Structure et dynamique des communautés écologiques

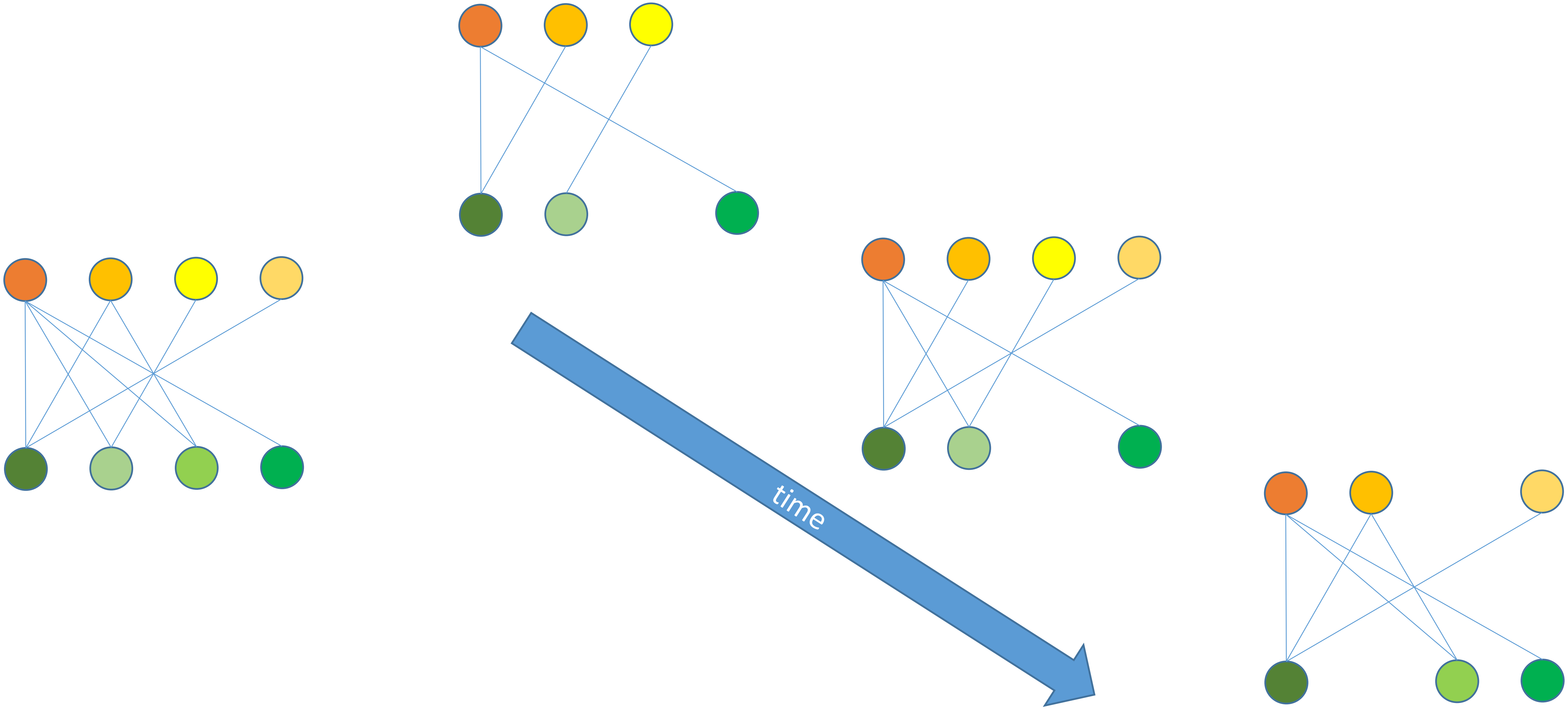
(ii)

Daily and seasonal dynamic of ecological networks and the spread of perturbation, plant pollinator communities as a study case

Colin Fontaine

Aussois 2021

From aggregated networks to temporal networks



Phenology: an important determinant of the structure of plant-pollinator networks

Contr. biol. Lab. Kyoto Univ., Vol. 27, pp. 309 - 375 Issued 20 August 1990

Insect-flower Relationship in the Primary Beech Forest of Ashu, Kyoto: An Overview of the Flowering Phenology and the Seasonal Pattern of Insect Visits[1]

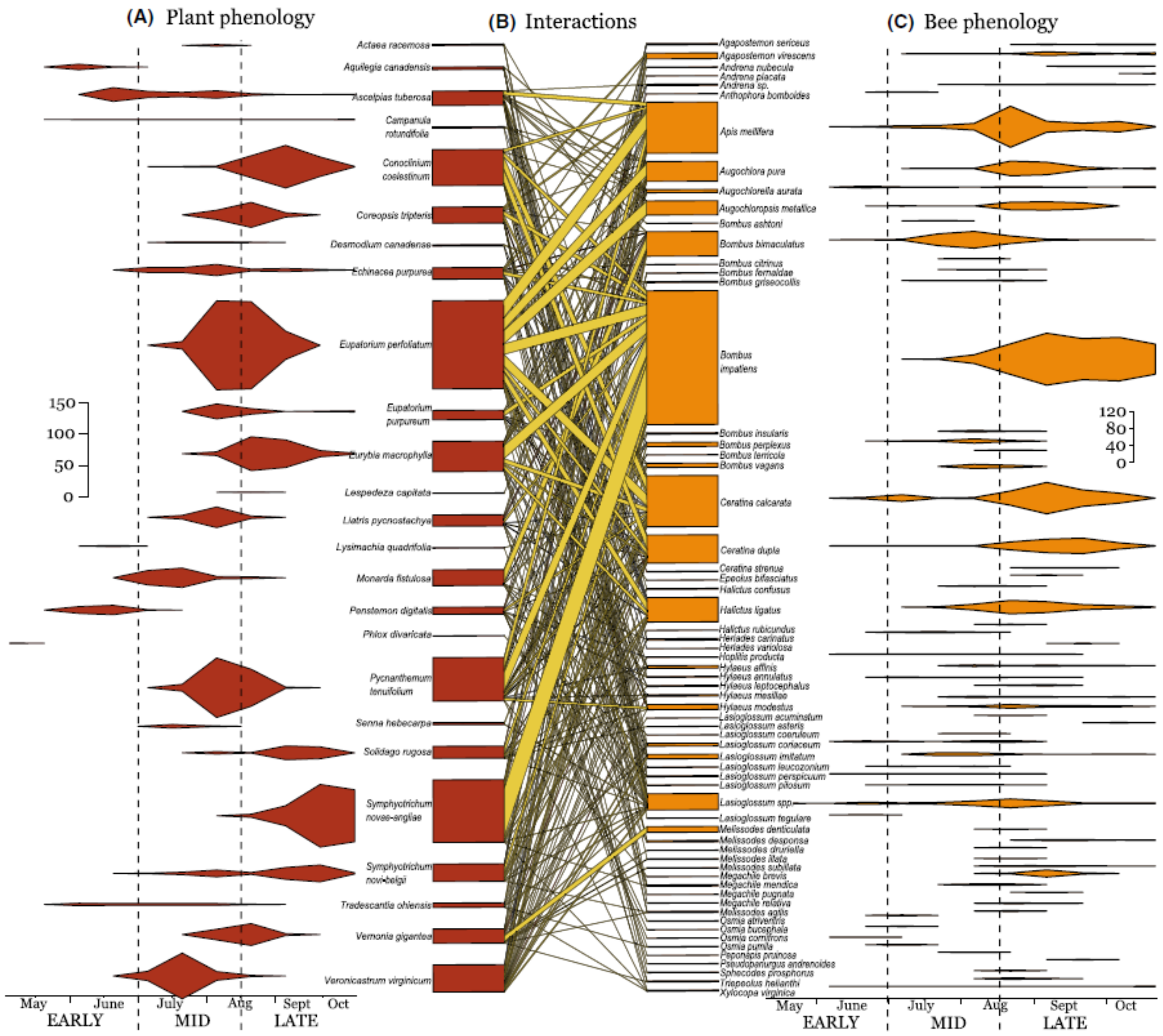
Makoto KATO, Takehiko KAKUTANI, Tamiji INOUE and Takao ITINO

Pollination specialization and time of pollination on a tropical Venezuelan plain: variations in time and space

NELSON RAMIREZ*

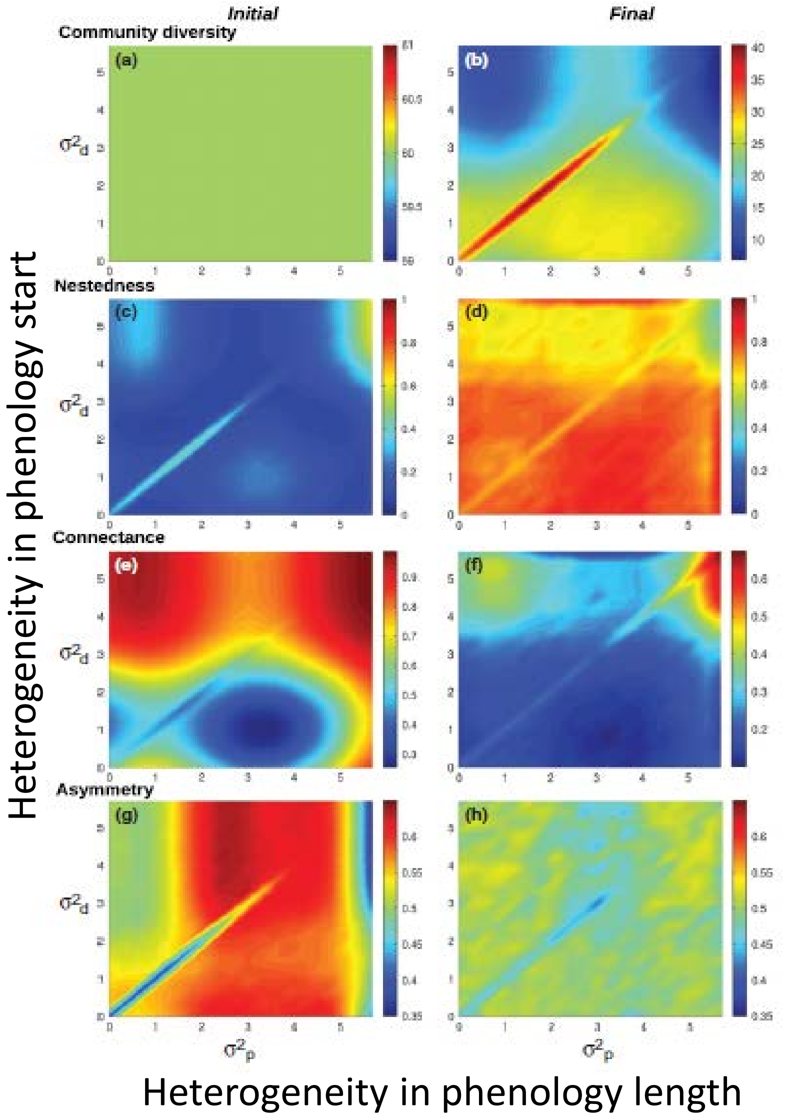
Universidad Central de Venezuela, Fac. Ciencias, Instituto de Biologia Experimental, Centro de Botanica Tropical. Aptdo. 48312. Caracas 1041 A, Venezuela

Received July 2001; accepted for publication January 2003



Russo et al. (2013)

Very few theoretical studies consider the effects of phenology on the stability of mutualistic webs



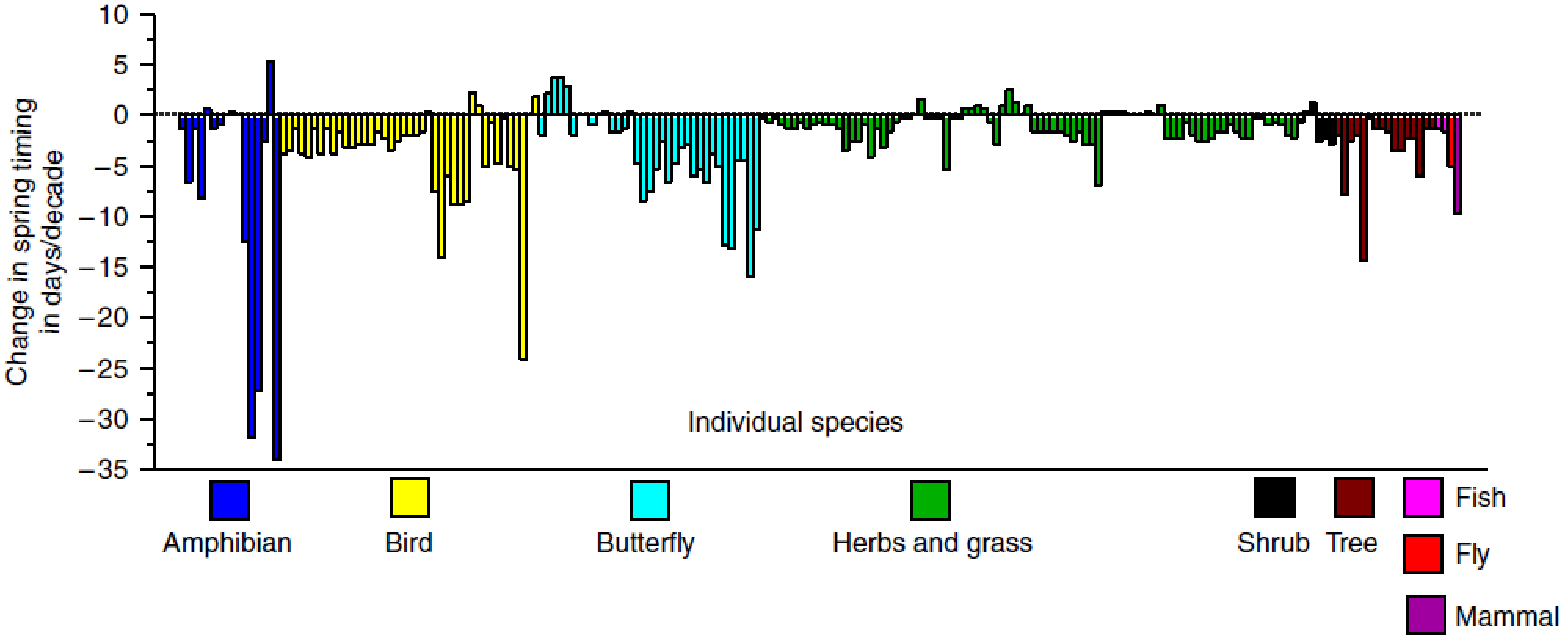
- ➢ Effects on network structure and species persistence

Encinas-Viso et al. (2012)

- ➢ Effects of species phenological attributes on species persistence

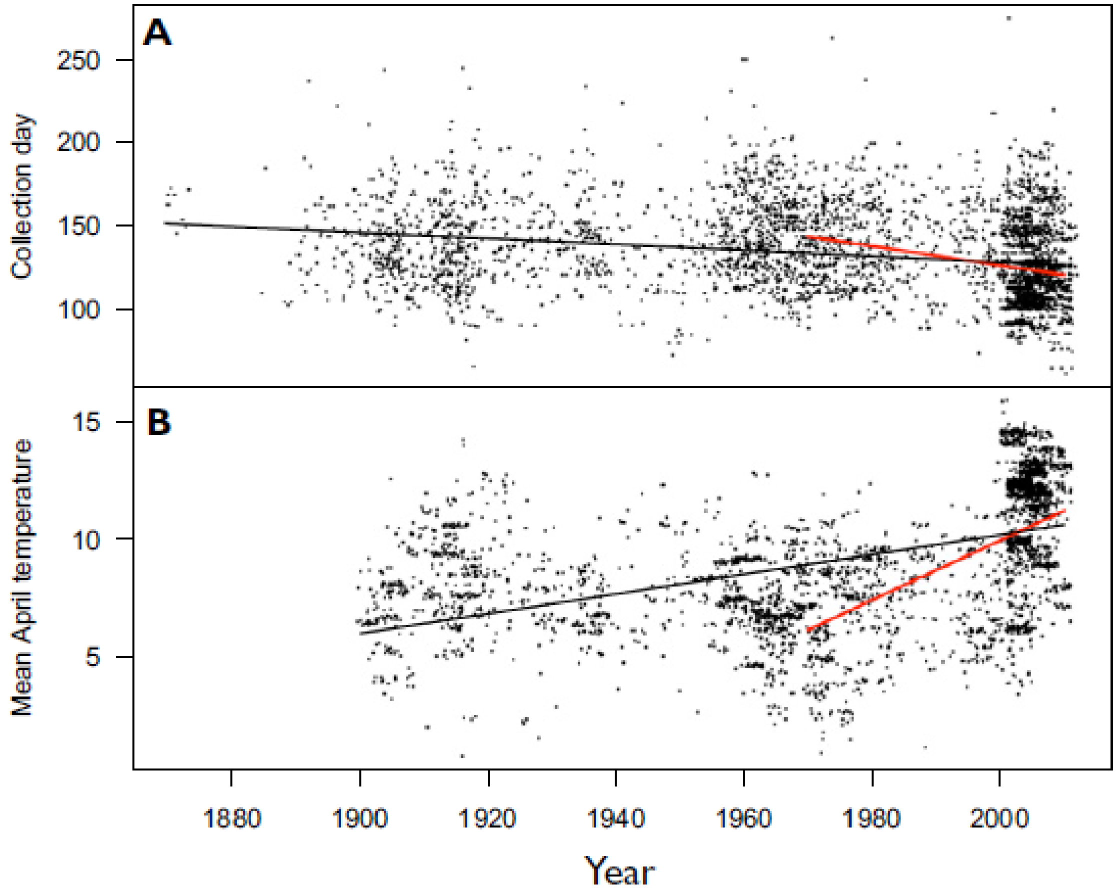
Ramos-Jiliberto et al. (2018)

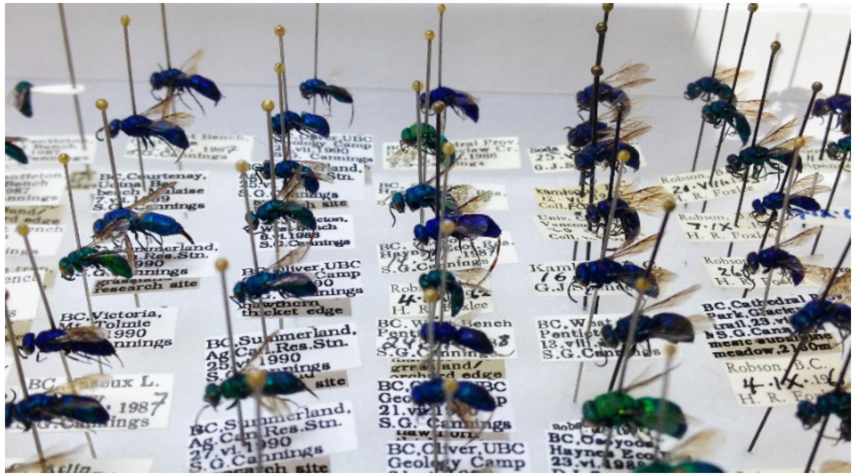
Effects of climate warming on the phenology of many taxa



Parmesan (2007)

Effects of climate warming on the phenology of pollinators

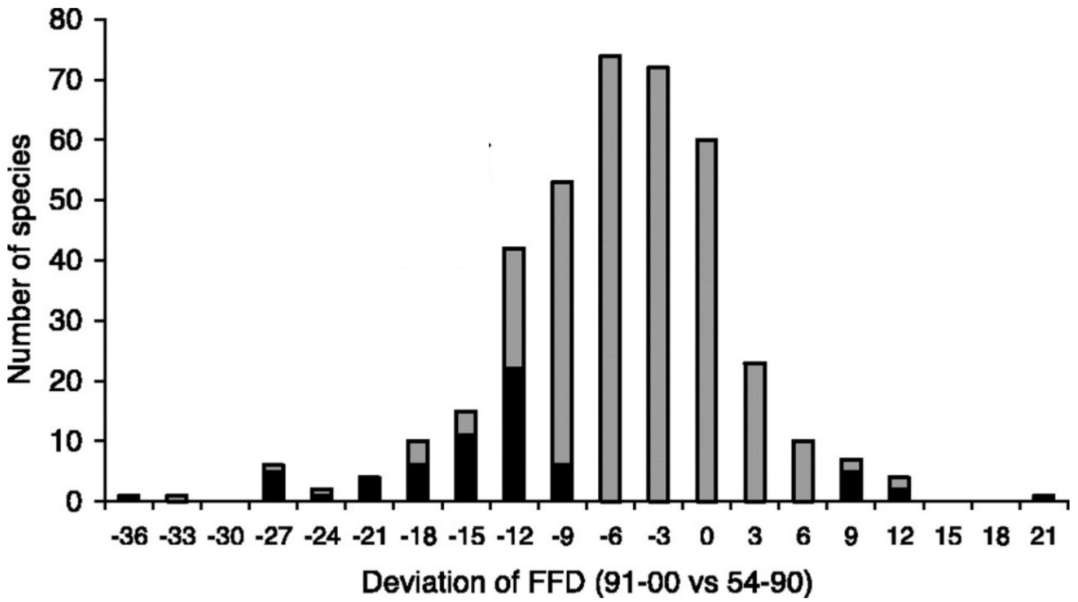




- ➢ Knowledge still restricted to few species of flower-visitors outside Lepidoptera
- ➢ Need to assess consequences at the scale of ecological communities

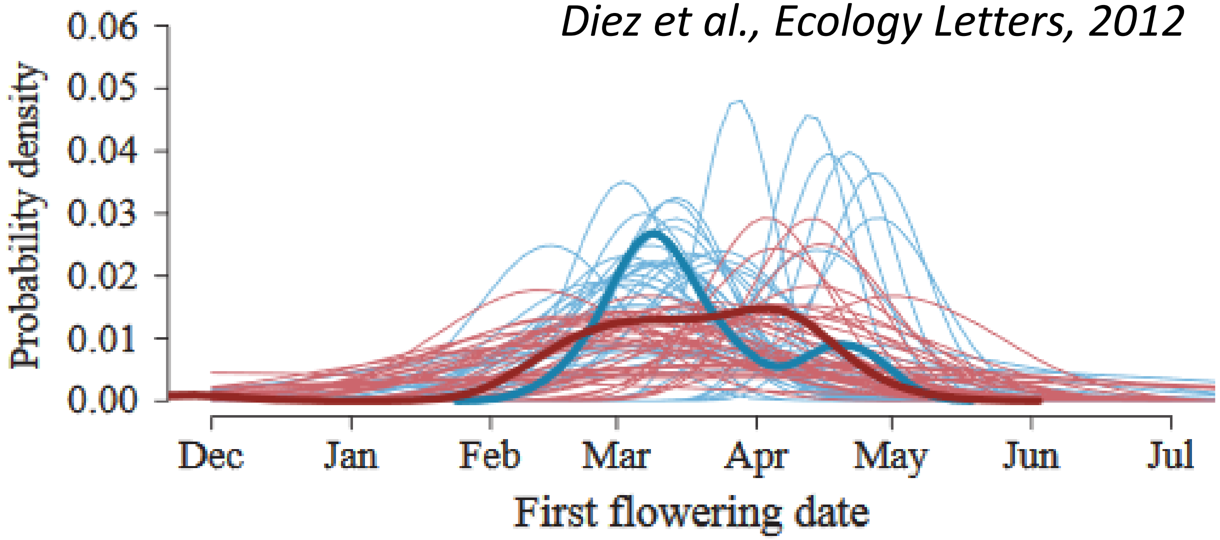
Bartomeus et al. (2011)

Plant response: from species to community

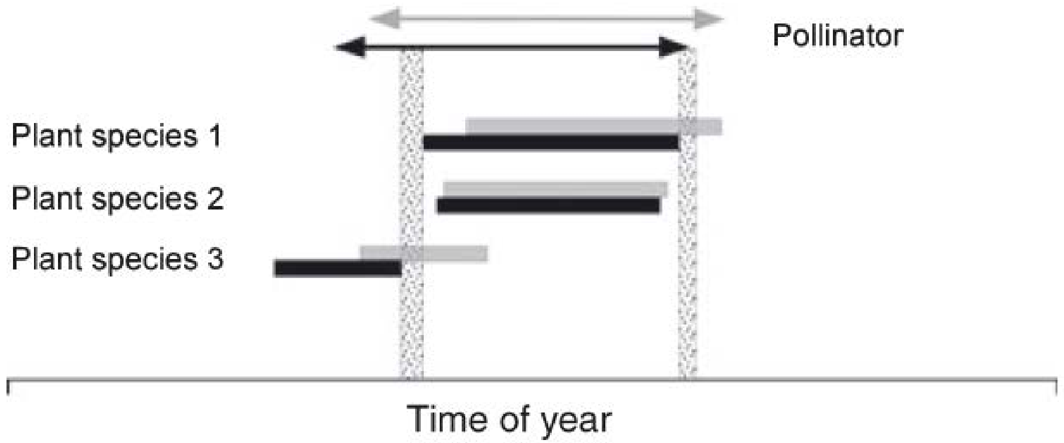


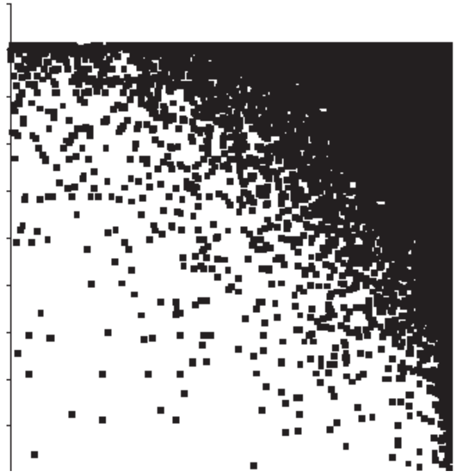
Fitter & Fitter, Science, 2001

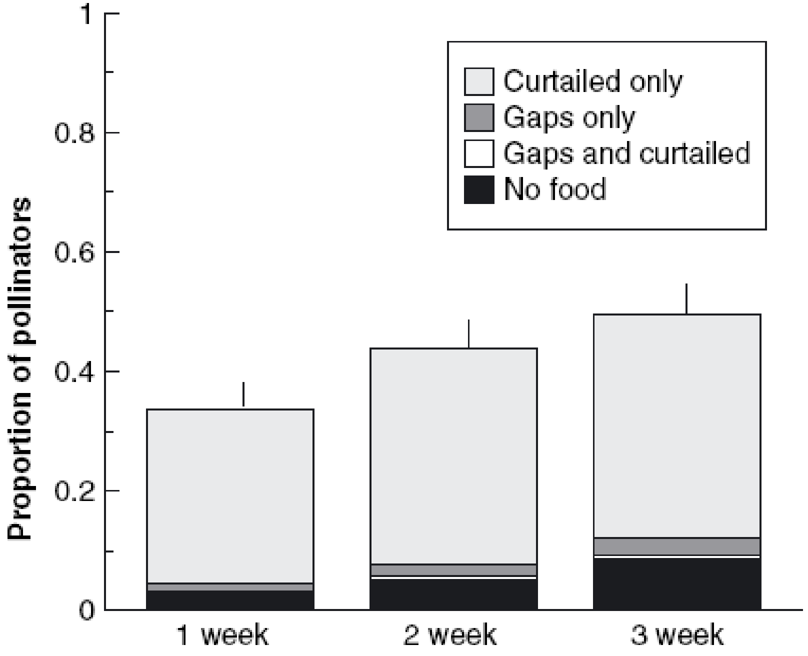
Diez et al., Ecology Letters, 2012



Consequences of phenological shifts on plant-pollinator networks







Memmott et al. (2007)

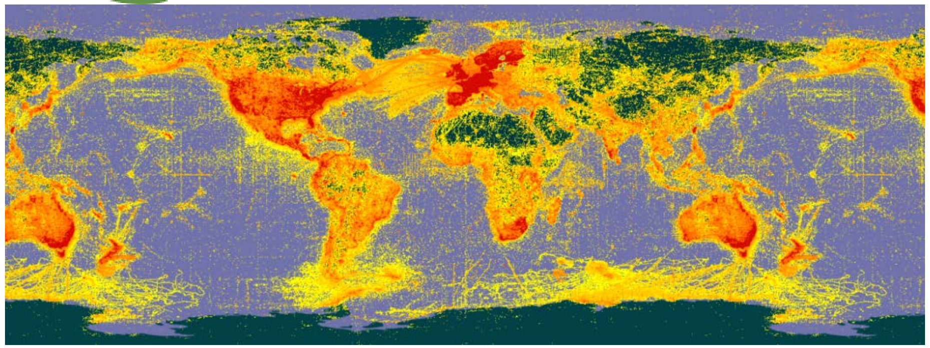
François Duchenne

- Investigate the potential consequences of climate warming on pollinator assemblages by extending our knowledge on phenological shifts of flower-visitors

- Understand how species phenologies and seasonality determine plant-pollinator networks and their stability

The data:
Historical and current records of occurrences of potential insect flower visitors

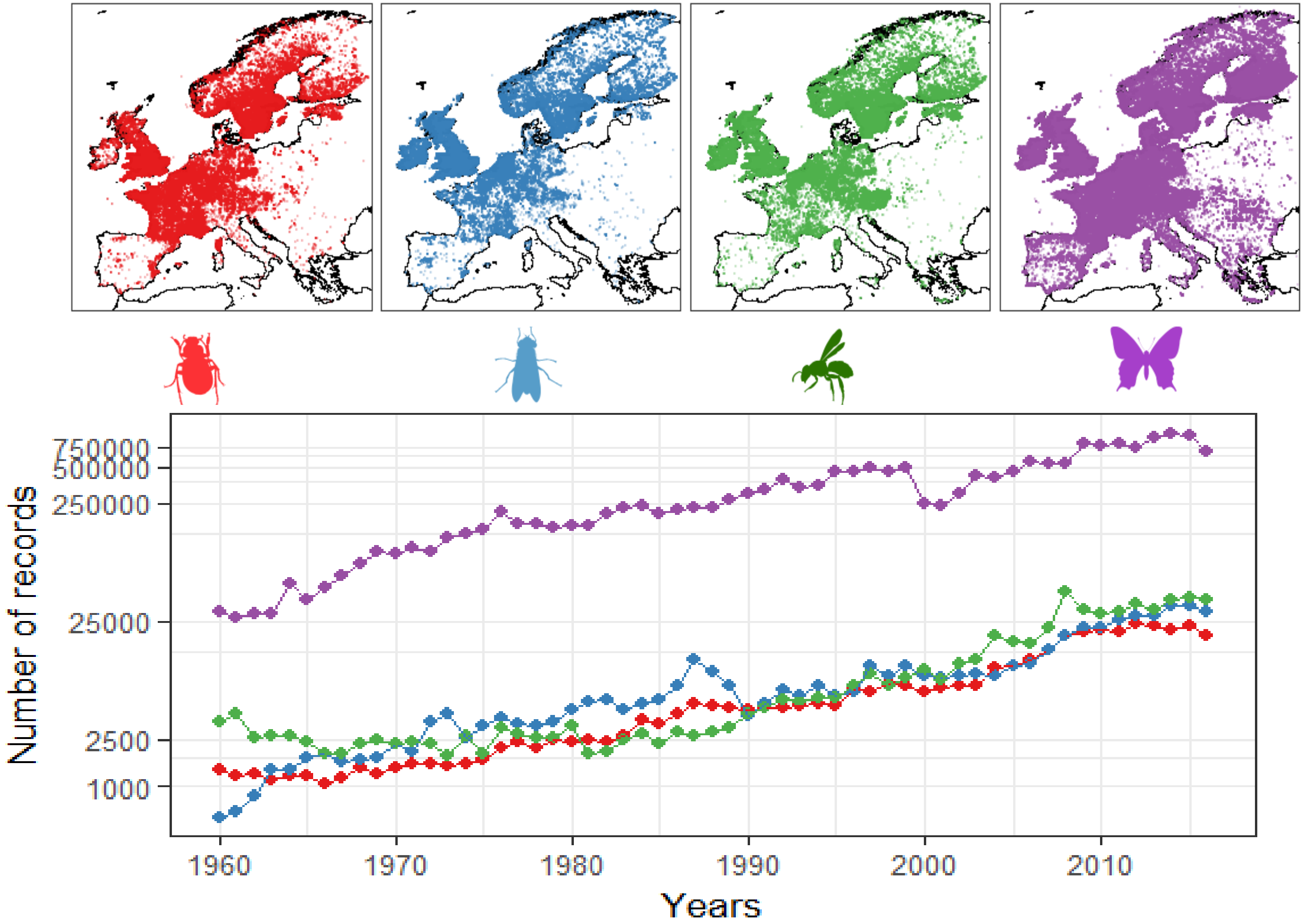
GBIF | Global Biodiversity Information Facility



French National Natural History Museum collections + private collections

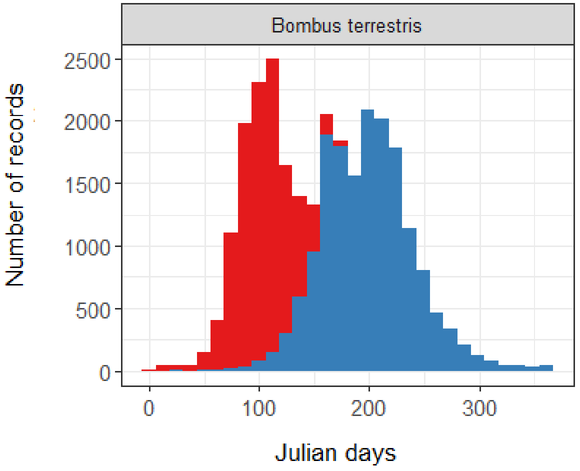
The data:
Historical and current records of occurrences of potential insect flower visitors

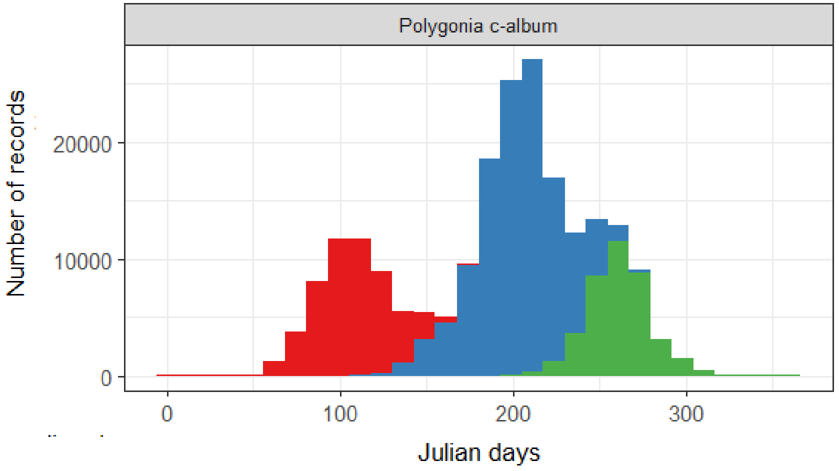
- 19 765 457 records for 2023 species between 1960 and 2016



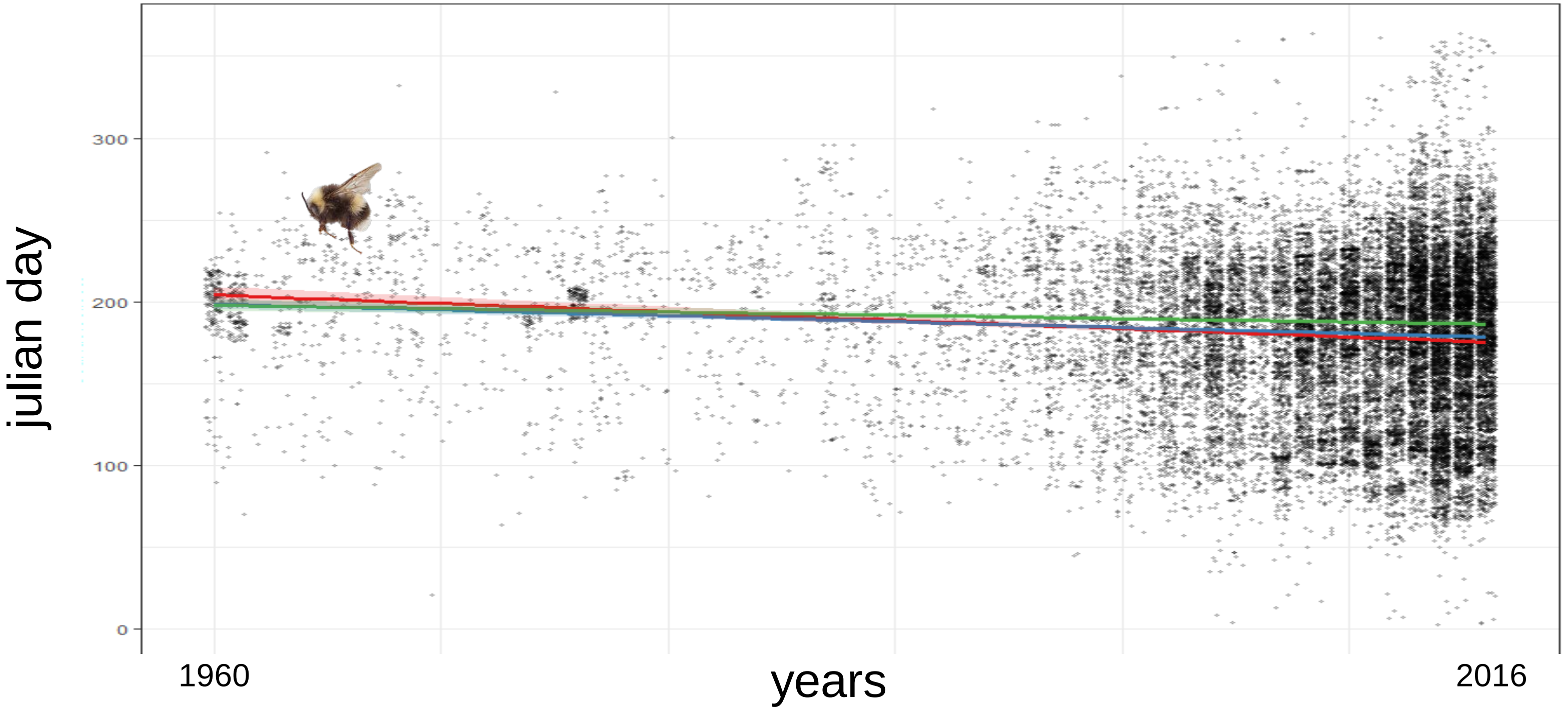
Methods:
Estimating phenological shifts

Identifying phenological modes for species with multimodal phenologies using clustering gaussian mixture models
(e.g. multivoltine species, queens and workers)





Methods:
Estimating phenological shifts



Coupled models for each species to estimate:

shift in mean flight date (MFD)

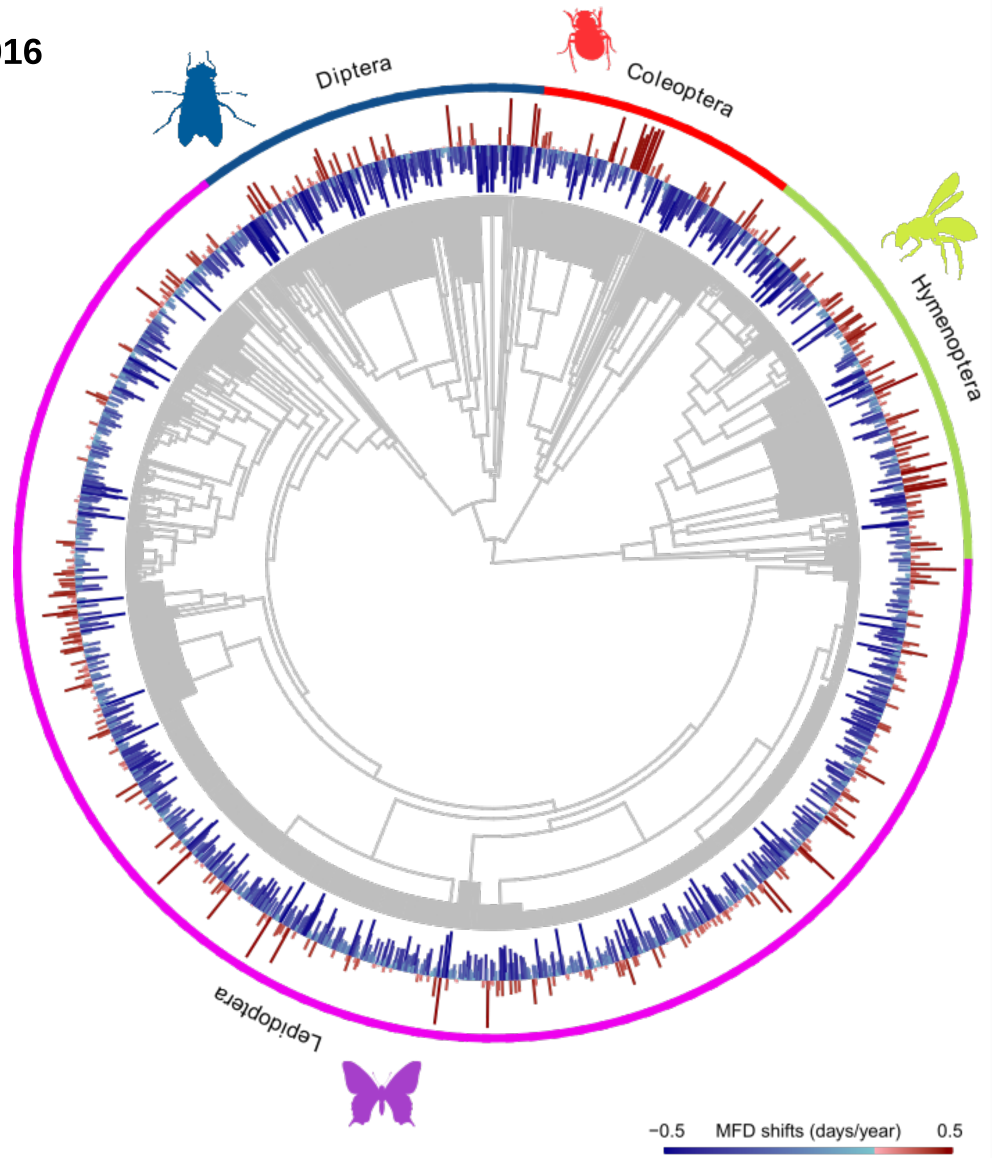
$$Y_k = \mu + (\pi + \alpha \times latitude_k + \delta \times longitude_k) \times year_k + (\rho_1 + \gamma_1 \times longitude_k) \times latitude_k + (\rho_2 + \gamma_2 \times longitude_k^2) \times latitude_k^2 + (\rho_3 + \gamma_3 \times longitude_k^3) \times latitude_k^3 + (\sigma_1) \times longitude_k + (\sigma_2) \times longitude_k^2 + (\sigma_3) \times longitude_k^3 + \theta \times altitude_k + E_k$$

change in phenology length (SD)

$$\log(\sigma^2) = \mu_v + (\rho_v \times latitude_k + \sigma_v \times longitude_k + \theta_v \times altitude_k + \pi_v) \times year_k$$

Mean flight date shifts

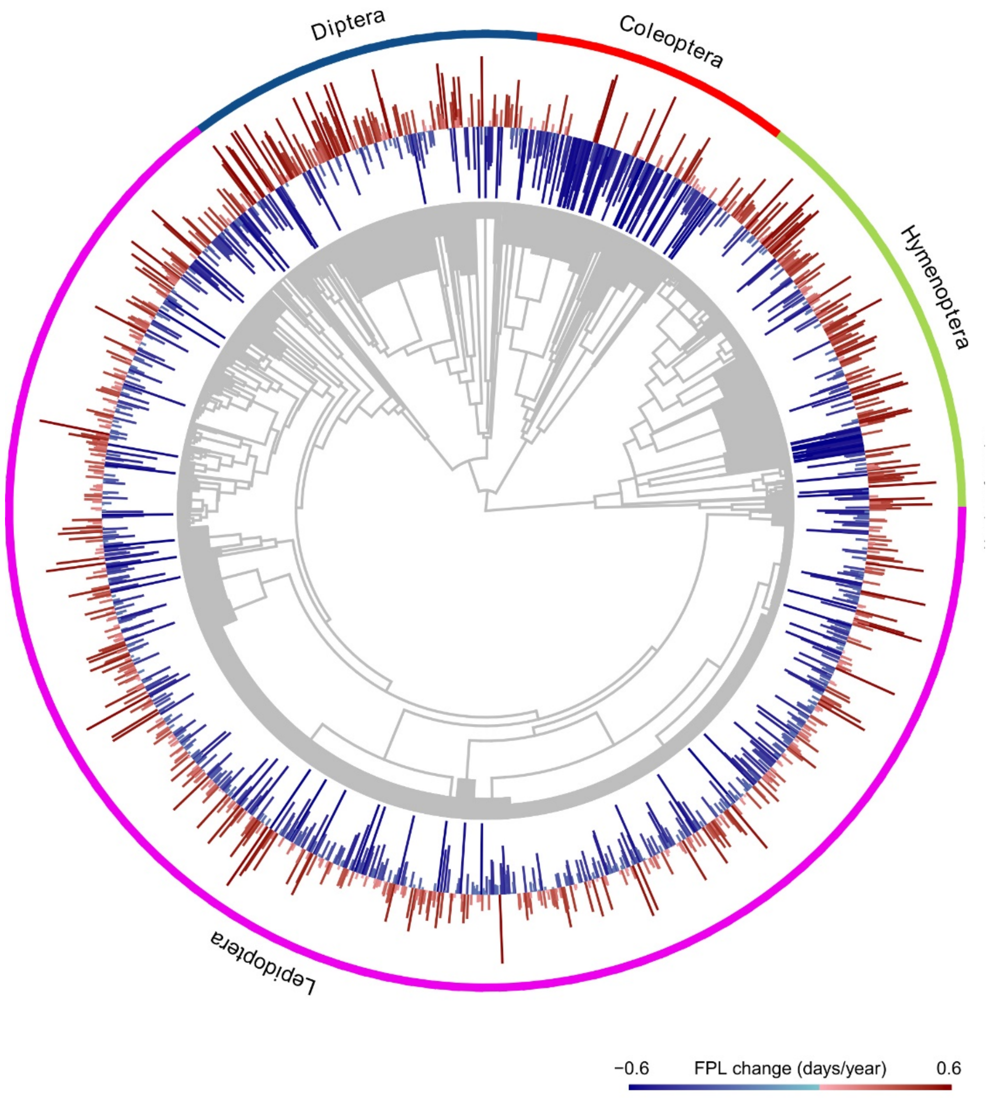
On average
5.8 days earlier in 2016
than in 1960



57% earlier
30% non significant
13% delayed

Changes of flight period lengths

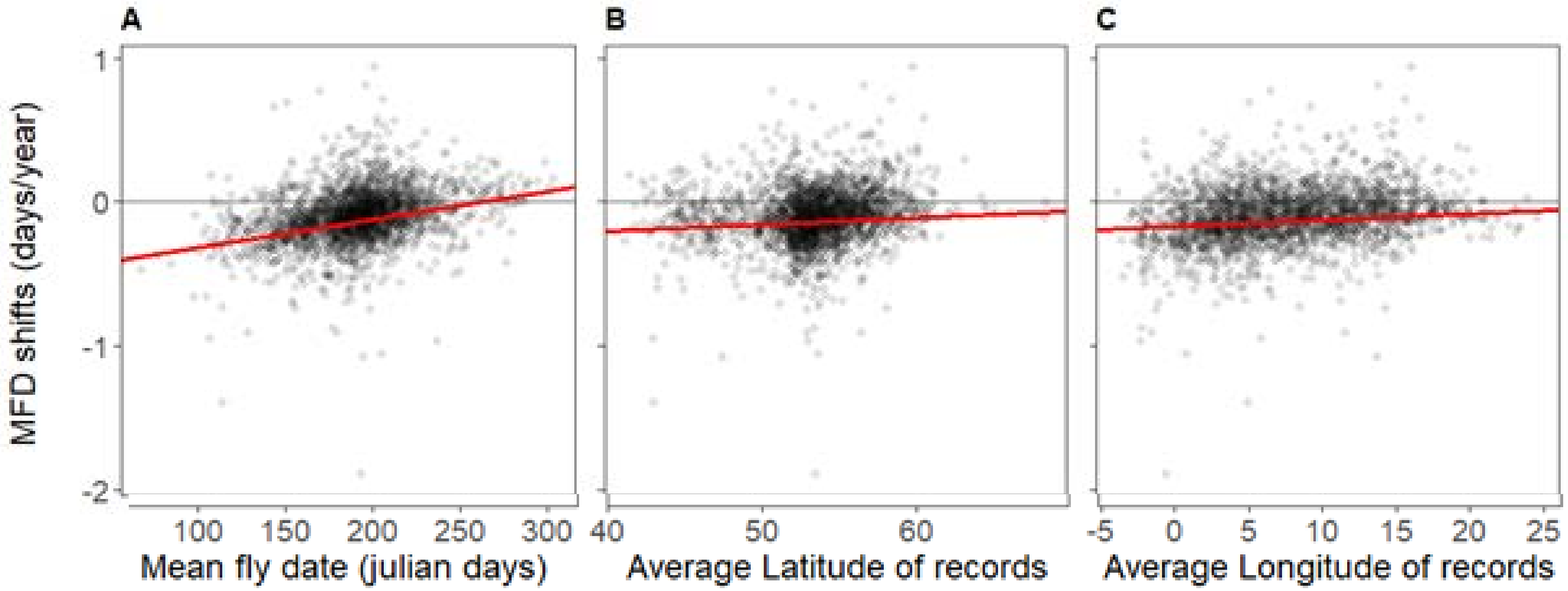
On average
1.8 days shorter in 2016
than in 1960



30% shortened
43% non significant
27% lenghtened

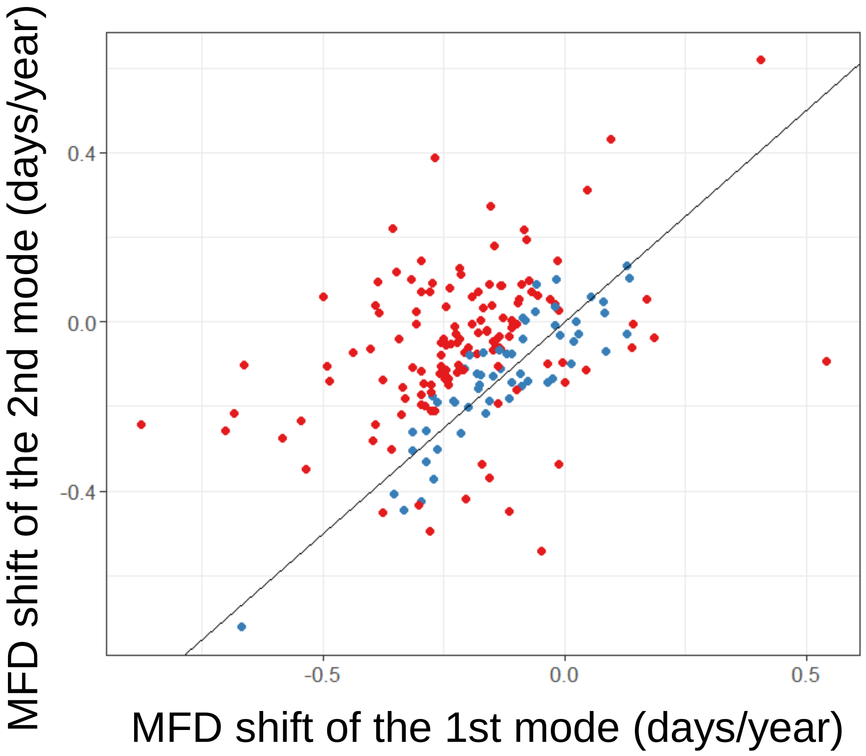
Duchenne et al. (2020)

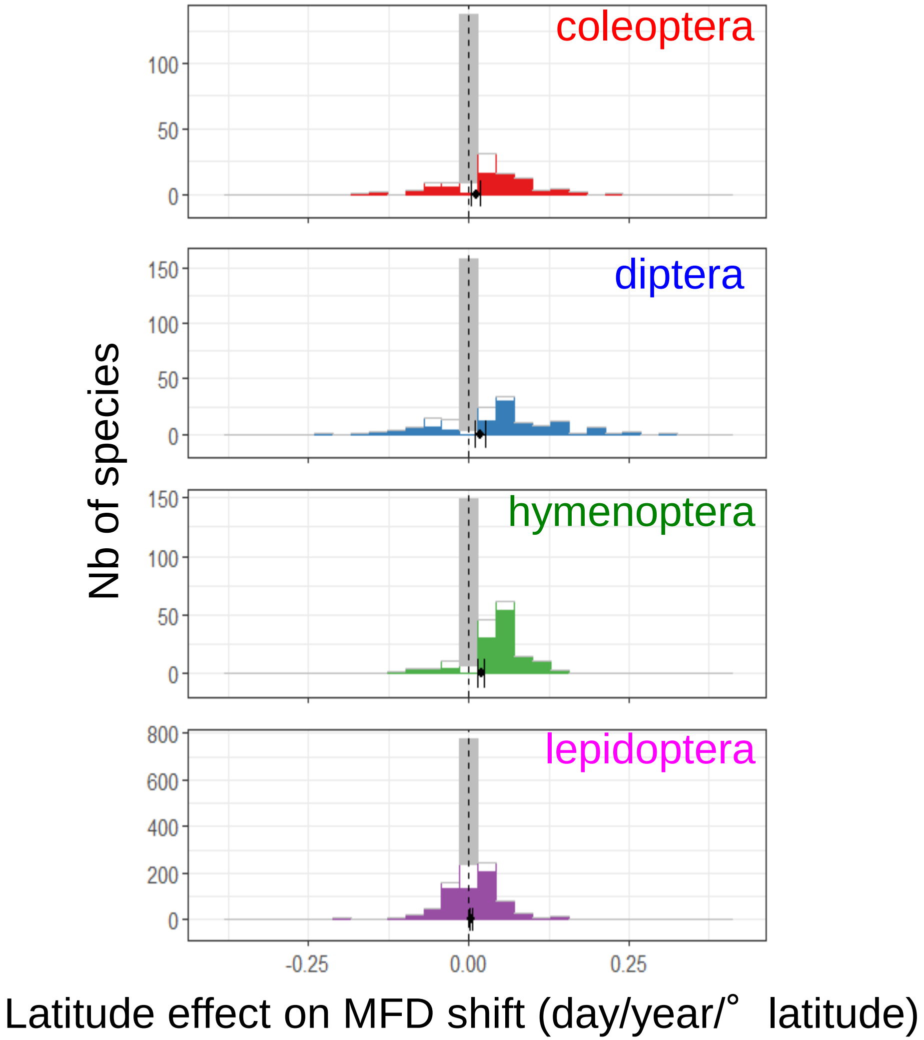
Interspecific phenological shift variations depend on mean fly date and location



Intraspecific variations in phenological shift that depend on mean fly date and location

Species with multimodal phenology





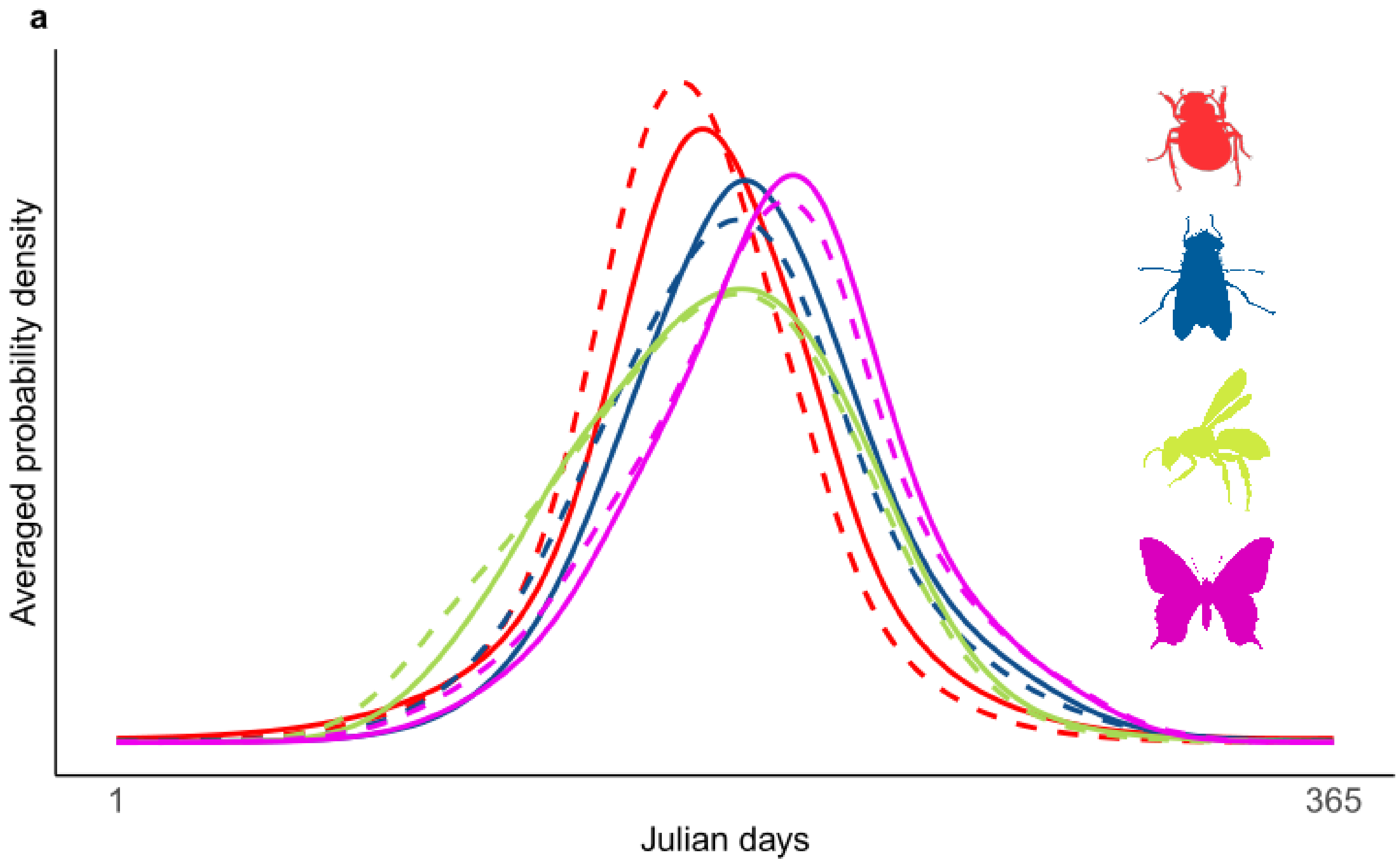
Climate warming and phenological shifts of flower visitor assemblages across Europe
Conclusion

- European flower visitors are flying on average 5.8 days earlier and their phenologies are 3.8 days shorter in 2016 than in 1960

- Substantial heterogeneity in phenological shifts that depends on evolutionary history, seasonal precocity and location

- What consequences?

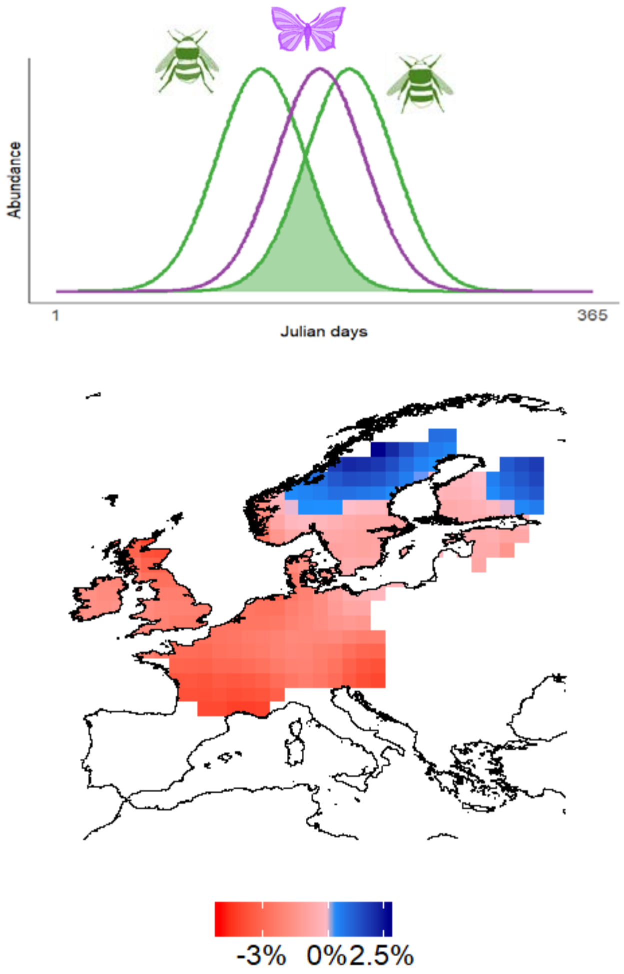
Changes in the seasonal structure of flower visitor communities



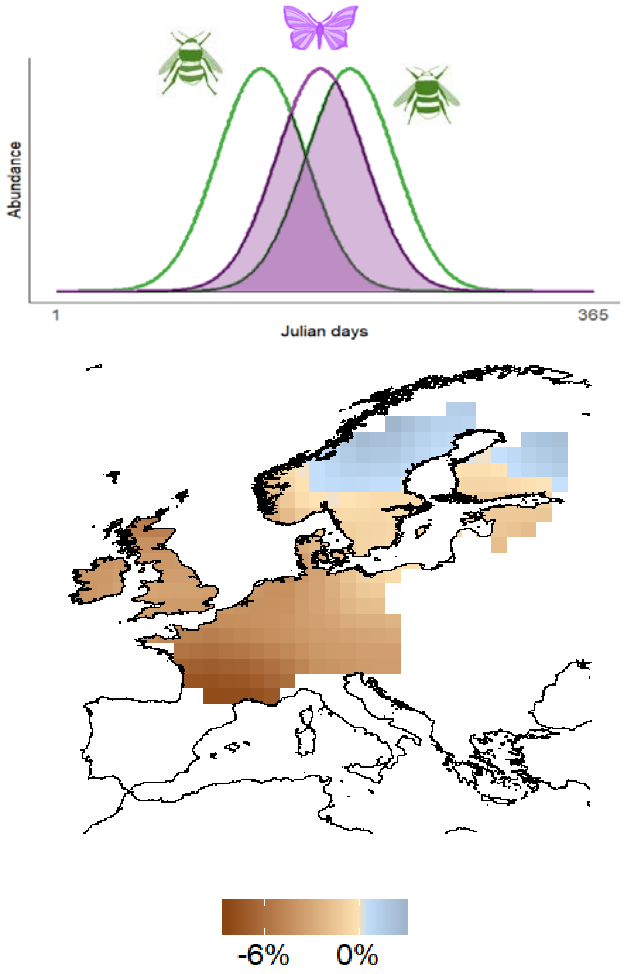
Changes in the average phenology overlaps of flower visitor communities

Changes between 1980 and 2016

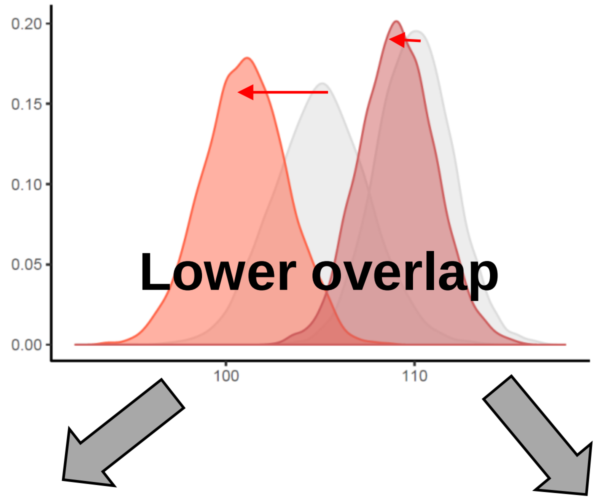
within orders



among orders



Which consequences on plant-pollinator networks?



Lower temporal redundancy and complementarity for plant pollination?

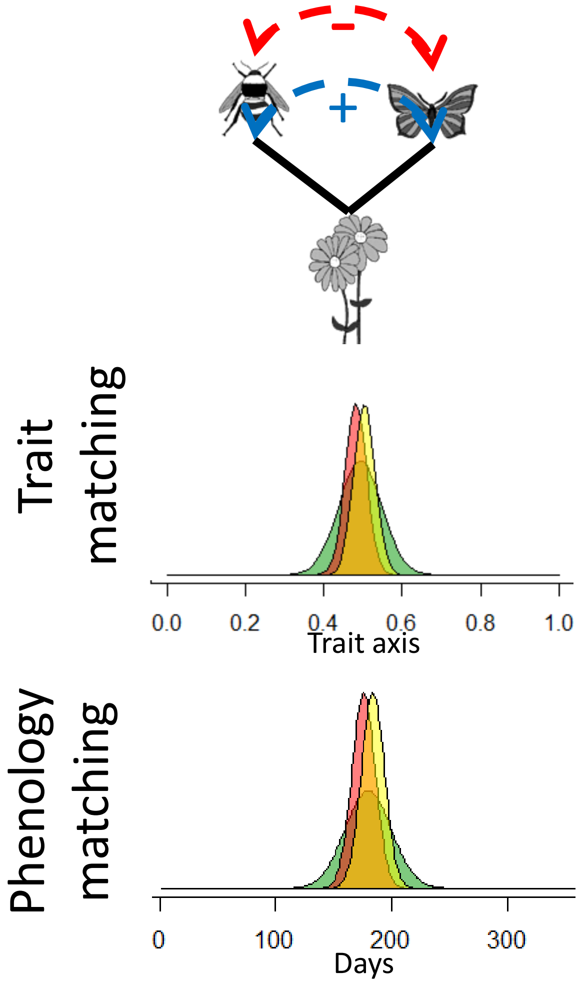
Decrease competition pressure among pollinators for resources (nectar/pollen)?

- Investigate the potential consequences of climate warming on pollinator assemblages by extending our knowledge on phenological shifts of flower-visitors

- Understand how species phenologies and seasonality determine plant-pollinator networks persistence

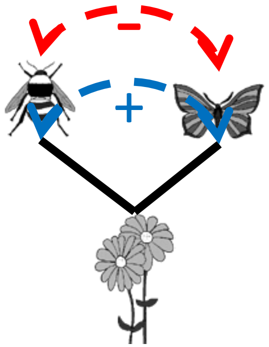
Phenology and indirect effects in mutualistic networks

High trait similarity
High phenology overlap

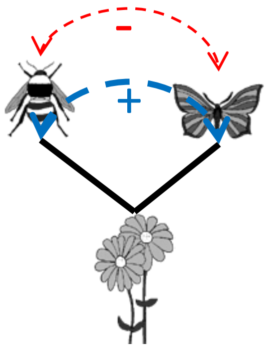


Phenology and indirect effects in mutualistic networks

High trait similarity
High phenology overlap



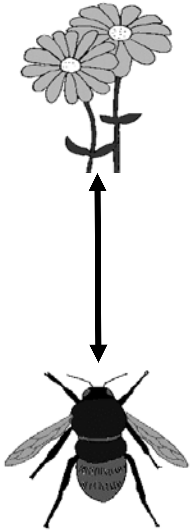
High trait similarity
Low phenology overlap



What are the respective impacts of trait vs phenology matching on species persistence in mutualistic networks?

How do they determine indirect effects between plants and between pollinators?

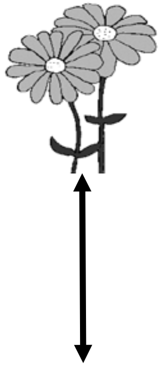
A model for the dynamics of mutualistic networks



$$\frac{dF_i}{dt} =$$

$$\frac{dP_j}{dt} =$$

A model for the dynamics of mutualistic networks



$$\frac{dF_i}{dt} = F_i(r_i - \frac{F_i}{K_i} \qquad)$$

$$\frac{dP_j}{dt} = P_j(r_j - \frac{P_j}{K_j} \qquad)$$

Intrinsic growth rates $r_i < 0$ ➔ obligate mutualism

Carrying capacity K_i ➔ intraspecific competition

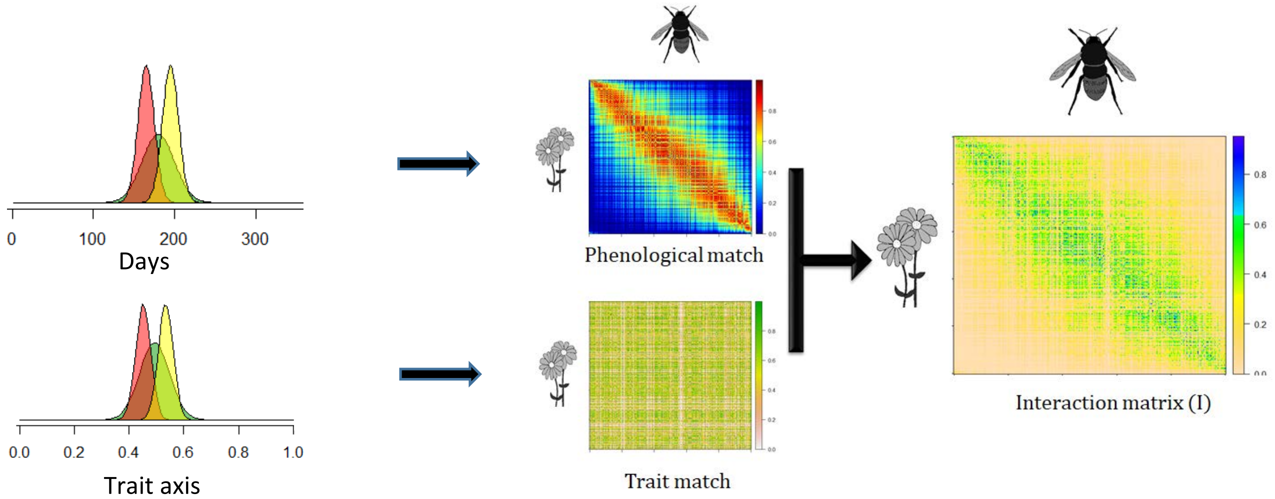
Interactions depend on trait & phenology matching

$$\frac{dF_i}{dt} = F_i\left(r_i - \frac{F_i}{K_i} + \frac{\alpha_f \sum_{k=1}^{np} I_{ik} \times P_k}{1+\beta_f \sum_{k=1}^{np} I_{ik} \times P_k}\right)$$

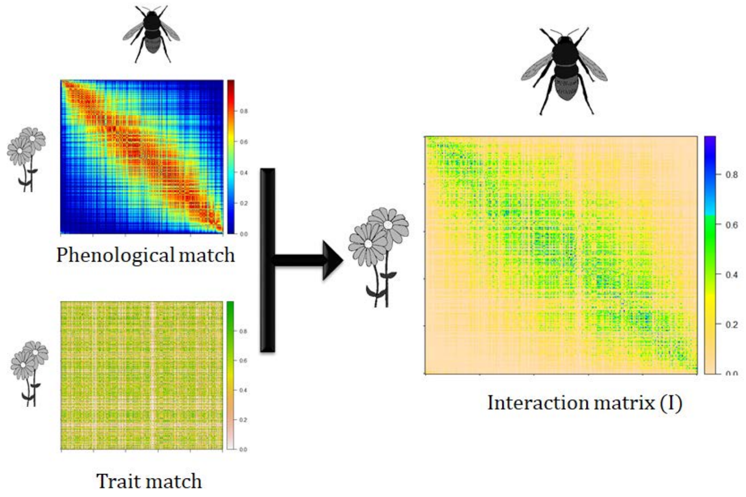
$$\frac{dP_j}{dt} = P_j\left(r_j - \frac{P_j}{K_j} + \frac{\alpha_p \sum_{k=1}^{n_f} I_{kj} \times F_k}{1+\beta_p \sum_{k=1}^{n_f} I_{kj} \times F_k}\right)$$

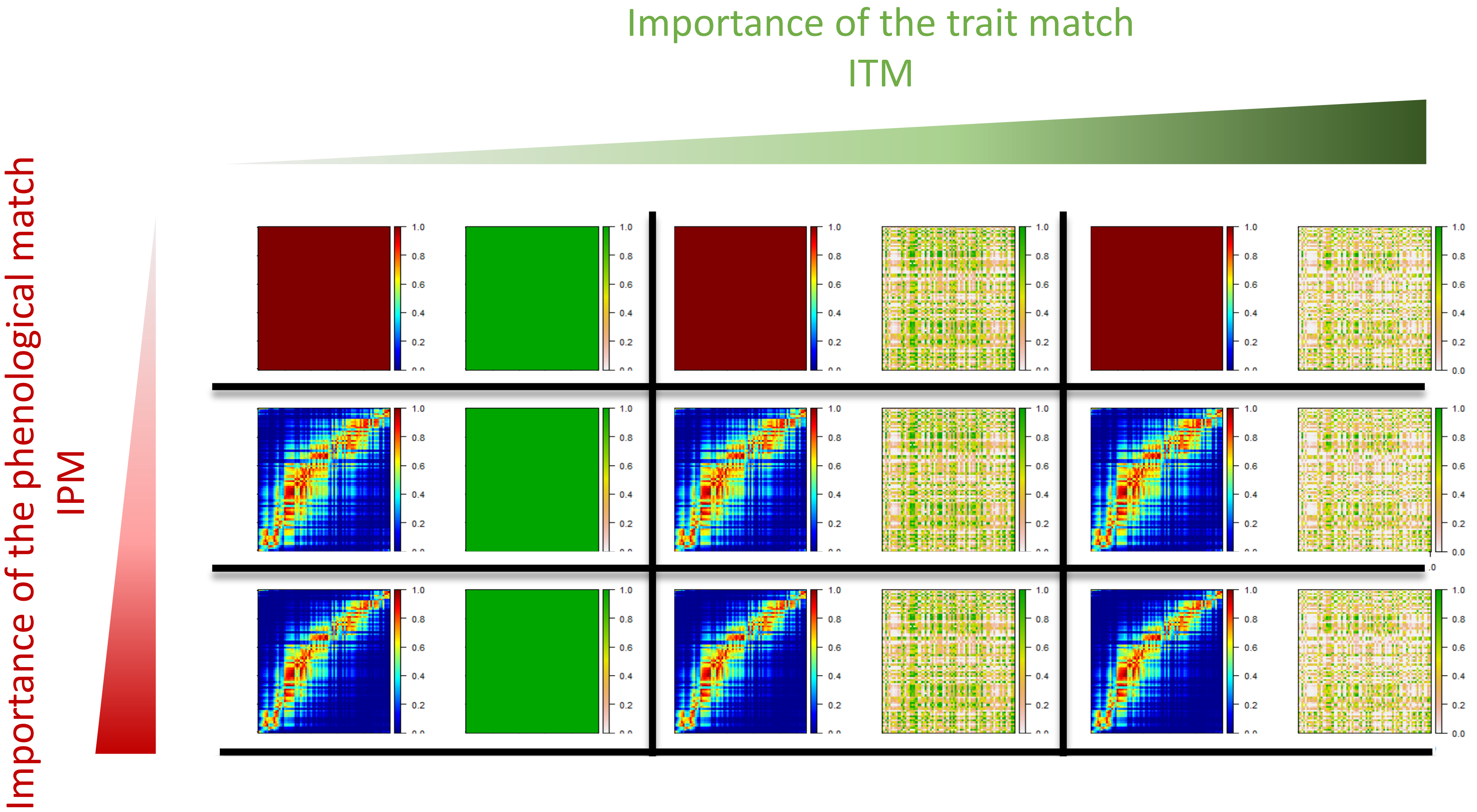
Interaction term saturates with mutualistic partner densities Bastolla et al. (2009)

I_{ij} defines the interaction probability as a function of trait and phenology matching

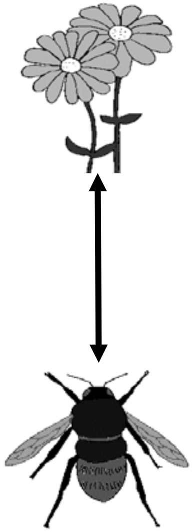


Testing the relative impact of trait and phenological matching





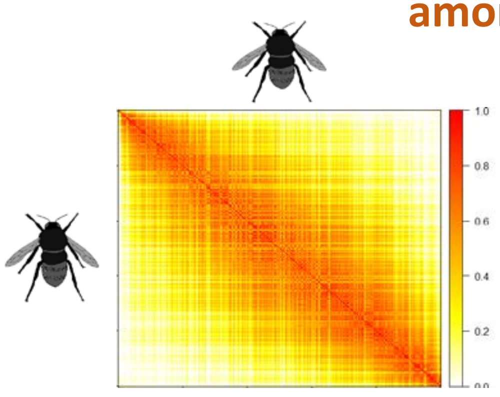
Competition for mutualistic interactions depends on phenological overlapp



$$\frac{dF_i}{dt} = F_i\left(r_i - \frac{F_i}{K_i} + \frac{\alpha_f \sum_{k=1}^{np} I_{ik} \times P_k}{1 + \beta_f \sum_{k=1}^{np} I_{ik} \times P_k + c_f \sum_{k=1}^{n_f} \theta_{ik} \times F_k}\right)$$

$$\frac{dP_j}{dt} = P_j\left(r_j - \frac{P_j}{K_j} + \frac{\alpha_p \sum_{k=1}^{n_f} I_{kj} \times F_k}{1 + \beta_p \sum_{k=1}^{n_f} I_{kj} \times F_k + c_p \sum_{k=1}^{np} \omega_{jk} \times P_k}\right)$$

Competition/interference between plants and between pollinators depends on competition strength c_p and c_f as well as on phenological and morphological overlap among interacting partners θ_{ik} and ω_{jk}



Phenological overlap among pollinators (M_p)

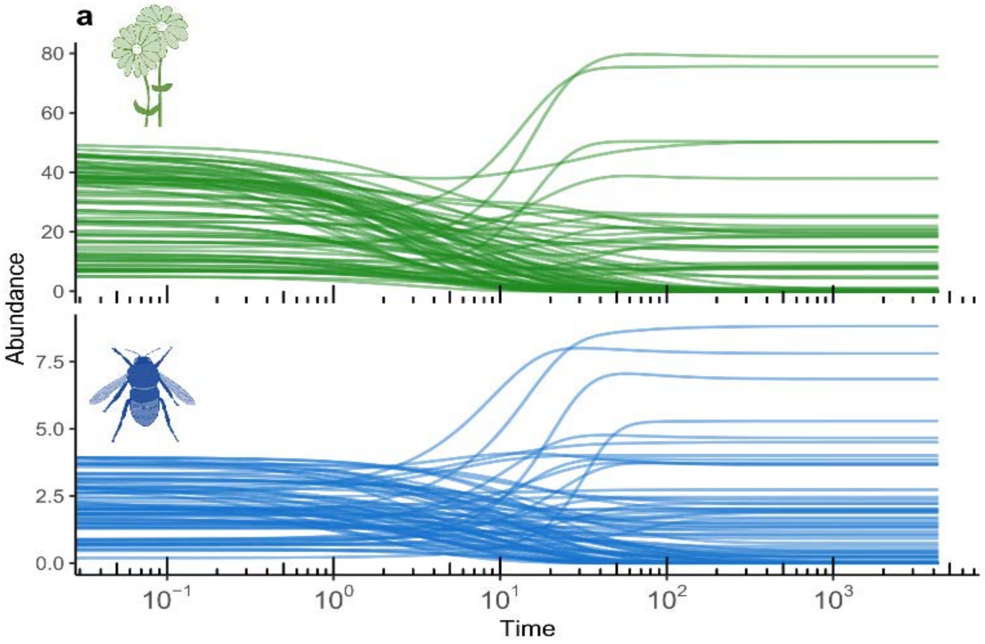
$$\omega_{jk} = \left\{ M_{p_{jk}}^{IPM} \times \sum_{i=1}^{n_f} \left(\frac{F_i \times I_{ij}}{\sum_{i=1}^{n_f} I_{ij} \times F_i} \times I_{ik} \right) \right\}_{k \in \{1 \dots n_p\}}$$

Phenological overlap of poll *j* and *k*

dependance of poll *j* on plant *i*

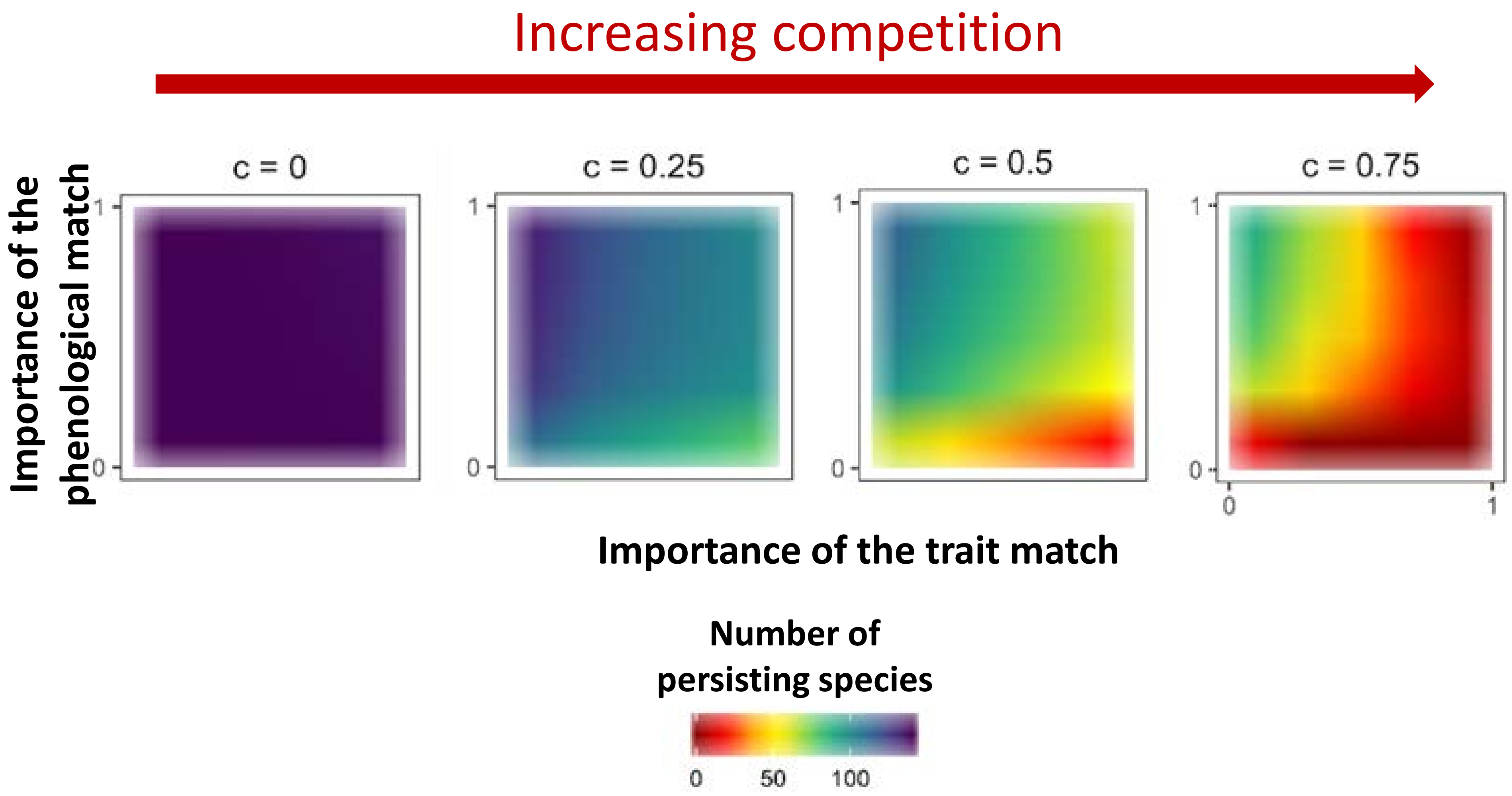
interaction of poll *k* with plant *i*

Testing the relative impact of trait and phenological matching



Effects on species persistence

Relative impact of trait and phenological matching on persistence



Testing the relative impact of trait and phenological matching on indirect interactions

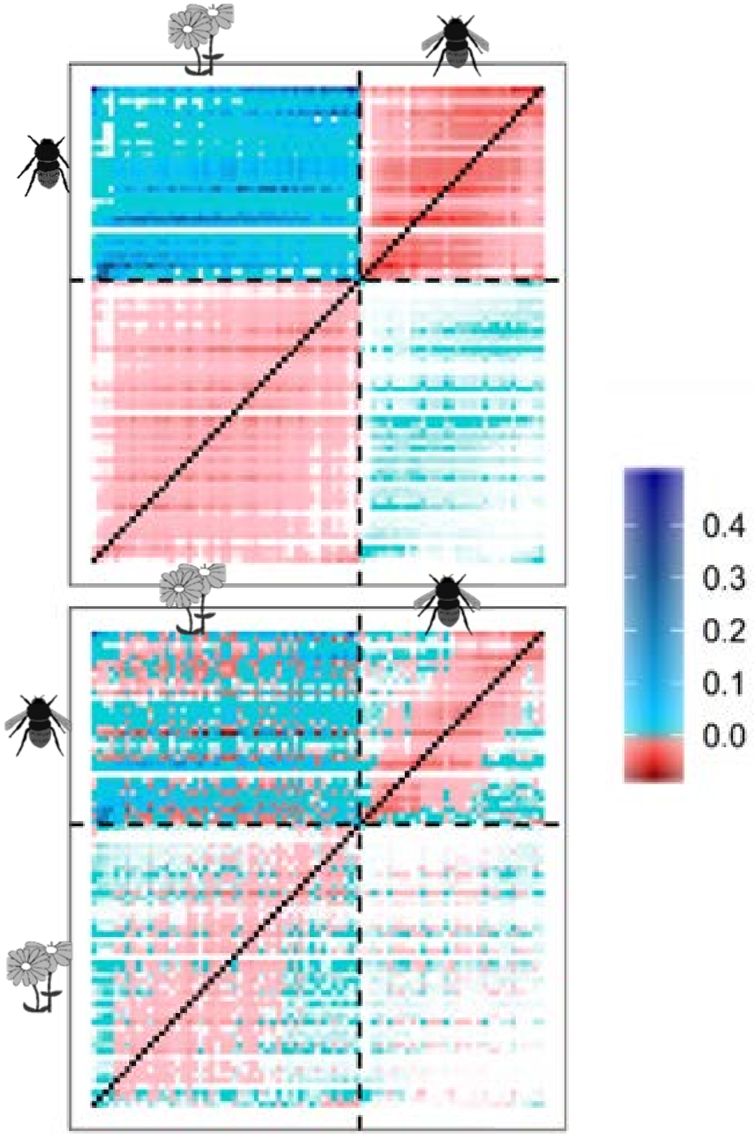
Direct effects

Higashi & Nakajima (1995)

$$T_{ij} = \frac{s_{ij}}{s_{ii}s_{jj} - s_{ij}s_{ji}}$$

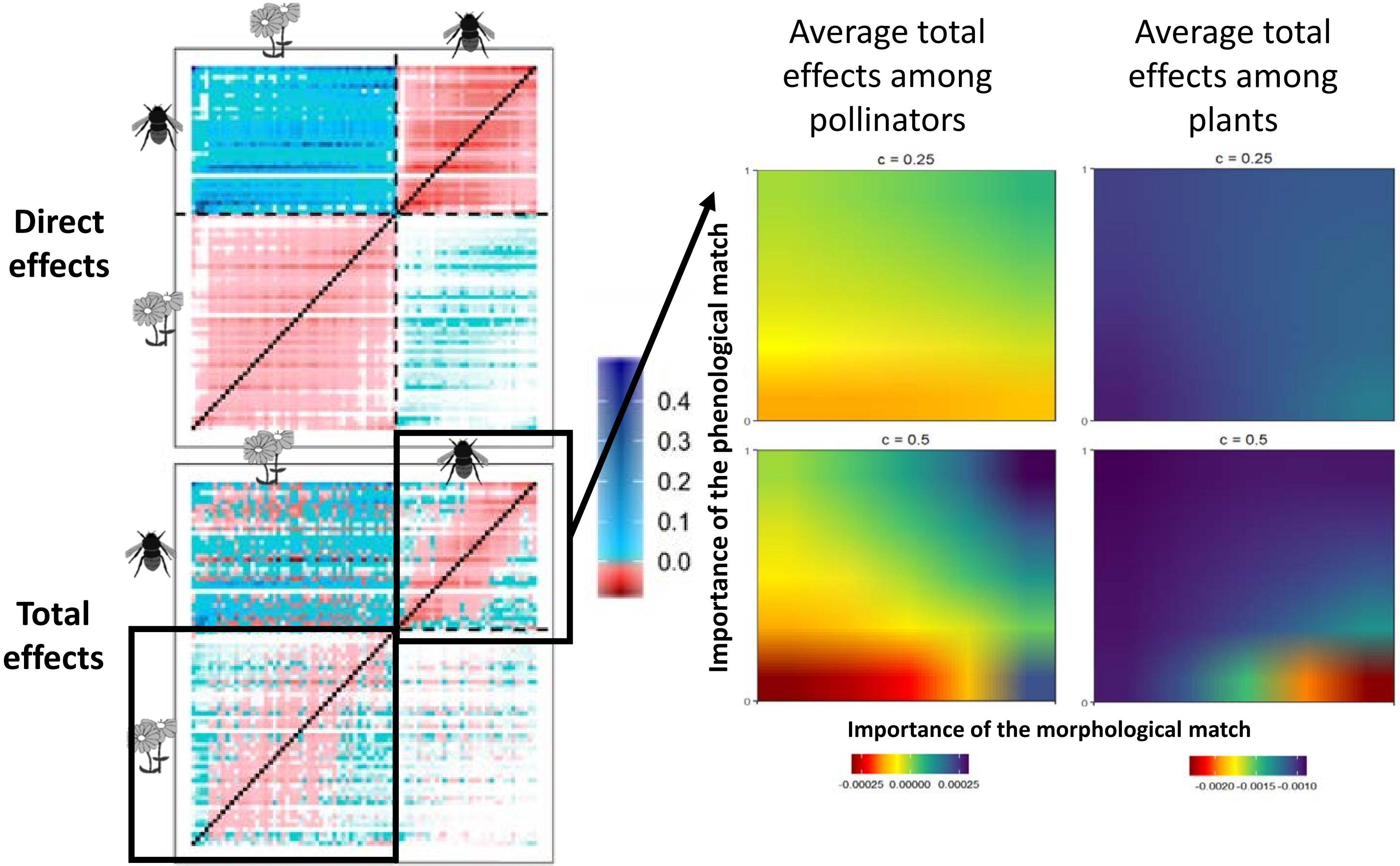
$$S = A^{-1}$$

Total effects



Direct and indirect effects between plants and between pollinators at equilibrium?

Testing the relative impact of trait and phenological matching on indirect interactions



Phenological structure and the dynamics of mutualistic networks
Some preliminary conclusions

- Constraints on morphological matching and phenological matching can have different consequences on the dynamics of mutualistic networks
- When there is competition, the phenological structure of the community can promote species persistence
- In addition to mismatch, phenological changes related to climate warming can change the balance between competition and facilitation within guilds

- Investigate the potential consequences of climate warming on pollinator assemblages by extending our knowledge on phenological shifts of flower-visitors

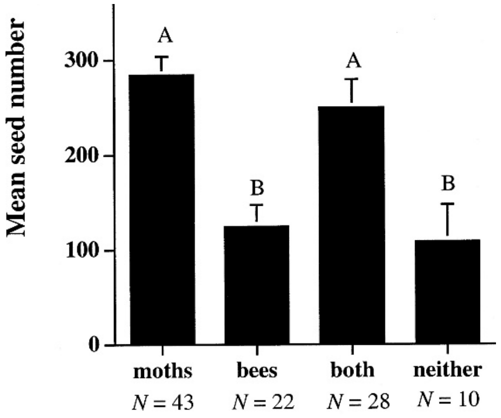
- Understand how species phenologies and seasonality determine plant-pollinator networks and their stability

- Pollination around the clock and the concequences of light pollution

Eva Knop

What about nocturnal pollination?

Young (2002)

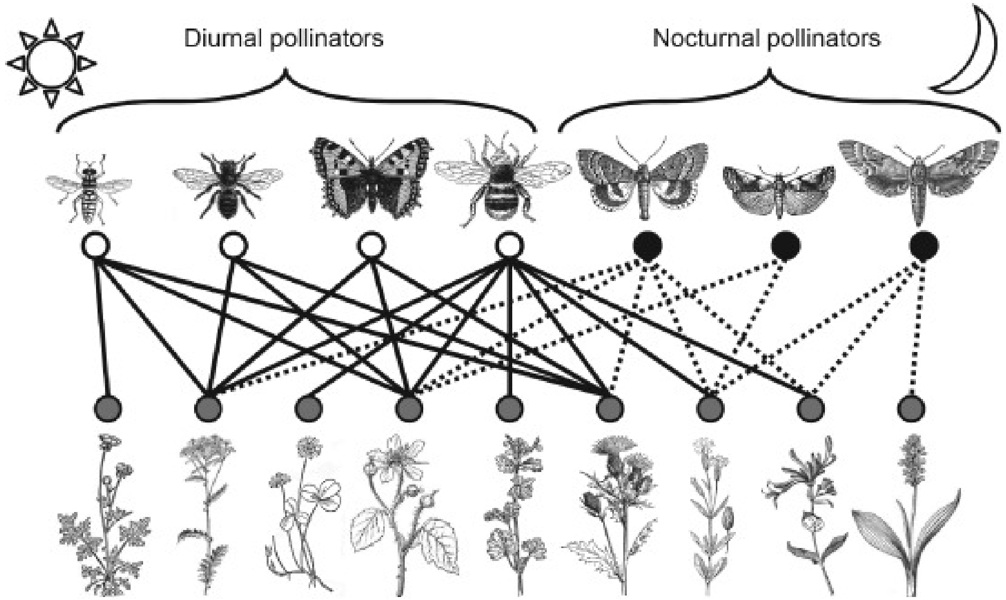


Only 168 studies on nocturnal pollination (moth) between 1971 and 2013

rarely at community level

very few pollination effectiveness measures

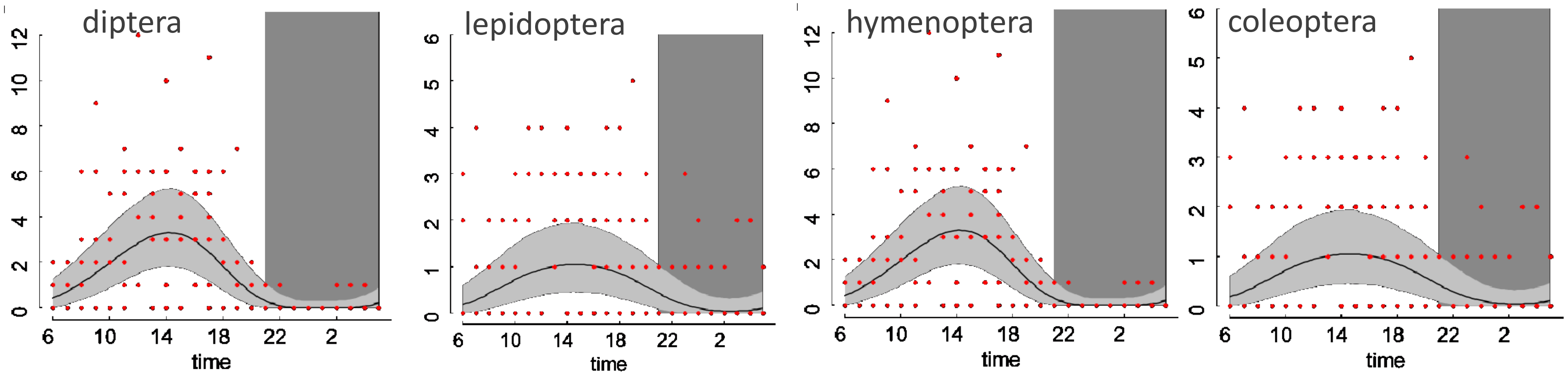
appears to involve numerous plant families



McGregor et al. (2015)

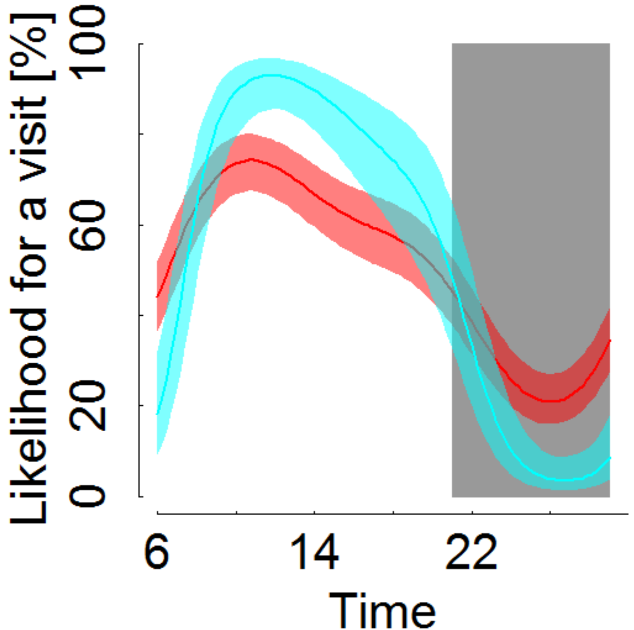
Quantifying pollination around the clock

Most frequent visitor orders



On average:
79.5% diurnal visits
20.5% nocturnal visits

Most visited plants



Plants visited during day and night:

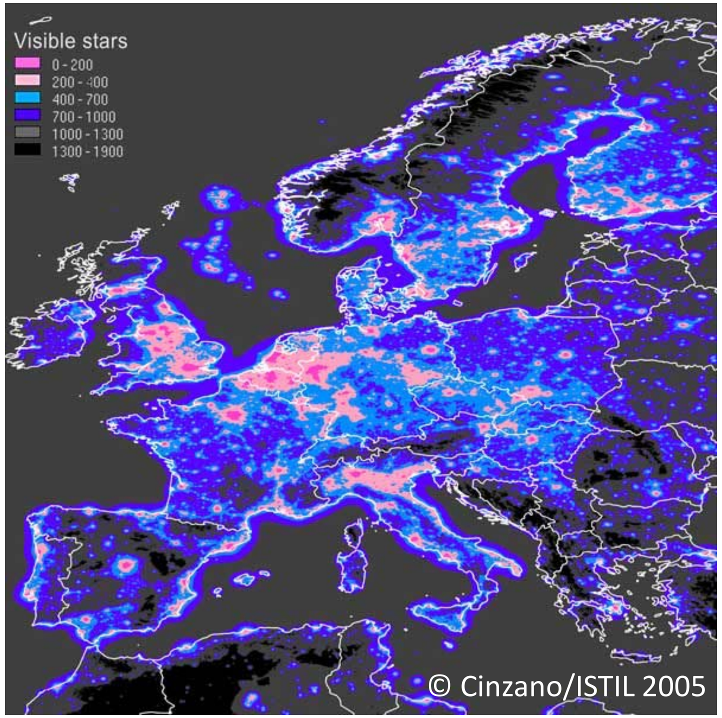
Aruncus dioicus
Cirsium oleraceum
Valeriana officinalis

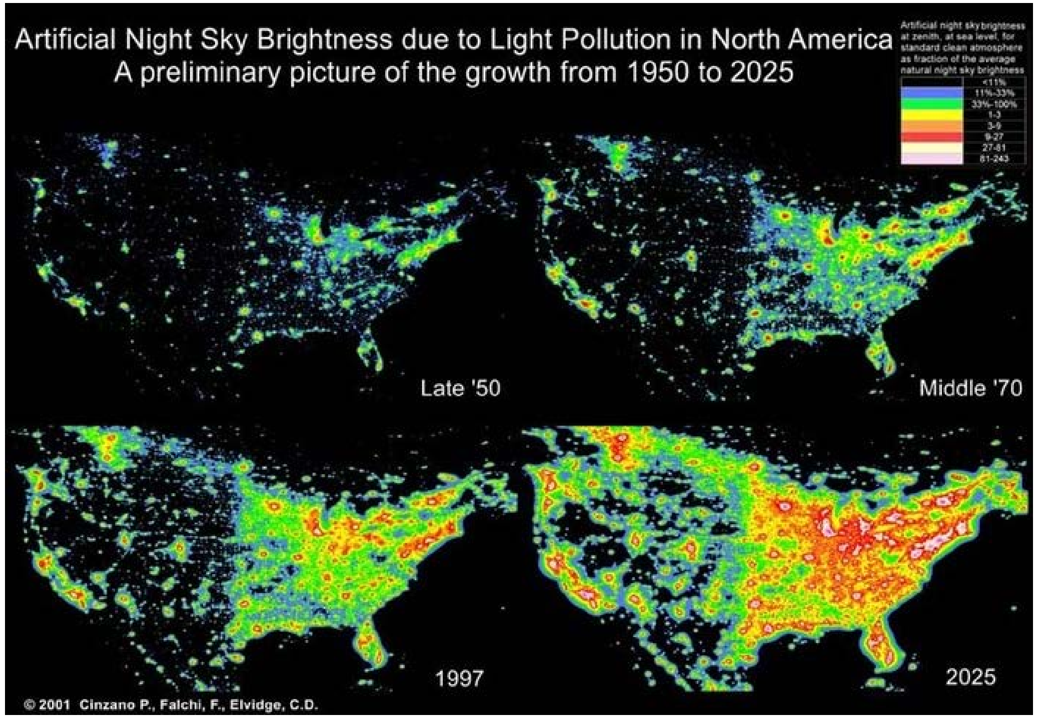
Plants visited only during day :

Centaurea sp.
Daucus carota
Erigeron annuus
Heracleum sphondylium

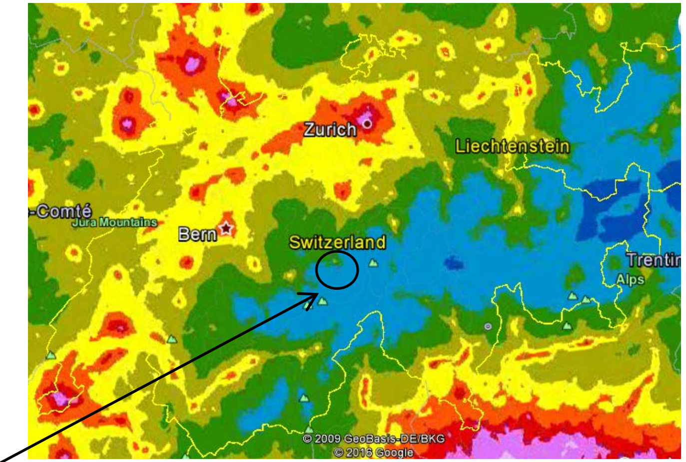
What about light pollution?

- artificial light at night affect moth behaviour
- 99% of Europeans live in light-polluted areas
- global annual increase in area of about 6 %





Light pollution and nocturnal pollinators

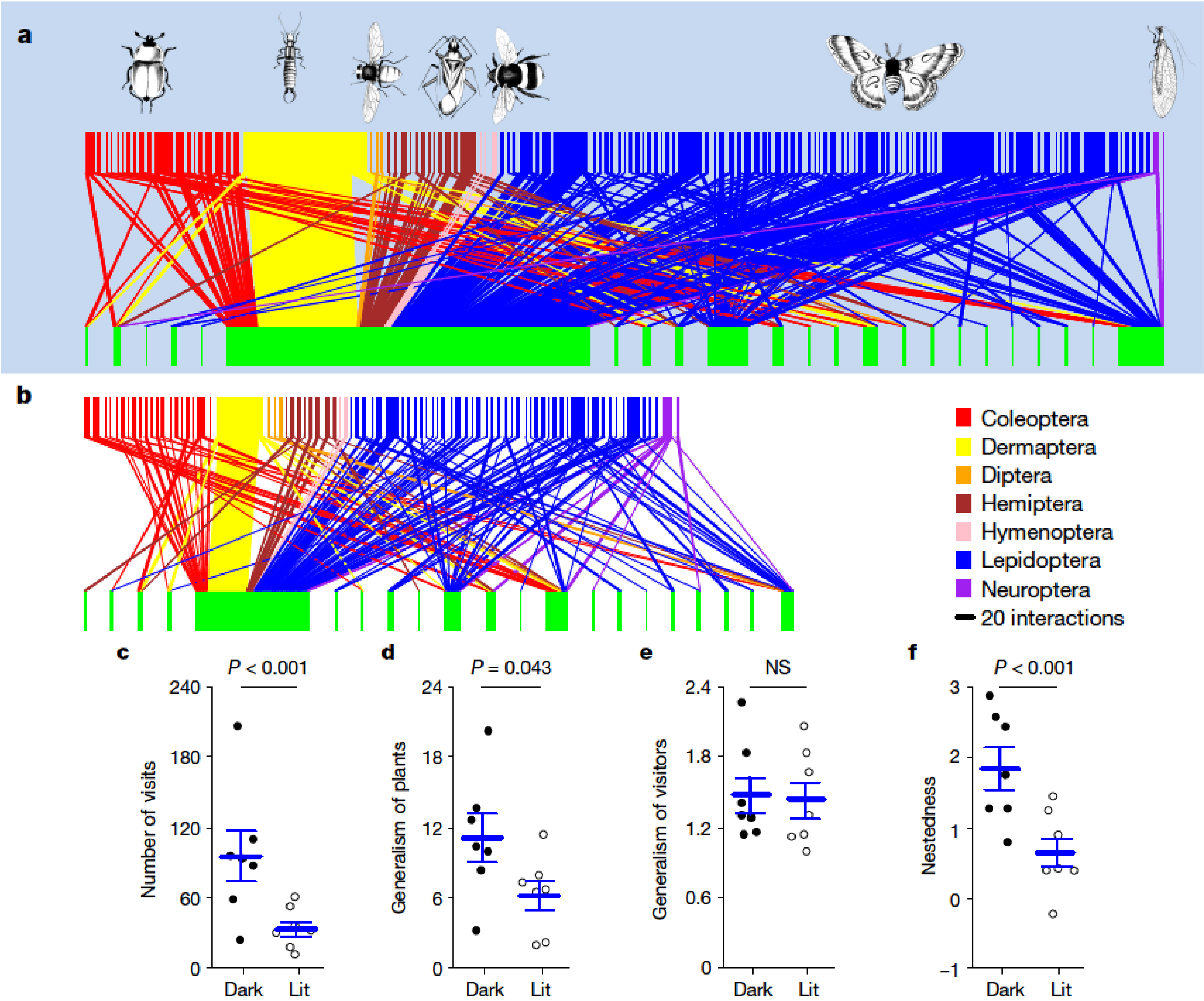


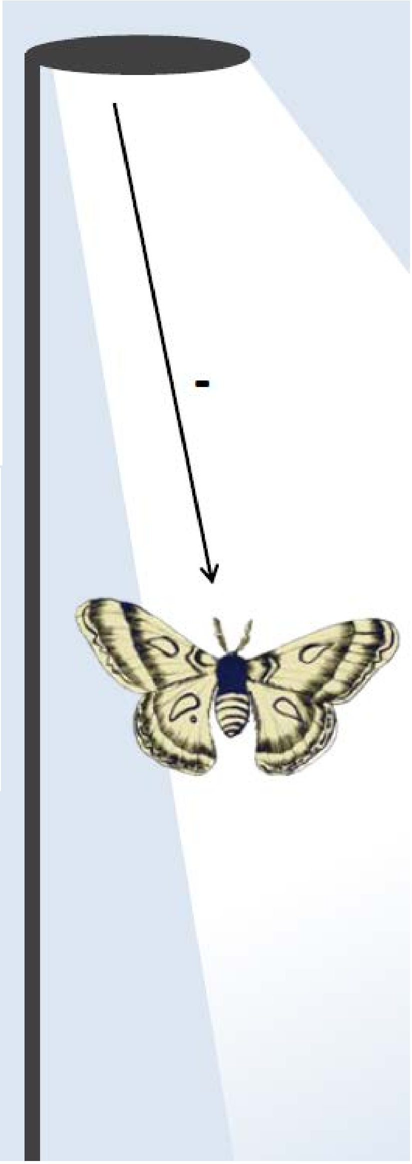
7 ruderal meadows located in Bernese Oberland

2 sampling sites per meadow separated by 500m with one where LED streetlamps were installed

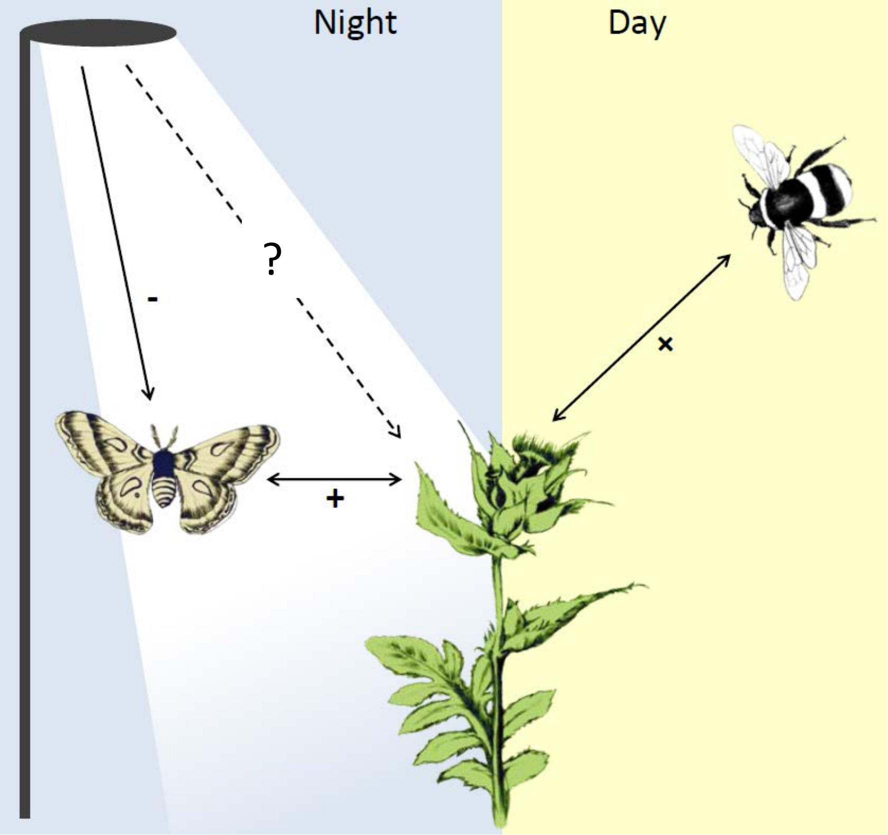
Sampling along 100m transect every 30 min all night between June and September 2015

Light pollution and nocturnal pollinators





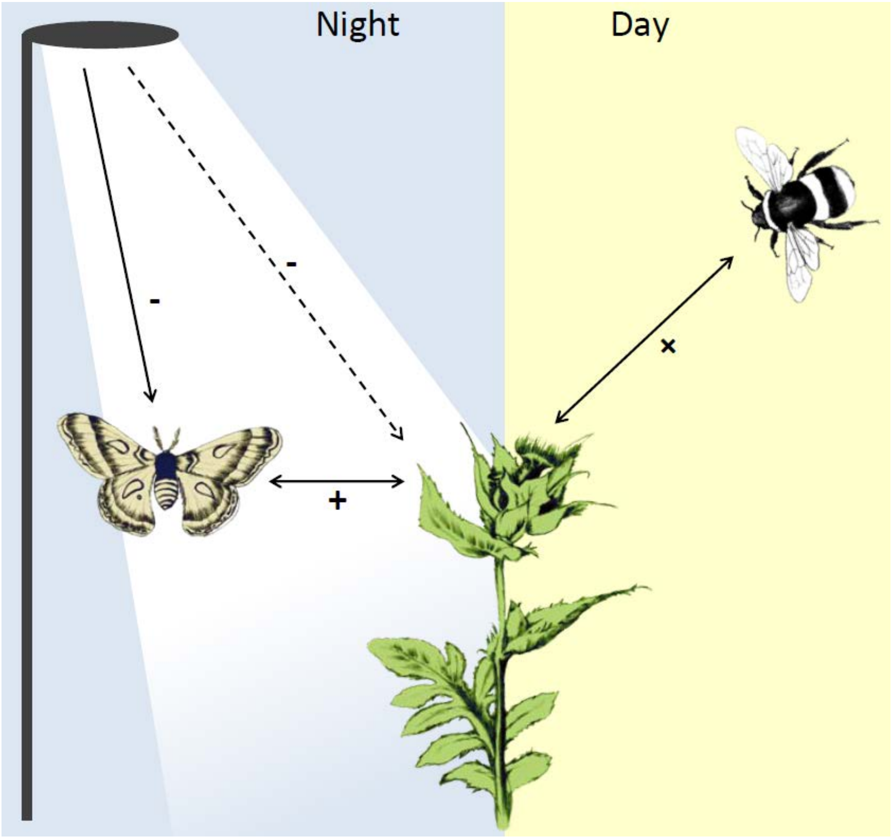
Light pollution and plant seed set

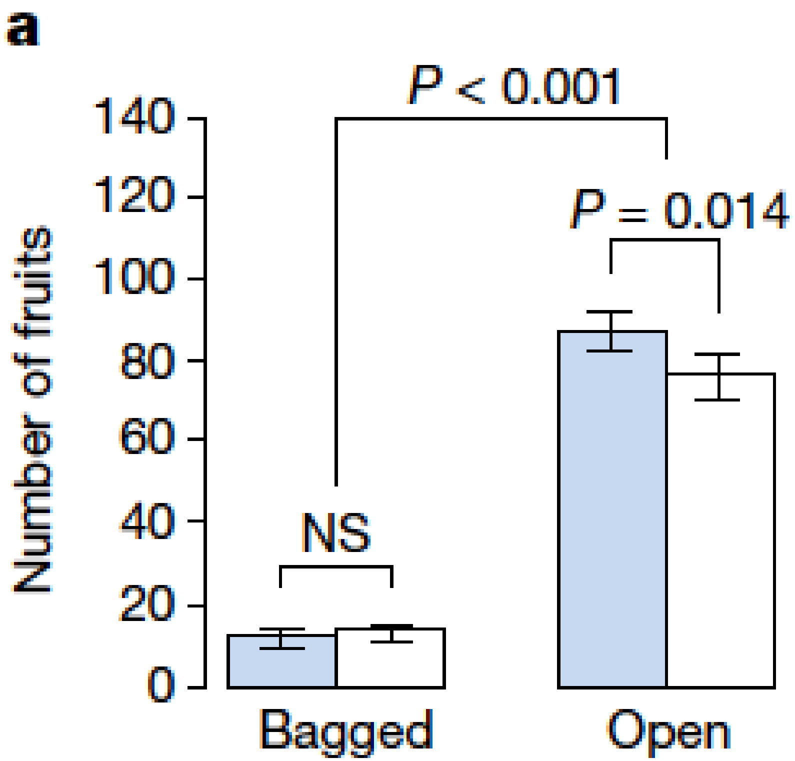


5 ruderal meadows located in Bernese Oberland

artificial light vs. control

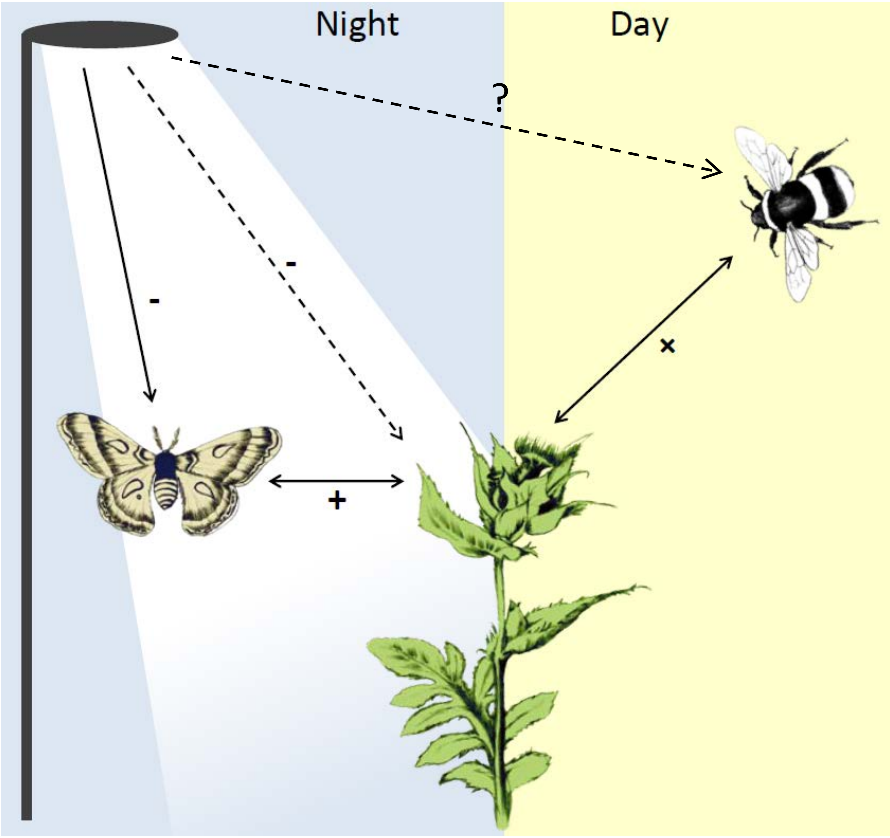
Light pollution and plant seed set



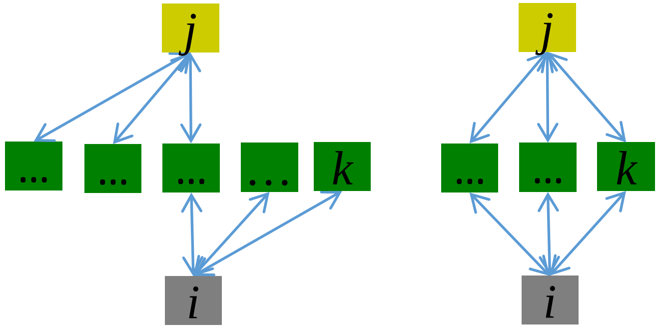


13% reduction
in seed set

Light pollution and diurnal pollinators



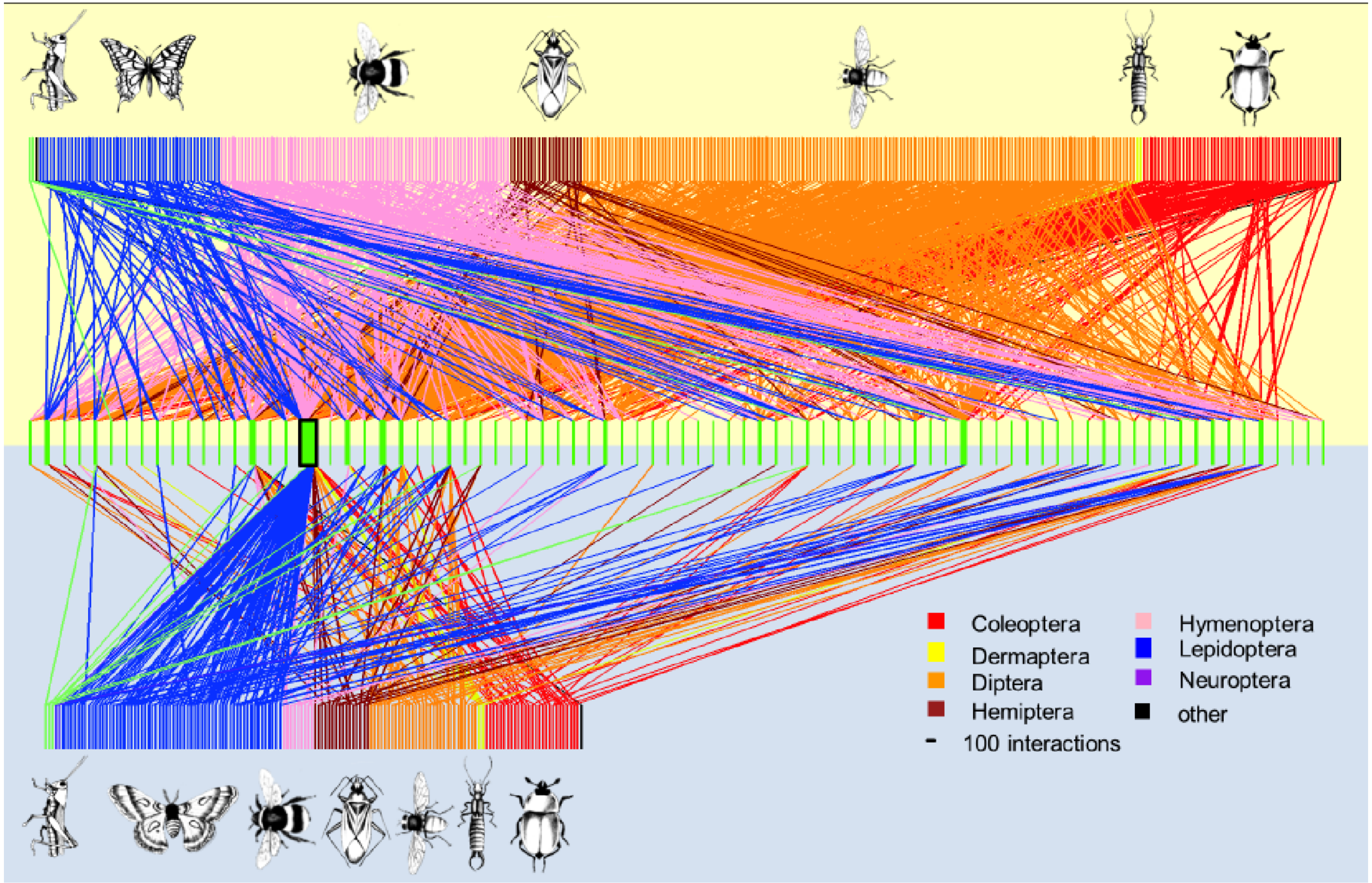
Potential for indirect interactions



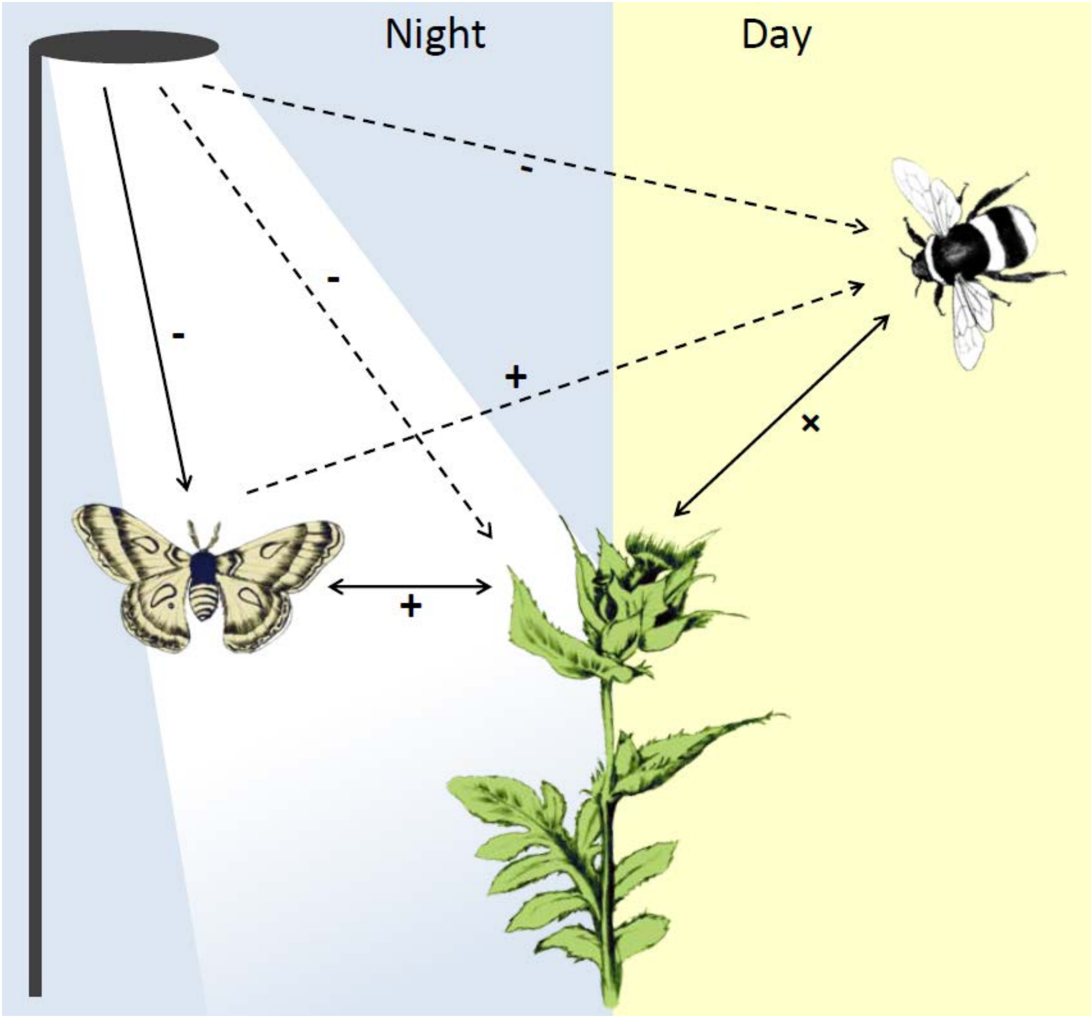
Height ruderal meadows

Sampling every 30min from 17:00 to 16:59
along 50m transect
four 24h sampling rounds per site

Potential indirect effect from nocturnal to diurnal pollinators



Conclusion



Nocturnal pollination is not neglectable, with 20% of visits being nocturnal

Artificial light impact nocturnal pollinator with negative consequences for plant pollination.

Nocturnal pollinators are not redundant with diurnal ones

The architecture of merged diurnal and nocturnal pollination networks tend to favor the spread of artificial light perturbation from nocturnal to diurnal pollinators


Remo Ryser


Leana Zoller


Maurin Hörler


Christopher Gerpe


Myles Menz

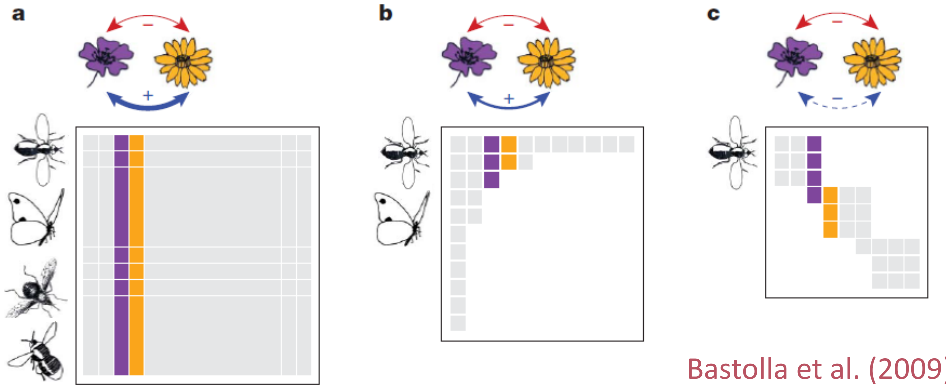

Eva Knop

Thank you and thanks to…


Artificial light effects
on plant-pollinator networks


Eva Knop

Stability of mutualistic networks: a balance between mutualism and competition?



Bastolla et al. (2009)

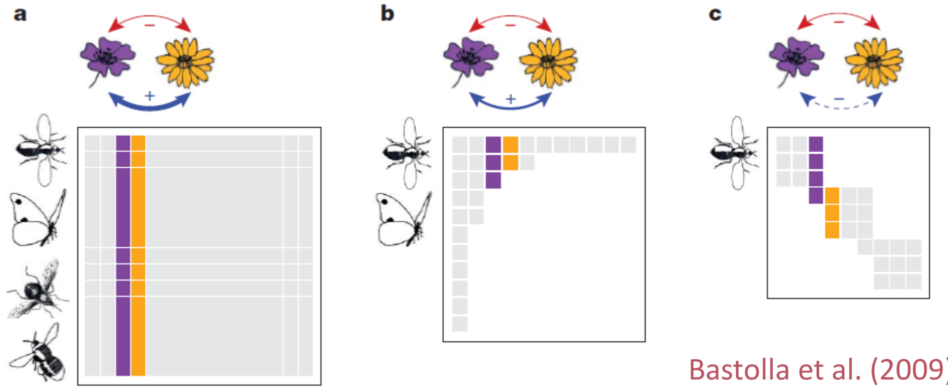
- In connected and in nested networks, positive effects outweight negative ones, enhancing persistence

THEBAULT Elisa, DUCHENNE François,

MICHEZ Denis, ELIAS Marianne, CERRETTI Pierfilippo , DAUGERON Christophe, DELFOSSE Emmanuel, TEULIERE Elsa, DEVAUX Céline, GERARD Maxence

Thank you for your attention

Stability of mutualistic networks: a balance between mutualism and competition?



Bastolla et al. (2009)

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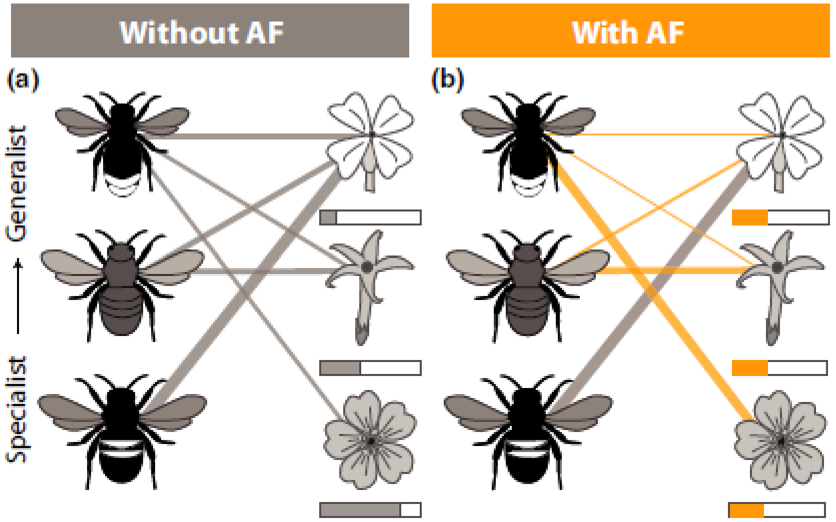

- When competition for resources are included, nestedness enhances persistence only in case of adaptive foraging, leading to niche partitioning

Valdovinos et al. (2016)

Stability of mutualistic networks: a balance between mutualism and competition?

Network structure (e.g. nestedness) arises from constraints linked with species traits and phenologies.

How do these constraints affect the balance between mutualism and competition in mutualistic webs?

Phenology and indirect effects in mutualistic networks

High trait similarity
High phenology overlap