11.45-12.45
Chair: Ørjan Totland
Talks:
1) Elizabeth Crone: Life history traits predict pollinator responses to disturbance and landscape change
2) Jane Stout: Impacts of invasive species on native plant-pollinator interactions
3) Anders Nielsen: Effects of plant population structure on flower visitation and seed set of wild plants at two spatial scales: a pan-European approach

(Lunch)

Session 4: Climate change and pollination interactions
Time: 15.30-16.30
Chair: Jane Stout
Talks:
1) Oliver Schweiger: Spatial mismatch of interacting species in the course of climate change
2) Roosa Leimu: Plant phenology as response to climate change: synthesizing effects of plant traits and potential for microevolution
3) Stein Joar Hegland: Climate warming and plant pollinator interactions: a review

(Coffee Break)

Session 5: Adaptation and life history
Time: 16.30-18.00
Chair: Jon Ågren
Talks:
1) Mariken Kjøhl: Experimental assessment of the qualitative and quantitative components of pollen limitation in alpine *Ranunculus acris*
2) Jaboury Ghazoul: Non-viable seed set enhances plant fitness: the sacrificial sibling hypothesis
3) Bodil K. Ehlers: How plants may locally adapt to other plants

Sunday

Session 6: Plant tolerance and resistance to herbivory and environmental stress
Time: 10.00-11.00
Chair: Roosa Leimu
Talks:
1) Elin Boalt Effects of ploidy level and herbivore pressure on tolerance to herbivory in *Cardamine pratensis*.
2) Anne Muola: Genetic variation and constraints in plant resistance and tolerance
3) Andrea Coulter: Establishing additional functions for the conifer ovular secretion

(Coffee Break)

Session 7: Pollination success, hybridisation and specialisation
Time: 11.15-12.15
Chair: Bodil K. Ehlers
Talks:
1) Anne Jäkäläniemi: Pollination and fruit production of rare northern orchid *Calypso bulbosa*
2) Laurent Natalis: Pollinator behaviour, pollen transfer and hybrid formation between *Rhinanthus minor* and *R. angustifolius*
3) Bo Dalsgaard: Plant-hummingbird interactions in the West Indies: floral specialization gradients associated with environment and hummingbird size

Posters at SCAPE 2008

Variation in the size of plants and the reproductive success in central and peripheral populations of *Daphne laureola*

Antonio Castilla

Doñana Biological Station, Spain

Biogeographic models predict that geographically peripheral populations should be smaller, more sparsely distributed and have a lower per-capita reproductive rate than populations near the centre of a species' range. This idea is supported by the next assumption: individuals of peripheral populations experiment more stressful ecological conditions than those of central populations. In this study, we want to test if individuals of peripheral populations of *Daphne laureola* have lower individual size, floral display and female reproductive success than those of central populations. On the other hand, *D.laureola* is gynodioecious specie and we were interested in differences between sexes. In concrete, we tested if females had some advantage, in relation with the plant size and/or the female reproductive success, in a stressful situation as the borders of distribution.

Our results support a higher ecological stress in the border of distribution of the study region. Plants of central populations showed higher areas, number of whorls, floral displays and fruit production than plants of peripheral populations. Nevertheless, fruit set was higher in plants of border suggesting a more efficient behaviour of pollinators in these populations. Hermaphrodites and females didn't show differences neither plant size, nor floral display, nor per-capita reproductive rate, both central and marginal populations. This result support an insignificant cost of male function in *D. laureola* or that extra resources becoming available to females are mostly redirected to a qualitative improvement of fruits and seeds.

A historical comparison of bumblebee diversity in red clover fields in Denmark

Kirsten Haugaard Wermuth

Aarhus University, Denmark.

Since the intensification of the Danish agriculture in the 1950 and 1960's decline in the bumblebee population has become more and more pronounced. The main goal of this study is to investigate the historical change in abundance data and species diversity of *Bombus* spp. in red clover fields in Denmark. We compare data from the island of Fun collected in the 1930's with data collected this year in the same areas on Fun in addition to East Jutland. Another aim of the study was to investigate factors related to the bumblebee diversity. The study fields included both organic and conventional fields, and fields of different size, shape and surroundings, particularly presence/absence of hedgerows. These factors may affect the population size and diversity of bumblebees. We also investigate if the bumblebees prefer the middle or the edge of the field and comparing of the yield and the number of bumblebees found. Thirdly, we examine bumblebees for multiple viruses, which have caused a high death rate among honey bees this year and may have spread to the bumblebees.

What makes attractive plants attractive?

Effects of floral display size on pollinator behavior

Annette Kolb, Marina Jofe & Dorothea Brückner

Department of Ecology and Evolutionary Biology, University of Bremen,

Many plant species depend on pollination by insects for successful reproduction. Pollinator behavior in turn may be influenced by plant phenotypic traits such as plant size, floral display and flowering phenology. Correspondingly, interactions between plants and pollinators are generally considered to be of fundamental importance to trait evolution in plants. In this study we experimentally investigated effects of floral display size on pollinator behavior in the self-incompatible, perennial herb *Phyteuma spicatum* (Campanulaceae). *Phyteuma spicatum* is mainly pollinated by bumblebees. First, we used artificial arrays of potted plants to test for effects of inflorescence height and size on visitation by *Bombus pascuorum, Bombus pratorum* and *Bombus terrestris*. Plants with tall or large inflorescences received more pollinator visits than shorter plants or plants with smaller inflorescences, irrespective of total inflorescence density in the array. Second, we used a Y-shaped maze to investigate spontaneous choice and learning of floral display traits, using *Bombus terrestris*. We found a high spontaneous choice for plants with large and multiple inflorescences (compared to plants with small and single inflorescences), which could be partly enhanced by learning. In summary, floral display traits strongly influence pollination in *Phyteuma spicatum*, which is likely to cause differences in plant reproductive success and might shape the evolution of reproductive characters.

Nectar choice behaviour by *Maniola jurtina* in agricultural landscapes

Julie Lebeau, Renate Wesselingh and Hans VanDyck

Laboratoire d'Ecologie et de biogéographie, Centre de Recherche sur la biodiversité, Université Catholique de Louvain, Louvain-la-Neuve, Belgique

This study takes place in the context of habitat selection by individuals, which implies a behavioural response to certain environmental cues, among them ecological resources, such as food for example. Such ecological resources are typically spread heterogeneously over time and space. Ecosystems under severe anthropogenic influence (e.g. agricultural landscapes) provide an interesting model for the study of behavioural response to major changes in environmental conditions.

The studied species, *Maniola jurtina*, is a common satyrid species in our agricultural landscape, typically found in grasslands and in uncultivated area such as roadsides and hedgerows. The ecological resource in focus in this study is nectar, the main food source for the adult butterflies. Nectar choice behaviour is observed in four sites located in the Famenne region in Belgium, all of them being permanent grassland bordered by a wooded area on the north side, with similar soil and climate conditions. Two of them are managed intensively, while the other two are located in natural reserves and are extensively managed. Since nectar offer varies from one site to another, we might expect butterflies to change their behaviour towards nectar choice accordingly. Moreover, feeding behaviour is expected to be made in order to optimize fitness. Nectar choice experiments associated with study of life history traits are considered to assess whether butterflies make their choice so that they optimize their fitness.

Yeast inhabiting *Helleborus foetidus* (Ranunculaceae) nectar: spatial and temporal patterns

María Isabel Pozo Romero

Doñana Biological Station, Spain

Nectar is considered the most important reward in most angiosperms plants, and during last decades it had been emphasized the adaptativo role of chemical composition in pollinator attraction. Although the presence of yeast communities living en nectar of angiosperms flowers is well known for microbiologists since more than one century ago, the ecological role of nectar-inhabiting yeasts remain unexplored yet. Only recent investigations have shown how yeast metabolism changes nectar composition, dramatically decreasing energetic value for pollinators. In this context, we think that should be interesting for pollinator biologists to measure quantitative data and patterns of yeasts inhabiting floral nectar in natural conditions.

Here we show that incidence of yeast in nectar vary widely in the wild, including their frequency and abundance across habitats (six populations located by pairs in an altitudinal gradient) and across flowering period
(three collection dates for one population) in Helleborus foetidus (Ranunculaceae) plants, in Southeastern Spain.

So, we focused on smaller scales of study, measuring how variance could be attributable at differences inter individual plants, flower within plants and nectaries within flowers. The extreme intraplant variation in yeast incidence found in this study for H. foetidus may have important consequences for pollinators, since it occurs at the single nectary, the smallest scale like it is perceived by a foranging insect.

Arthropod diversity in *Vincetoxicum hirundinaria* populations in south-western Finland -Comparing "true" diversity between higher level taxa and species level taxa-

Eero J. Vesterinen[1*], Anne Muola[1], Liisa Laukkanen[1], Marianna Lilley[1], Ilari E. Sääksjärvi[1], Pia Mutikainen[2], & Roosa Leimu[3]

[1] Section of Ecology, University of Turku, [2] Institute of Integrative Biology, ETH-Zurich, [3] Department of Plant Sciences, University of Oxford

Diversity of living organisms is much studied and especially measuring of biodiversity has been debated. However, the importance of the different attempts to describe diversity has seldom been questioned. Conservation of both economically and ecologically important areas and levels of biodiversity requires some estimates for diversity. A good parameter of diversity would enable comparison between separate locations and contain all the information about diversity in the studied areas. In most cases, it is, however, impossible to collect all species occurring in an area, which has led to many kinds of biodiversity indicators. In this study we examined arthropod diversity in 22 populations of *Vincetoxicum hirundinaria* (Asclepiadaceae) in south-western Finland to test recently updated "true" diversity indices and to compare figures calculated from higher taxa to those calculated from species level data. We aim to test whether some higher taxa of Arthropoda describe the diversity in the same way as species. This would have several advantages to traditional sampling methods. We collected Arthropoda using window traps during the summer 2007. The samples were first grouped into orders. We further classified certain categories to species level. So far few groups are determined to species. In the near future, most of the remaining groups will be determined to species. In addition we will examine how diversity varies on a mainland–island gradient and how it is influenced by the size and age of the islands and *V. hirundinaria* populations. Moreover, we will identify potential pollinators and estimate their abundances in the plant populations.

Ants visiting *Euphorbia cyparissias* – flowers of uninfected and pseudoflowers of rust-fungus infected plants: A look on the role of odour for orientation

Manja Wendt, Michael Rostás

Department of Botany II – Ecophysiology and Vegetation Ecology, University of Würzburg

Ants, among a variety of other insects, have been shown to participate in the pollination of Cypress spurge, *Euphorbia cyparissias* (Euphorbiaceae). As the result of an infection with the rust fungus *Uromyces pisi* the plant´s reproduction is surpressed. Moreover, *U. pisi* causes considerable alterations in habitus and physiology. It induces development of a so-called pseudoflower offering nectar containing fungal gametes (spermatia). The fungus is dependent on insects for transport of those spermatia onto fungus-infected plants of the opposing mating type for continuation of it`s lifecycle. Although ants contribute to pollen carriage between uninfected *E. cyparissias* they do not act as vectors in fungus spermatia exchange.

We use the distinct parts that ants play in pollen and spermatia transfer in the interacting system of *E. cyparissias* and *U. pisi* to estimate nectarivorous ants` foraging strategies. We ask whether ants use odour or other factors for orientation. Both, uninfected and infected plants emit a strong and pleasant honey-like scent, that is however well distinguishable.

In the field we find that ants and other insects prefer uninfected over rust-fungus infected *E. cyparissias* for nectar gathering. Visitors also seem to compete for *E. cyparissias* nectar, a situation which might be aggravated by its early flowering season.

Do ants use odour signals for finding their preferred nectar source? Under laboratory conditions we tested individual ants in a Y-maze offering them the odour of uninfected and rust-fungus infected *E. cyparissias* simultaneously. We find that they do not distinguish between or prefer either of the odour bouquets.

Talks at SCAPE 2008

Colour preferences of pollen eating insects

Klaus Lunau

Sensory Ecology Group, Heinrich-Heine-University, Düsseldorf, Germany

Flower-visitors exhibiting colour preferences rank flowers according to parameters of their colour properties. Colour vision of flower-visitors may differ fundamentally from human colour vision due to less sensitivity in the range of red wavelengths, additional perception of ultraviolet light, a deviant number of photoreceptor types contributing to colour vision, or different neuronal processing of photoreceptor excitation. Moreover, whether a flower-visiting species exhibits colour vision and which colour parameters it uses for orientation has to be tested. In the talk three main questions are addressed: Do flower-visiting insects possess innate flower colour preferences? Do flower-visiting insects possess innate pollen colour preferences? How do innate colour preferences affect colour learning? Hoverflies (*Eristalis tenax*) and bumblebees (*Bombus terrestris*) show innate colour preferences aimed at flower colours. Moreover, they respond spontaneously to visual colour properties of stamens and pollen. *Eristalis tenax* extends its proboscis preferably towards small colour patches that reflect light in the range of wavelength from 510 - 600 nm. Small amounts of ultraviolet and blue light inhibit the proboscis reflex. The hoverflies cannot be trained to show the proboscis reaction towards other colours than yellow. Before landing, *Bombus terrestris* workers target at small colour patches of high spectral purity and of high colour contrast to the surrounding colour. The antenna reaction towards anther-mimicking colour patches hampers learning of discriminative cues. The colour preferences shown in spontaneous choice tests with naïve and untrained individuals, and in colour learning experiments with pre-trained individuals are discussed with respects to the flower colour choices of bees and hoverflies foraging in their natural habitats.

Scents as floral filters: the challenge to attract *and* defend

Robert R. Junker, Nico Blüthgen

Department of Animal Ecology & Tropical Biology, University of Würzburg, Germany

Not all flower visitors are pollinating mutualists, other organisms such as herbivores, nectar-thieves or even microorganisms are interested in floral resources but are unable to pollinate. Therefore, flowers require attractive and protective measures. We demonstrate that floral scents possess, next to the attractive function, also a defensive function which may even be more pronounced.

Both functions were tested in a community context (interaction network) in an old field in Würzburg, Germany. Flower-visitor interactions were assigned as "hot" and "cold links", corresponding to higher or lower observation frequency than expected by a null-model. Using a mobile olfactometer, we tested whether the "link temperature" can be explained by the animal's response to scents emitted by the flower.

Overall, we found a strong positive correlation between the "link temperature" and the animal's responses. This confirms that floral scents contribute to the partitioning of flower visitors among different plant species. Moreover, the experience of flower visitors affected the response of many visitors, suggesting that associative learning is involved in flower fidelity. A meta-analysis suggests an underlying mechanism that is able to explain these contrasting functions: the dependency on floral resources determines the response to floral scents.

Microorganisms have been overlooked in floral ecology, although they may have negative effects on plant's reproduction or even infect pollinators. The ubiquity of potentially harmful bacteria suggests that our hypothesis that floral scents act as defence may also be extended to microscopic flower "visitors". We therefore compared the microbial community on flowers and leaves from two plant species.

These results indicate that volatiles act as floral filters that promote the visitation of some visitors and inhibit others.

Population growth rate in the clonal moss *Hylocomium splendens* as a function of sporophyte frequency and sex ratio

Knut Rydgren[1], Rune H. Økland[2] & Nils Cronberg[3]

[1] Sogn og Fjordane University College, Norway; [2] Natural History Museum, University of Oslo, Norway; [3] Plant Ecology and Systematics, Lund University, Sweden

Unisexual bryophytes normally have imbalanced sex ratios, usually female biased in contrast to male biased in unisexual seed plants. The female bias in bryophytes is surprising since it is assumed that the females carry the largest cost during reproduction. One approach to understanding sex-ratio patterns is to study the influence of sex distribution on population growth rates (λ). We examined how variation in sex ratio and sporophyte frequency influenced λ by matrix modeling using a linear two-sex model followed by GLM analysis. We found strong variation in λ in response to variation in sex ratio and sporophyte frequency, with the highest λ observed at very low sporophyte frequency and at a slightly female-biased sex ratio. An explanation for this sex-ratio pattern, common among bryophytes, may be that males generally perform slightly poorer with respect to survival and vegetative offspring than non-sporophytic females.

Size-specific interaction patterns and size matching in plant-pollinator interaction webs

Martina Stang

Institute of Biology, University of Leiden, The Netherlands

Many recent studies show that plant-pollinator interaction webs exhibit consistent structural features such as long-tailed degree distributions of generalization, nestedness of interactions, and asymmetric interaction dependencies. Recognition of these shared features has led to a variety of mechanistic attempts at explanation. Here we hypothesize that beside size thresholds and species abundances the frequency distribution of sizes (nectar depths and proboscis lengths) will play a key role in determining observed interaction patterns. In an earlier study we showed that nectar-seeking pollinators found at flowers were random selections out of all potential visitors of the local community, i.e., all those with proboscises longer than the threshold imposed by nectar depth. This could be expected to lead to a closer size matching between nectar depth and proboscis length for plants with concealed nectar or pollinators with short proboscis than for plants with openly accessible nectar or pollinators with long proboscises. However, such an expectation ignores actual size distributions in the local community. To test the influence of size distributions we compared the observed degree of size matching between flowers and pollinators with the expected degree based on joint probability distributions, integrating size thresholds and abundance. Our results suggest that in addition to size thresholds and species abundances, size distributions are important for understanding interaction patterns in plant-pollinator webs. We propose that size-specific interaction patterns should be included in network studies to distinguish between different existing hypotheses that try to explain patterns of interaction among species.

How does habitat degradation modify the structure of pollination webs of Seychelles inselbergs?

Christopher N. Kaiser-Bunbury

ETH Zürich, Switzerland

Oceanic islands have undergone multiple ecological assaults since human colonisation. Invasion by introduced species has displaced critically endangered plants from their natural habitat, and created fragmented populations of endemics. On the Seychelles, such populations are mostly confined to granitic inselbergs where harsh abiotic conditions and isolated environment have provided some natural protection against invasive species. Inselberg species, however, may encounter strong reproductive constraints through disruption of their pollinator mutualisms by invasive plant species. We investigate plant–pollinator interaction within inselberg communities to determine the likelihood of such reproductive constraints. We link the structure of fully quantified networks of six sites that have varying degrees of invasion to the reproductive performance of endemics and invasives. Using such approaches we hope to further our understanding on vulnerabilities of rare endemics and thus to develop effective conservation measures in response.

Spatial and temporal robustness of modular structure and network keystone species in Danish heathland pollination networks

Yoko L. Dupont and Jens M. Olesen

University of Aarhus, Denmark

Modularity is a non-random structure of networks, when the network tends to be organized into sub-groups of species interacting more tightly with one another than with species outside the sub-group. Modularity of networks is a property, which has received much interest, but has been little investigated, mainly due to lack of a powerful method. Recently, however, Guimerà and Amaral (2005 *Nature*) developed a new computational tool, functional cartography by simulated annealing (FCSA), an optimization technique, which can reliably identify modules. Applying this algorithm to 51 pollination networks, Olesen et al. (2007 *PNAS*) showed that all large networks (>150 species) are significantly modular. In the current study, we investigate the robustness of modular structure in pollination networks from one habitat type (heathland) at three different sites, and in networks of different temporal scaling. We show that modularity is remarkably constant. Similar modules are found across sites, and modules are formed at an early stage, often remaining throughout the flowering season. Thus, modular organization of pollination networks is robust across space and time. This stability appears to be connected to the existence of a few (8-9) hub plant species. These are highly generalist plant species, which attract a large number of insect species. Modules mostly aggregate round one or two such hub plant species. Thus, hub plants may be regarded as network keystones.

Life history traits predict pollinator responses to disturbance and landscape change

Neal M. Williams, Elizabeth Crone, T'ai H. Roulston, Bob Minkley, Laurence Packer

Wildlife Biology, University of Montana, USA

The loss and degradation of habitat resulting from human activities are among the greatest threats to biological diversity and to the ecological interactions and functions that depend on this diversity. Pollination is one such function that is a critical to plant and animal persistence, and that increases with the diversity and abundance of pollinators in the communities. Like for other organisms, the tendency has been to consider natural habitats as good for pollinators and human altered habitats as uniformly bad, however, recent studies call this generalization into question. We used hierarchical modeling to test the responses of native bee communities to different landscape changes and other anthropogenic disturbances. The more detailed hierarchical model allows us to explore whether functional-trait groups respond differently to common disturbance types or respond consistently among disturbances. Here we define functional-trait groups as species with similar life histories, nesting strategies, body sizes, or foraging strategies. Overall, bees were less abundant in disturbed than undisturbed areas, across a broad group of studies and ecosystems. Furthermore, life history traits mediated responses to disturbance in logical ways, e.g.: smaller species were more sensitive to isolation, and ground-nesting bees were more sensitive to tilling in agricultural systems. While not surprising, these responses suggest that bee communities will change in nonrandom but somewhat predictable ways as land use changes.

Impacts of invasive alien plants on native pollinators

Jane C Stout, Anke C Dietzsch, Caroline M Nienhuis

Trinity College Dublin, Republic of Ireland

Although there is a rapidly growing body of research into the effects of invasive plants on native plant pollination via disruption of native mutualisms, there has been little research on the impacts of invasive plants directly on bees. Such impacts are likely to vary according to the taxa of plant, the functional specificity of the native bees, and ecosystem context. We present data from recent investigations into direct and indirect impacts of invasive alien plants on native bees in Ireland in terms of their foraging behaviour and population structure. We find some positive impacts of mass-flowering, highly rewarding invasive plants on generalist native bees, and discuss the implications of this finding.

Effects of plant population structure on flower visitation and seed set of wild plants at two spatial scales: a pan-European approach

Anders Nielsen[1], Jens Dauber[2], Jacobus Biesmeijer, Doreen Gabriel, William E. Kunin, Ellen Lamborn, Birgit Meyer, , Simon Potts, Virve Sõber, Ingolf Steffan-Dewenter, Jane Stout, Tiit Teder, Thomas Tscheulin, Daniele Vivarelli, Theodora Petanidou[1]

[1] University of the Aegean, Department of Geography, Greece; [2] University of Leeds, Institute of Integrative and Comparative Biology UK

Fragmentation and loss of seminatural habitats have become increasingly common phenomena in European cultural landscapes, leading to a likely decline in plants and their pollinators. Small plant populations often fail to recruit sufficient numbers of pollinators. This can lead to pollination limitation, which reduces plant fitness and impedes the long-term survival of small populations. The structure and spatial distribution of plant individuals within populations can have an effect on the number of pollinator visits and on the composition of deposited pollen.

To disentangle the causes of pollination limitation, we studied flower visitation and seed set of 10 different plant species in 75 populations in several fragmented habitats in 5 European countries. We focussed on both size and density of plant occurrence at two spatial scales, the population (i.e. all plant individuals of a focal species occurring in a habitat fragment) and the patch scale (i.e. distinct aggregations of the focal plant species within a population).

We have found the general pattern that seed set and flower visitation are primarily controlled by variables at the patch level, with higher number of visitors and seed set in larger and denser patches. For number of flower visitors we also found a significant interaction between patch size and patch density describing a higher number of visitors in large patches with intermediate flower density. In these models population level variables did not appear to have significant effects, suggesting that flower visitors move towards the plants based on behavioural decisions that are made on a relatively fine scale. Seed set in all plants increased with increasing patch extent and density. Population area was only significant in interaction with patch area and patch density, showing that the effects of patch extent and density are only apparent in small populations but not in large ones. The pattern of a strong patch level control was found both when modelling all 10 plant species and only the 8 self-incompatible (SI) species. In contrast, number of flower visitors appeared to have a significant effect on seed set only in SI plants.

We believe that effects of "rarity" (as defined by size and density of flower patches) interact between population and patch level, thus pollen limitation is controlled by processes operating at different spatial scales. Small plant populations don't seem to be more threatened than large populations, but important is the attractiveness of the flower patches at scales perceived by the pollinators.

Spatial mismatch of interacting species in the course of climate change

Oliver Schweiger[1,2], Josef Settele[1], Otakar Kudrna[3], Stefan Klotz[1,2], Ingolf Kühn[1,2]

[1]UFZ, Helmholtz Centre for Environmental Research, Department of Community Ecology; [2]Virtual Institute for Macroecology, Germany. [3]Schweinfur, Germany.

Recent climate change has already affected the distributions of many species but future changes are likely to have even more severe impacts. However, climate is only one determinant for the distribution of species but many other factors are likely to contribute, such as dispersal, land cover, and biotic interactions. Considering interactions, climate change may have unexpected consequences when the occurrence of one species is influenced by the occurrence of others. Current studies have evidenced temporal mismatching of interacting species at single points in space. However, we are not aware that the ranges of interacting species may become substantially spatially mismatched.

Based on separate ecological niche models of the monophagous butterfly *Boloria titania* and its larval host plant *Polygonum bistorta*, we show that all of three chosen global change scenarios (moderate, intermediate, maximum change) will result in a pronounced spatial mismatch of both species' future niche spaces within Europe. The butterfly may expand considerably its future range distribution (by 124-258%) if the host plant has unlimited dispersal, but it could loose 52-75% of its current range distribution if the host plant is not able to fill its ecological niche, and 79-88% if the butterfly also is assumed to be highly dispersal limited. This approach is expanded on 34 butterfly species and their host plants.

First results strongly suggest that climate change has the potential to disrupt trophic interactions because co-occurring species do not necessarily react in a similar manner to global change, having important consequences at ecological and evolutionary time scales.

Plant phenology as response to climate change: synthesizing effects of plant traits and potential for microevolution

Roosa Leimu

Department of Plant Sciences, University of Oxford, UK

Variation in phenology maintains species coexistence in diverse plant communities by reducing competition for pollinators and other resources. Long-term datasets on seasonal activities evidence changes in phenology due to climate change. Therefore, climate change can alter the structure and dynamics of plant communities. Variation in phenological trends has been attributed, for example, to different life history traits and pollination type. Moreover, temperature effects on phenology are suggested to be associated with other cues such as photoperiod. The generality of these predictions has not been tested and, despite its coolness, to what extent the observed changes are due to microevolution is unclear. To address these issues I conducted a meta-analysis on climate change effects on plant phenology examining 28 studies and 500 plant species. Moreover, I examined the potential for microevolution by calculating the average rates of evolution (change in phenology as response to climate change), in haldanes (*h*). The obtained estimates for overall advancement in spring phenology are 1.29 days/decade and 0.45 days/degree °C. The advancement in spring phenology was found to be influenced by longevity and pollination type, and to vary between wild and cultivated plants. Interestingly, at northern latitudes, long-day plants showed a significantly weaker response to increased temperature compared to day-neutral plants or short-day plants. This suggests that at these latitudes plants introduced or invading from southern latitudes where day-length requirements differ have a competitive advantage compared to native plants more sensitive to greater day length. Finally, on average the phenotypic rates of change in terms of Haldane (*h*) are smaller than 0.1 suggesting phenotypic evolution to be mostly sustainable.

How does climate warming affect plant-pollinator interactions?

Stein Joar Hegland[1], Anders Nielsen[1,2], Amparo Lázaro[1], Anne-Line Bjerknes[1] & Ørjan Totland[1]

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Climate warming affects the phenology, local abundance and large-scale distribution of plants and pollinators. Despite this, there is still limited knowledge of how elevated temperatures affect plant-pollinator mutualism and how changed availability of mutualistic partners influences the persistence of interacting species. Here we review the evidence of climate warming effects on plants and pollinators and discuss how their interactions may be affected by increased temperatures. The onset of flowering in plants and first appearance dates of pollinators in several cases appear to advance linearly in response to recent temperature increases. Phenological responses to climate warming may therefore potentially occur at parallel magnitude in plants and pollinators, although considerable variation in responses across species should be expected. Despite the overall similarities in responses, a few studies have shown that climate warming may generate temporal mismatches among the mutualistic partners. Mismatches in pollination interactions are still rarely explored and their demographic consequences are largely unknown. Studies on plant-pollinator networks indicates that pollination interactions overall might be robust against perturbations caused by climate warming. We suggest potential ways of studying warming-caused mismatches and their consequences for plant-pollinator interactions, and highlight the strengths and limitations of such approaches.

Experimental assessment of the quantitative and qualitative components of pollen limitation in alpine *Ranunculus acris*.

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Pollen limitation compromises two components. Quantity limitation occurs when plants receive an insufficient number of pollen grains for complete fertilization, and quality limitation occurs when plants receive pollen of low quality. Aizen and Harders dose-response model implies that female reproductive success of many plants may be chronically limited by pollen quality. However, the extent of quality and quantity limitation may not be recognized by the traditional experimental assessment of pollen limitation because these components are often confounded in the experiment. I examined the importance of pollen quality- and quantity for the female reproductive success in alpine *Ranunculus acris* at two different elevations in southwestern alpine Norway in 2007. Spatially constrained pollen- and seed dispersal may create a spatial genetic structure within populations. Pollen supplementations with assumed different pollen quality did not significant affect seed production, seed weight or fertilization rate, but there was a treatment effect on fertilization rate at low elevation. A close to significant treatment effect was found on abortion rate. The strongest effect of treatment was found at low elevation. The results indicate that quality limitation influences components of female reproduction in *R. acris* at some sites, but the overall effect of pollen quality appears to be weak.

Non-Viable Seed Set Enhances Plant Fitness: the Sacrificial Sibling Hypothesis

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Many tree species produce far more fruit than eventually mature, with a large proportion of developing fruit being aborted mid way through the development process. Whether this is a maternally controlled late-acting self-incompatibility mechanism, or an expression of inbreeding depression, is difficult to determine. In either case, however, selection is expected to favour early abortion of inbred or incompatible zygotes to minimise loss of resources. In many species this does not occur, suggesting the possibility of adaptive reasons for retaining selfed or inbred seed that are aborted at relatively late developmental stages. I propose that such seed serve an important function in diluting the impact of pre-dispersal seed predators by acting as seed predator sink and thereby increasing the survival probabilities of outcrossed and fully viable seed. I suggest that selfed seed retained and developed through the periods of seed predator attack are effectively offered and sacrificed for the benefit of outcrossed seed

How plants may locally adapt to each other

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Thyme species produce essential oils. The main constituent of these oils are terpenes, and a polymorphism exist for the production of different terpenes both within and among species. The leaching of terpenes to its surrounding modifies the local environment and affect the performance of associated species. Some studies have shown that associated plant species may adapt to the presence of specific terpenes by performing better on soil containing its "home" terpene relative to other terpenes.

Essential for local adaptation to evolve is the presence of heritable variation for an adaptive response to growing with a "chemical" neighbour. We raised seed families from three associated species originating from "naïve" populations (never growing with thyme) and experienced ones (growing with T. pulegiodes). Our results showed that for all three species, experienced plant performed significantly better on soil treated with T. pulegiodes terpene than naïve plants. Moreover, reaction norm showed more seed families with a positive response to the terpene from experienced populations compared to naïve ones. The results suggest that 1) heritable variation for an adaptive growth response exist in natural populations and 2) selection has indeed been operating resulting in significantly more seed families from experienced populations exhibiting a better growth on "terpene" soil compared to control soil.

Genetic variation and constraints in plant resistance and tolerance

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A starting point in understanding how interacting species evolve or co-evolve is to examine genetic variation in the key elements of the interaction. In plant-herbivore interactions this applies genetic variation in the major plant defense strategies, resistance and tolerance, but also whether there is genetic variation in how the herbivores perform on different plant genotypes. If resistance and tolerance have allocation costs, a trade-off between the two is expected assuming these strategies serve the same function for the plants. Therefore, to understand the evolution of plant defense strategies their joint evolution should be considered. We examined genetic variation in resistance and tolerance and the potential trade-offs between the two defense strategies in a perennial herb, *Vincetoxicum hirundinaria*, and one of its specialist herbivores. We also examined tolerance to artificial damage (clipping), to simulate grazing, which frequently occurs in some of the study populations. Finally, we examined genetic variation in how the herbivores perform on different plant genotypes. Here, we present the results from the plants' point of view concentrating on genetic variation and trade-offs in resistance against one of the specialist herbivores, *Abrostola asclepiadis*, and in tolerance to *A. asclepiadis* and artificial damage. We found genetic variation in resistance when determined as inverse of herbivore performance, but not when determined as inverse of damage. We also found genetic variation in tolerance to artificial damage (clipping), but not in tolerance to damage by *A. asclepiadis*. Although tolerance seems to have costs indicated by lower number of flowers and fertile stems (reproductive potential) of more tolerant plants the year after damage, we didn't find any trade-offs between resistance and tolerance traits. In our study system, resistance is likely to be the strategy to defend against the highly specialized herbivores and mostly determined by the defensive chemicals. Tolerance, in turn, is more likely to serve as a defense against grazing. Our results further add to the findings that the type of damage and measures used to determine resistance and tolerance may matter.

Establishing Additional Functions for the Conifer Ovular Secretion

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Conifer ovules produce a liquid secretion as part of sexual reproduction. The secretion fills and protrudes from the micropyle in close coincidence with pollination. Termed ovular secretions, these exudates are widespread among modern conifers. To date they have been observed in all families of Coniferophyta except the Araucariaceae. Within the families that do contain drops, only the genera *Saxegothaea* (the family Podocarpaceae), *Abies*, and some species of *Tsuga* (both from the family Pinaceae) do not produce secretions. Because gymnosperms lack the complex receptive tissues for pollen found in the angiosperms, ovular secretions are widely viewed as a mechanism to capture wind-borne pollen. Recently, our lab has identified proteins in the ovular secretions of six conifer species in three families (Taxaceae, Pinaceae, Cupressaceae) using proteomic techniques. These proteins represent a significant metabolic investment and suggest that ovular secretions function as more than a simple pollination mechanism.

The first step towards establishing additional functions for the ovular secretion is to demonstrate functions for the proteins found within it. However, this has proved to be difficult. Ovular secretions are, on average, 20 nL in volume and are present for approximately two weeks each year. This small size and ephemeral nature has limited our ability to collect enough protein to conduct functional assays. So far, heterologous expression of these proteins has not been fruitful. Currently, we are utilizing functional assays that can be conducted on the micro- and nanoscale.

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Pollination and fruit production of rare northern orchid *Calypso bulbosa*

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Some studies have suggested that reproductive success of non-rewarding orchids can decrease with population size and often small and isolated populations tend to fail to set fruits. In some cases, pollination success of non-rewarding species may increase with local abundance of rewarding species. Inside the populations, clumps of plants have been shown to have higher fruit set than single plants.

In the present study, we recorded pollination success of the non-rewarding, bumblebee-pollinated northern orchid *Calypso bulbosa* (L.) Oakes. The study was carried out in the Oulanka National park in Northern Finland. First we examined the reproductive system of *Calypso* using controlled pollinations and pollinator monitoring. Secondly we investigated the effect of population size and density on the fruit set. Then we studied if clumped distribution increased the reproductive success. Finally, we recorded the amount of pollinia removal in experimental population with rewarding *Salix*-species.

We found that hand-pollination increased fruit production in all populations, indicating pollen limitation. Self-pollination was possible with an external pollinating agent. Three different species of bumblebee queens were observed to carry pollinia. Fruit production did not correlate with the local population sizes or density of plants. Opposite to our hypothesis single plants had higher fruit set than clumped plants. The pollen removal was faster and higher in volume in patches with rewarding species, while the fruit production was only slightly higher.

Pollinator behaviour, pollen transfer and hybrid formation between *Rhinanthus minor* and *R. angustifolius*

Laurent Natalis & Renate A. Wesselingh

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Rhinanthus minor L. and *R. angustifolius* Gmelin are annual hemi-parasitic Orobancaceae growing in very similar ecological niches and both bumblebee-pollinated. The flowering periods and geographical ranges of these species largely overlap in Europe, and in certain localities hybridation and introgression occur. In our lab and in the field we try to understand how this natural hybridation works by exploring the ecological, ethological and physiological borders between these two closely related species.

We have measured pollen tube growth rates in con-specific and hetero-specific styles and performed observations in the field on bumblebee species richness, visitation rates, and behaviour. The very first results of these experiments will be presented. Other experiments such as pollen competitive ability in mixed pollinations (hybrid detection via molecular tools), and quantifying bumblebee pollen uptake and deposition according to transition behaviour are also envisaged in the project.

Plant-hummingbird interactions in the West Indies: floral specialization gradients associated with environment and hummingbird size

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Floral phenotype and pollination system of a plant may be influenced by the abiotic environment and the local pollinator assemblage. This was investigated in seven plant-hummingbird assemblages on the West Indian islands of Grenada, Dominica and Puerto Rico. We report all hummingbird and insect pollinators of 49 hummingbird-pollinated plant species, as well as six quantitative and semi-quantitative floral characters which determine visitor restriction, attraction and reward. Using Nonmetric Multidimensional Scaling analysis, we show that hummingbird-pollinated plants in the West Indies separate in floral phenotypic space into two gradients - one associated with the abiotic environment and another with hummingbird size. Plants pollinated by large, long-billed hummingbirds had flowers with long corolla tube, large amounts of nectar and showy orange-red colouration. These attracted few or no insect species, whereas plants pollinated by small, short-billed hummingbirds were frequently pollinated by insects, particularly lepidopterans. The separation of plants related to environmental factors showed that species in the wet and cold highlands produced large amounts of dilute nectar, possessed no or a weak odour, and were associated with few insects, particularly few hymenopterans, compared to plants in the dry and warm lowlands. The most specialized hummingbird-pollinated plants are found in the West Indian highlands where they are pollinated by mainly large, long-billed hummingbirds. At the other extreme, highly generalized plants growing in the dry and warm lowlands are pollinated by small, short-billed hummingbirds and numerous insect species. This illustrates that, even within the hummingbird-pollinated flora, pollination syndrome and the degree of specialization may vary tremendously depending on pollinator morphology and environment.

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