From flowers to landscapes : spatial and temporal dynamics of floral resources for pollinators

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Institut d'écologie et des sciences de l'environnement de Paris (IEES-Paris)


Hyménoptères
Bourdon des champs

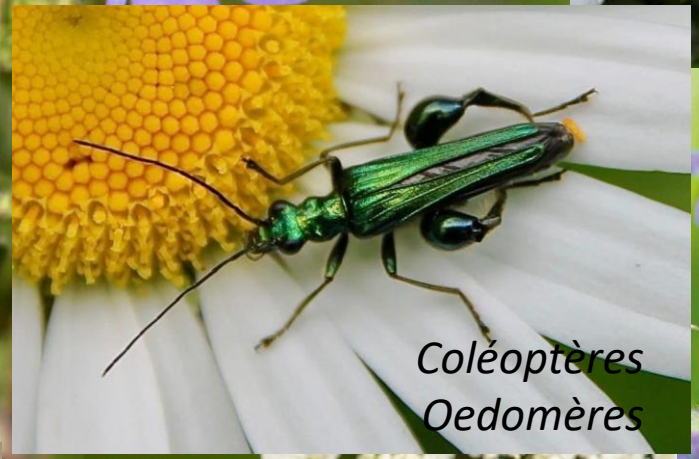

Hyménoptères
Andrene


Diptères
Syrphe ceinturé

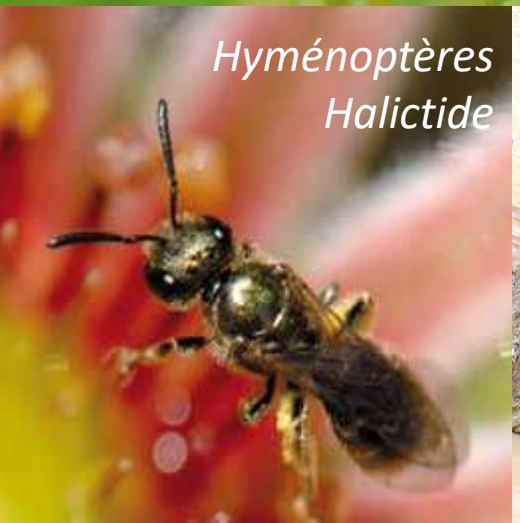

Lépidoptères
Sphinx orangé

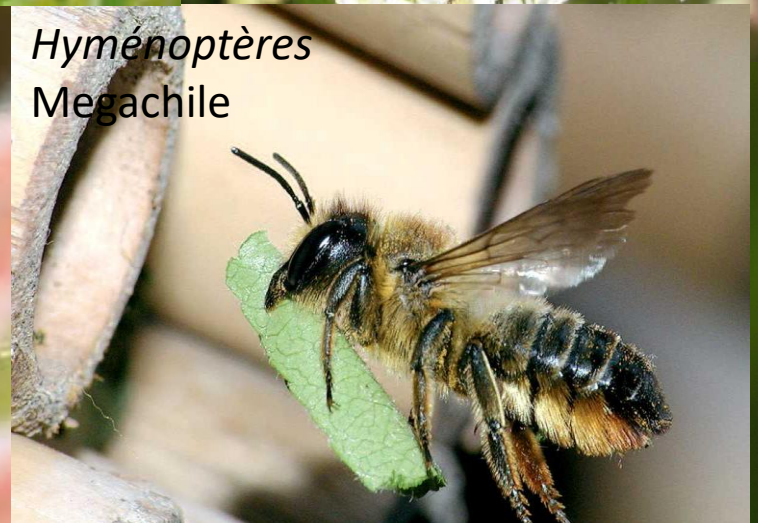

Hyménoptères
Abeille charpentière


Diptères
Eristale gluante


Coléoptères
Oedomères


Lépidoptères
Petit collier argenté

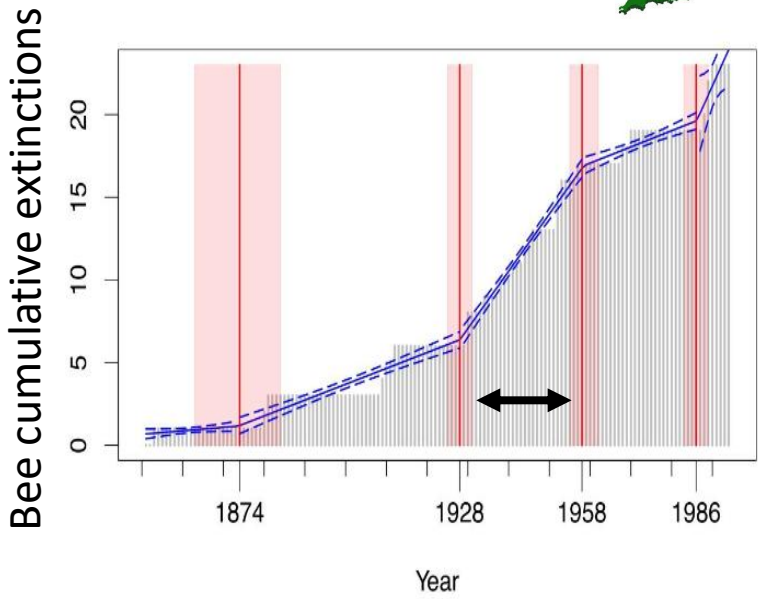

Hyménoptères
Halictide


Hyménoptères
Megachile


Coléoptères
Cétoine

Pollinator decline

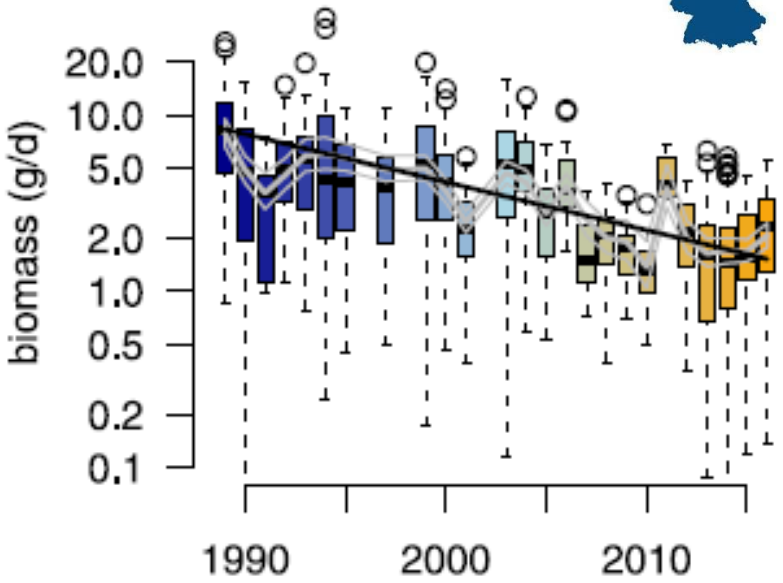
Species extinction



Ollerton et al. 2014

- ~ 10% of solitary bees are threaten of extinction in Europe (IUCN, 2025)
- ~ 35% of syrphids are threaten of extinction in Europe (IUCN, 2022)

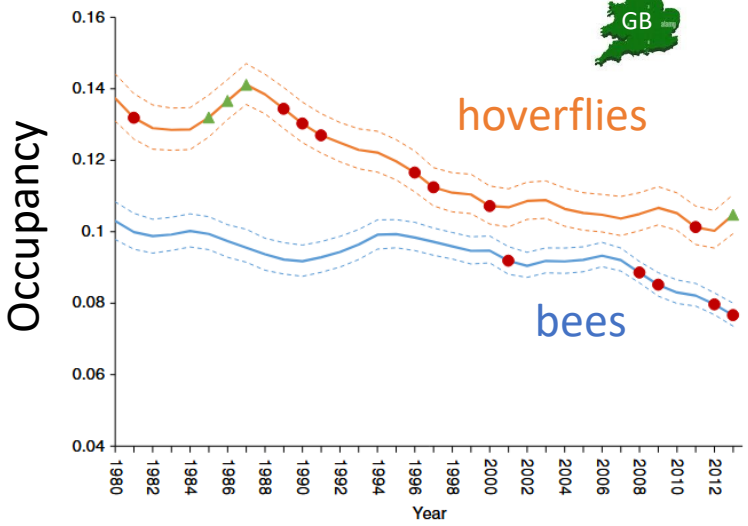
Biomass loss



Hallman et al. 2017

- Loss of 80% of biomass of flying insects in 30 years

Geographic range reduction



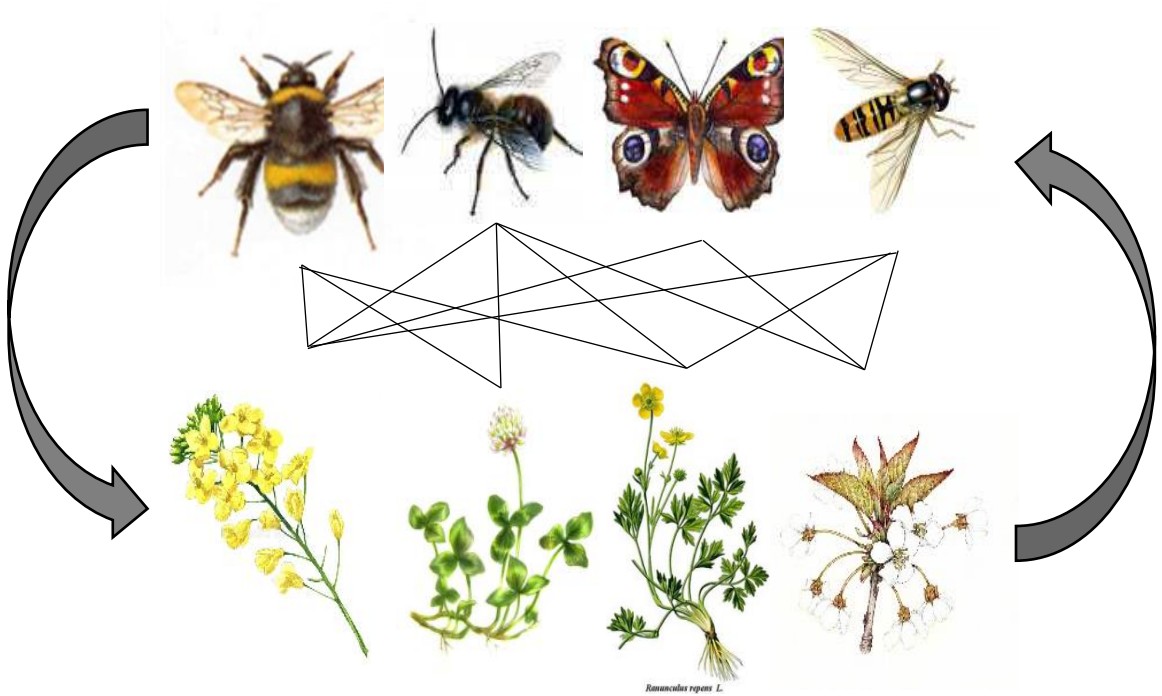
Powney et al. 2019

- Reduction of 25% for both wild bees and hoverflies

Plant-pollinator interactions

pollinating insects

Pollination interaction
(pollen transport and deposition)



Trophic interaction
(floral resource production & consumption)

crops wild plants

~75% of crops depend on animal pollination for production (Klein et al. 2006)
~ 90% of angiosperm species depend on animal pollination for reproduction (Ollerton et al. 2011)

Role of floral resources in pollinator decline

Review

Cell PRESS

Global pollinator declines: trends, impacts and drivers

2010

Simon G. Potts[1], Jacobus C. Biesmeijer[2], Claire Kremen[3], Peter Neumann[4], Oliver Schweiger[5] and William E. Kunin[2]

The Role of Resources and Risks in Regulating Wild Bee Populations

2011

T'ai H. Roulston[1] and Karen Goodell[2]

[1]Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22904-4123; email: tai.roulston@virginia.edu

[2]Department of Evolution, Ecology and Organismal Biology, The Ohio State University, Newark, Ohio 43055; email: goodell.18@osu.edu

Bee declines driven by combined stress from parasites, pesticides, and lack of flowers

2015

Dave Goulson,* Elizabeth Nicholls, Cristina Botías, Ellen L. Rotheray

School of Life Sciences, University of Sussex, Falmer, Brighton BN1 9QG, UK.

*Corresponding author. E-mail: d.goulson@sussex.ac.uk

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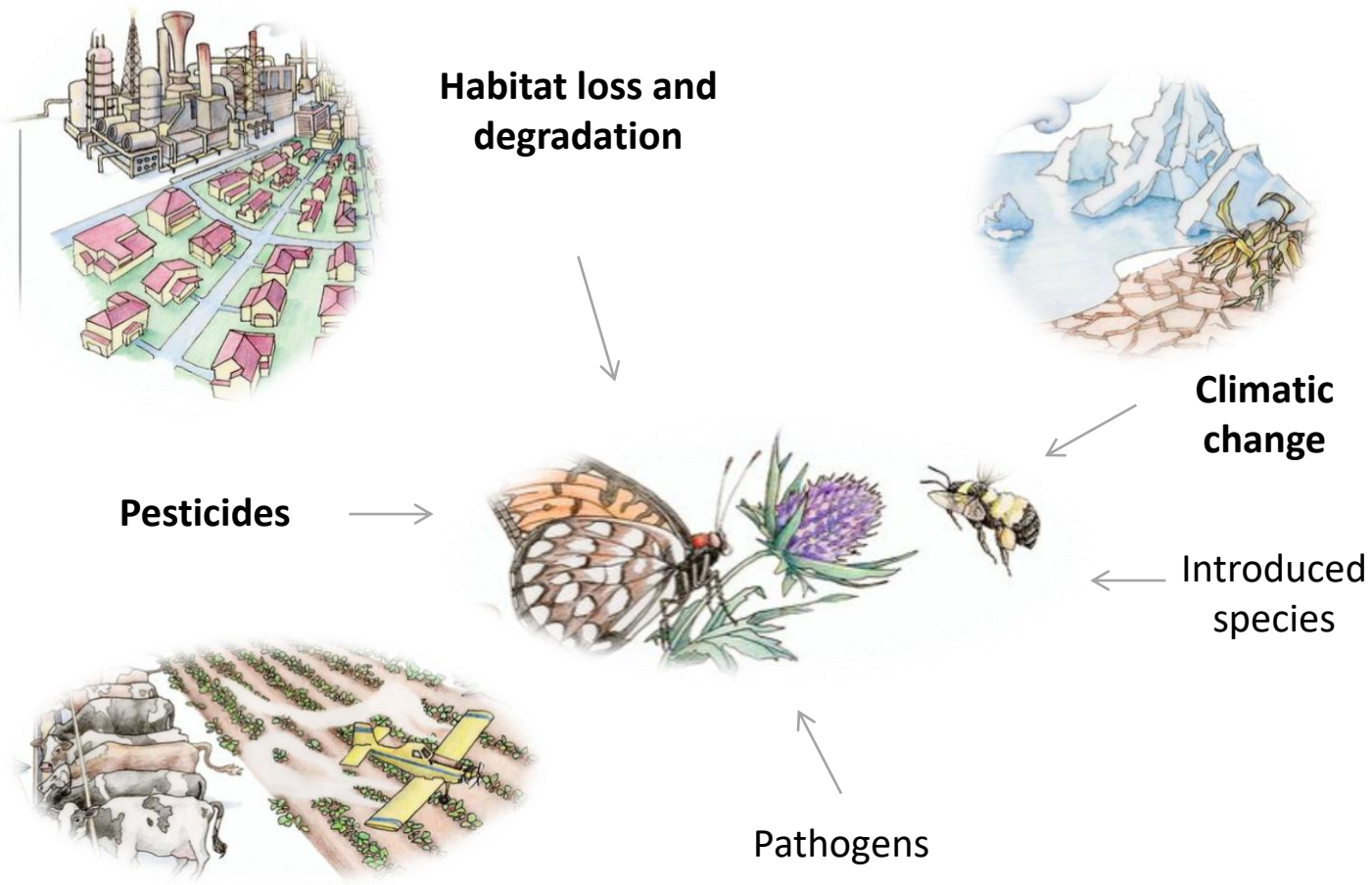


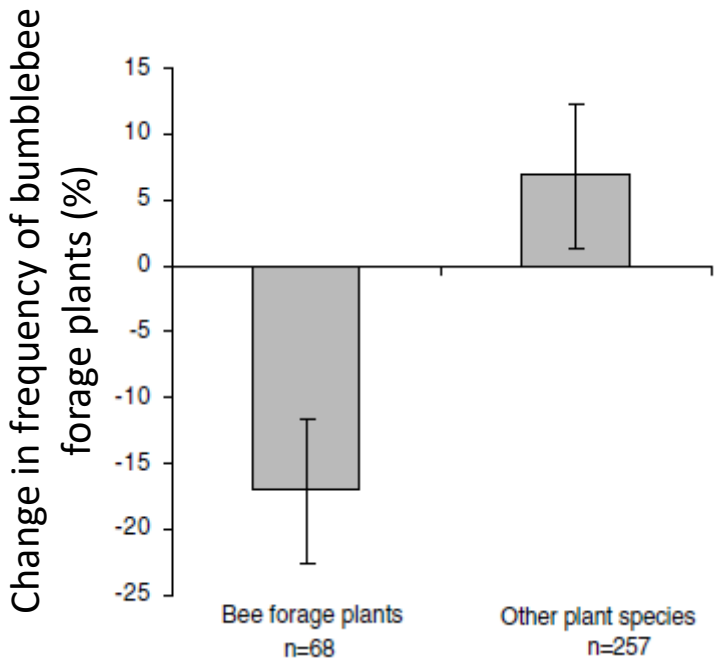
Adapted from Wagner et al. PNAS 2020

Evidence of actual decline in floral resources

Declines in forage availability for bumblebees at a national scale

Claire Carvell[a,], David B. Roy[a], Simon M. Smart[b], Richard F. Pywell[a], Chris D. Preston[a], Dave Goulson[c]*

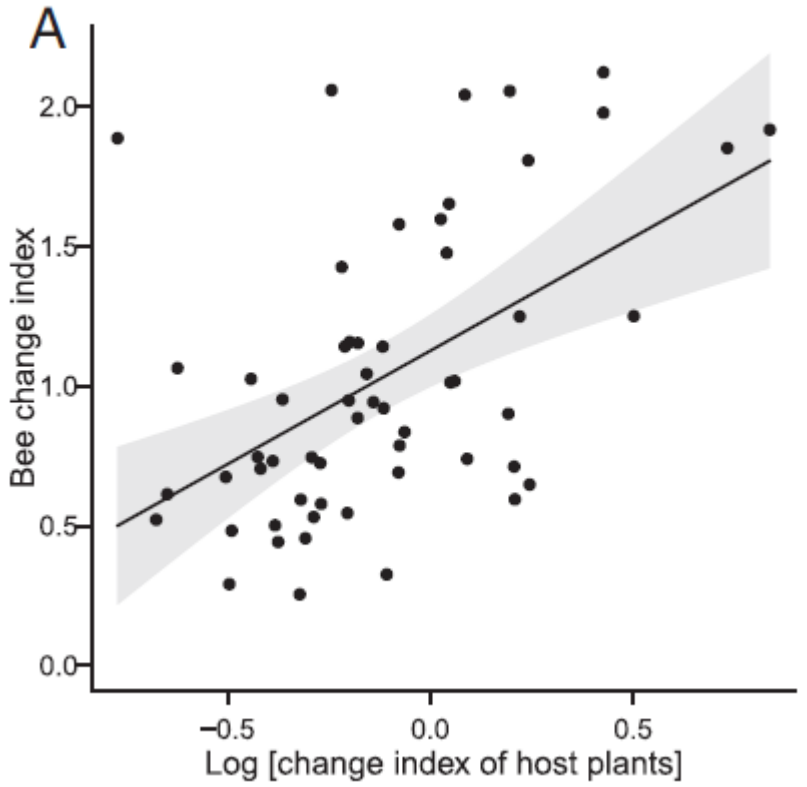
1978-1998



Museum specimens reveal loss of pollen host plants as key factor driving wild bee decline in The Netherlands

Jeroen Scheper[a,1], Menno Reemer[b], Ruud van Kats[a], Wim A. Ozinga[c,d], Giel T. J. van der Linden[e], Joop H. J. Schaminée[c,d], Henk Siepel[f,g], and David Kleijn[a,e]

(1902-1949) vs
(1975-1999)

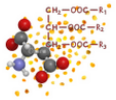


- Does the quantity of floral resources decline ?
- Need for quantified data on floral resources

Quantification of floral resources

Flower number or flower cover

Nectar production (nectar sugar content) => flux of energy

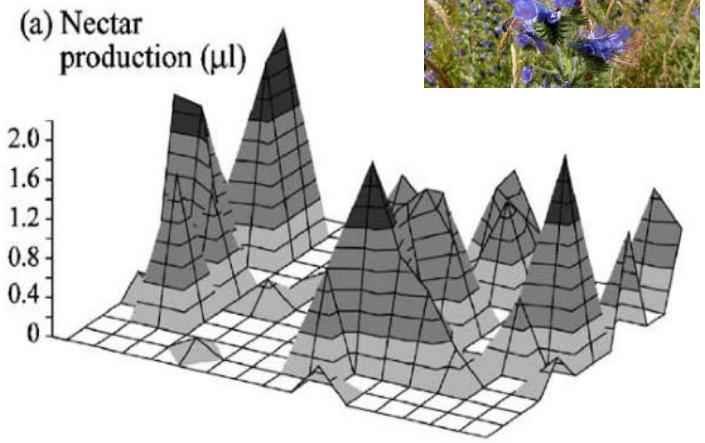


Pollen production (volume and composition) => nutritional value

- A unique quantified data easy to aggregate at various scales

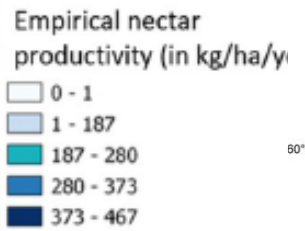
Floral resources are structured… spatially

Population scale



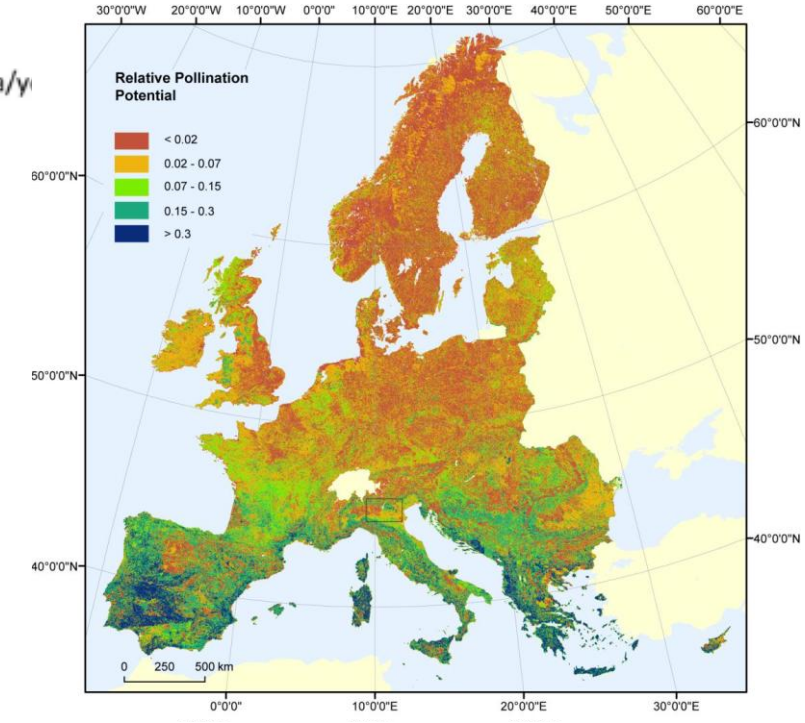
Leiss & Klinkhamer (2005)

Landscape scale



Alignier et al. 2023

Europe scale

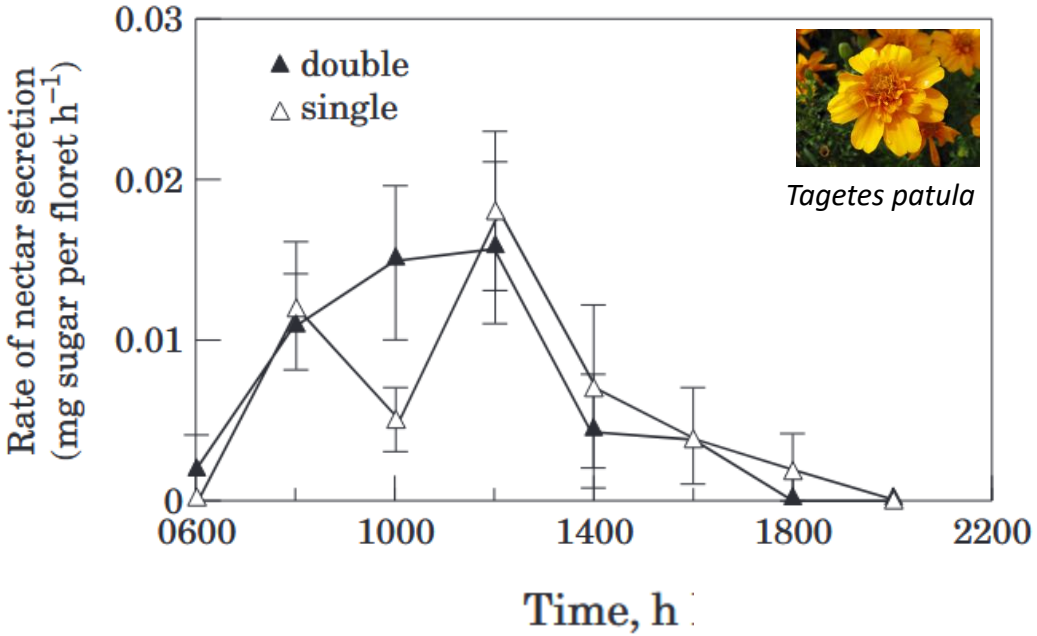


Zulian et al. 2013

- Convert land cover maps into floral resource maps to predict the presence of pollinators

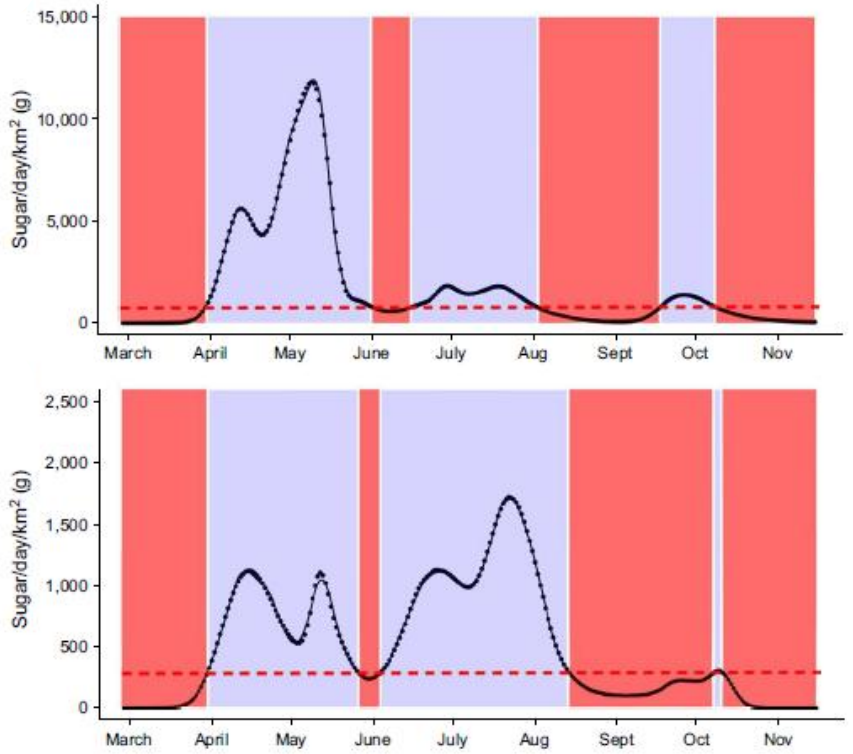
Floral resources are structured… temporally

Daily scale



Comba et al. 1999

Seasonal scale



Timberlake et al. 2019

➢ Existence of critical periods (supply vs demand) ?

Floral resources are structured… temporally

- Are floral resources limiting pollinators? When & where?

….yet floricol insects are herbivores….

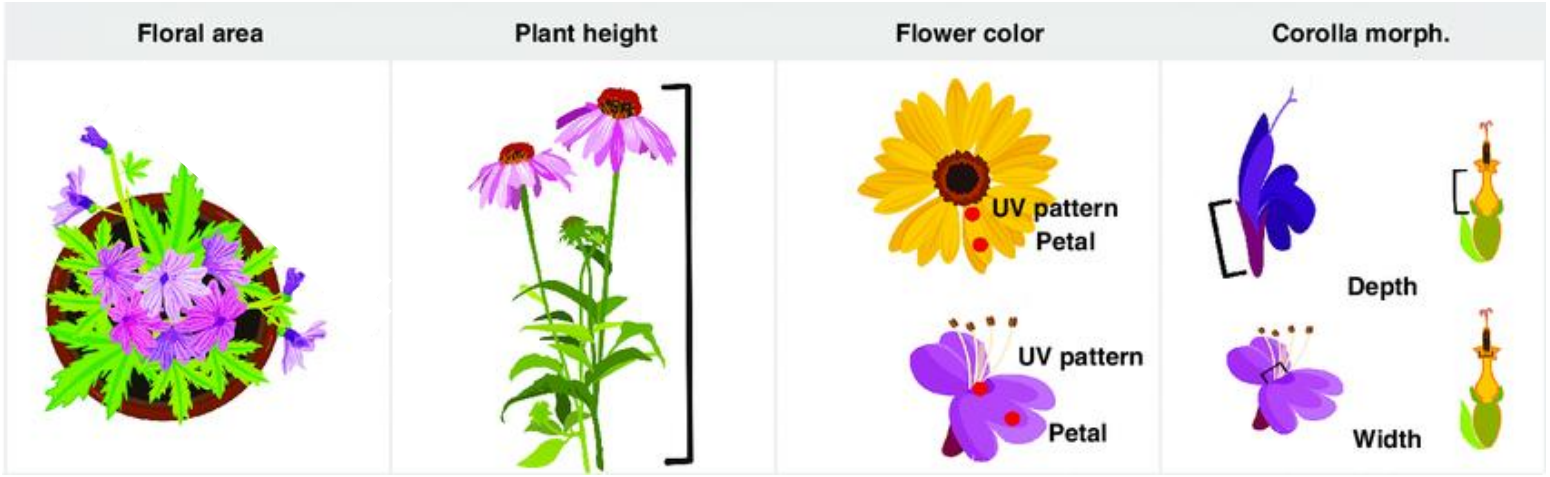
Green world hypothesis

(Hairston et al. 1960)

Sweet world hypothesis?

(Sponsler et al. 2023)

Floral resources are structured… functionally



Adapted from Erickson et et al. 2022

Floral traits determine attractivity & accessibility to floral resources

Floral traits can filter different groups of pollinators

➢Coexistence & competition among pollinators

1 **From the handbook to the ‘Bloom’ database**

How to measure and compile floral resources data?

2 **Historical dynamics of nectar and pollen production at the national scale**

Did historical shifts in vegetation induce changes in floral resources?

3 **Seasonal dynamics of nectar and pollen production**

What are the critical periods for floral resource availability?

➢ **How spatial and temporal changes in vegetation translate into changes in the availability of floral resources for pollinators ?**

1 From the handbook to the ‘Bloom’ database

How to measure and compile floral resources data?

The plant functional approach

"Functional traits are defined as morpho-physio-phenological traits which impact fitness indirectly via their effects on growth, reproduction and survival, the three components of individual performance".

Violle et al. 2007

Fonctions	Marqueurs fonctionnels
Fécondité Dissémination Etablissement	Masse de graine Hauteur Reproductive Phénologie reproductive
Interception de la lumière Aptitude à la compétition	Hauteur végétative
Acquisition de ressource Croissance Décomposition de la litière	Taille des feuilles Structure morpho-anatomique des feuilles Teneurs en éléments minéraux des feuilles
Absorption (nutriments, eau) Flux de carbone (exsudation…) Compétition souterraine	Densité racinaire Diamètre et longueur racinaires Surface spécifique racinaire

Garnier & Navas 2012

The handbooks for plant traits

RESEARCH ARTICLE Next

A handbook of protocols for standardised and easy measurement of plant functional traits worldwide

J. H. C. Cornelissen, S. Lavorel, E. Garnier, S. D
H. ter Steege, H. D. Morgan, M. G. A. van der

Australian Journal of Botany 51(4) 335 - 380
Published: 31 July 2003

Received: 6 June 2019 | Revised: 14 February 2020 | Accepted: 26 February 2020
DOI: 10.1111/jvs.12877

SYNTHESIS

Journal of Vegetation Science

The neglected importance of floral traits in trait-based plant community assembly

Anna E-Vojtkó[1,2] | Francesco de Bello[1,3] | Walter Durka[4,5] |
Ingolf Kühn[4,5,6] | Lars Götzenberger[1,2]

➢ **Floral traits are not included!**

Functional Ecology / Volume 33, Issue 3 / pp. 372-387

REVIEW | Open Access

Handbook for the measurement of macrofungal functional traits: A start with basidiomycete wood fungi

Samantha Katherine Dawson, Lynne Boddy, Hans Halbwachs, Claus Bässler, Carrie Andrew, Thomas Ward Crowther, Jacob Heilmann-Clausen, Jenni Nordén, Otso Ovaskainen, Mari Jönsson

First published: 10 November 2018
https://doi.org/10.1111/1365-2435.13239
Citations: 41

New Phytologist

Community resources | Open Access

A starting guide to root ecology: strengthening ecological concepts and standardising root classification, sampling, processing and trait measurements

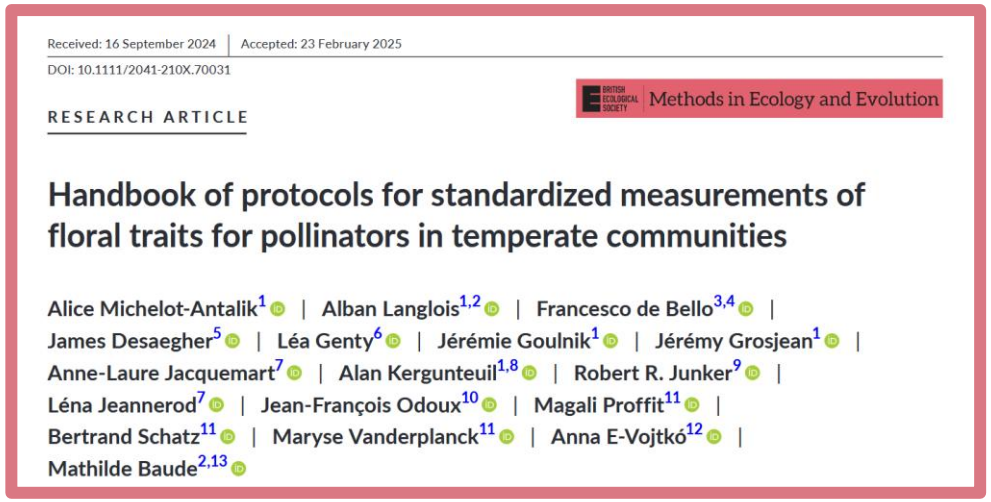
Correction(s) for this article

Grégoire T. Freschet, Loïc Pagès, Colleen M. Iversen, Louise H. Comas, Boris Rewald, Catherine Roumet, Jitka Klimešová, Marcin Zadworny, Hendrik Poorter, Johannes A. Postma, Thomas S. Adams, Agnieszka Bagniewska-Zadworna, A. Glyn Bengough, Elison B. Blancaflor, Ivano Brunner, Johannes H. C. Cornelissen, Eric Garnier, Arthur Gessler, Sarah E. Hobbie, Ina C. Meier, Liesje Mommer, Catherine Picon-Cochard, Laura Rose, Peter Ryser,

lized measurement of terrestrial invertebrate 367

e Bello, Florian Altermatt, Steven L. Chown,
ournier, Mickaël Hedde, Joaquín Hortal, Sébastien Ibanez,
Matty P. Berg ... See fewer authors

The handbooks for floral traits and floral resources



Received: 16 September 2024 | Accepted: 23 February 2025
DOI: 10.1111/2041-210X.70031

Methods in Ecology and Evolution

RESEARCH ARTICLE

Handbook of protocols for standardized measurements of floral traits for pollinators in temperate communities

Alice Michelot-Antalik[1] | Alban Langlois[1,2] | Francesco de Bello[3,4] | James Desaegher[5] | Léa Genty[6] | Jérémie Goulnik[1] | Jérémy Grosjean[1] | Anne-Laure Jacquemart[7] | Alan Kergunteuil[1,8] | Robert R. Junker[9] | Léna Jeannerod[7] | Jean-François Odoux[10] | Magali Proffit[11] | Bertrand Schatz[11] | Maryse Vanderplanck[11] | Anna E-Vojtkó[12] | Mathilde Baude[2,13]

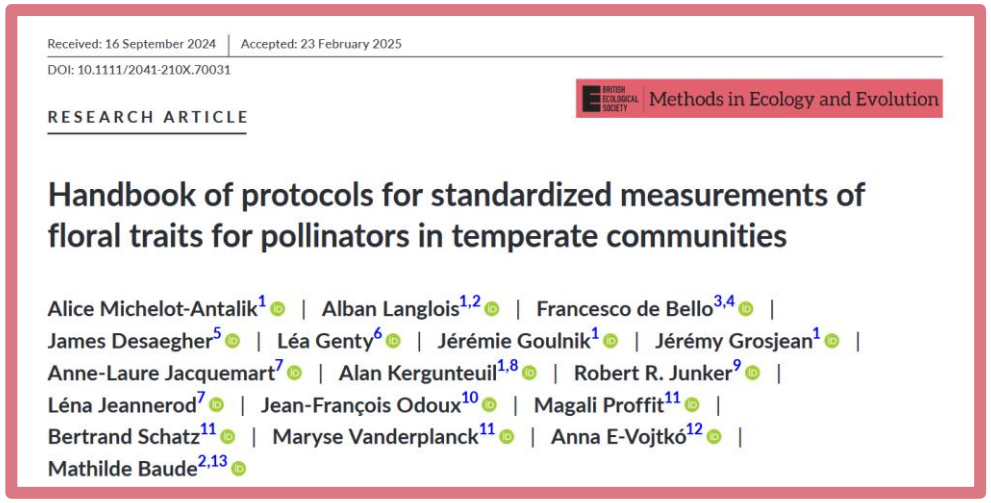
RT POLLINÉCO

Alice Michelot-Antalik, LAE

24 floral traits grouped in 3 categories:

- visual and olfactory cues
- accessibility
- resources (quantity & composition)

The handbooks for floral traits and floral resources



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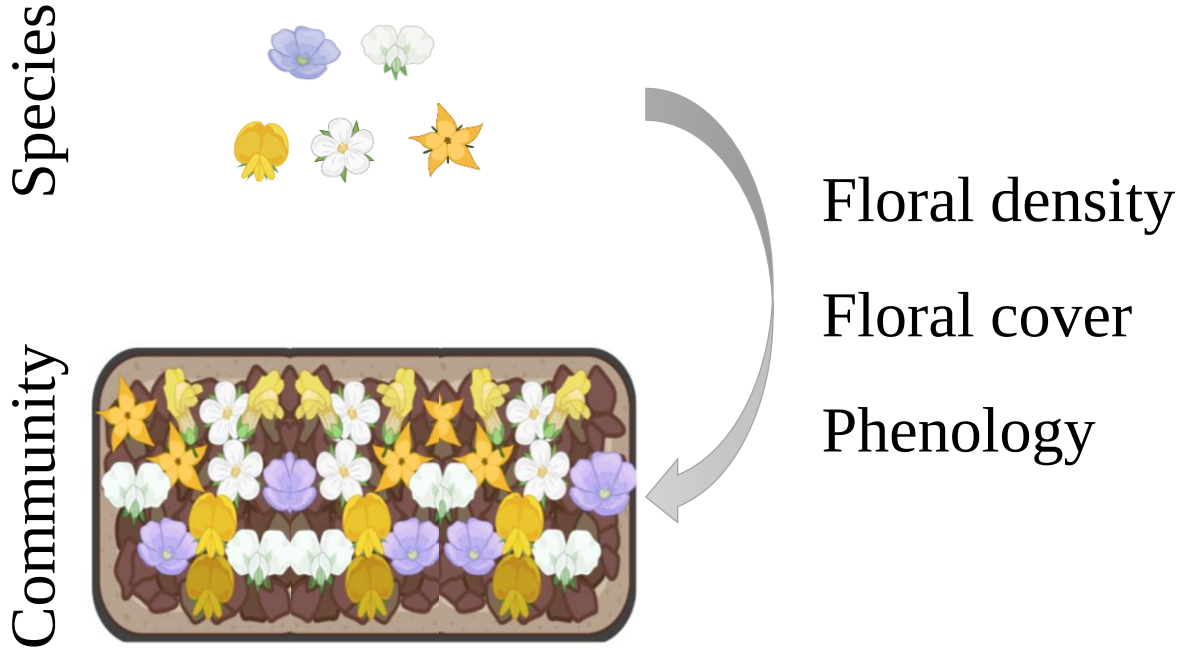
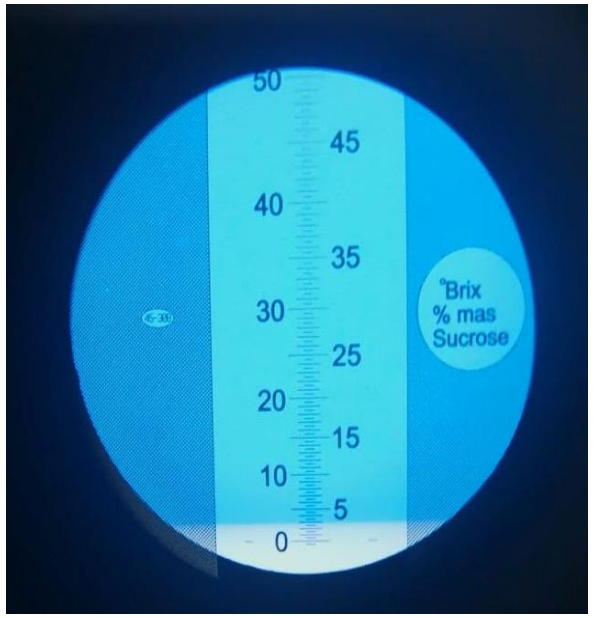
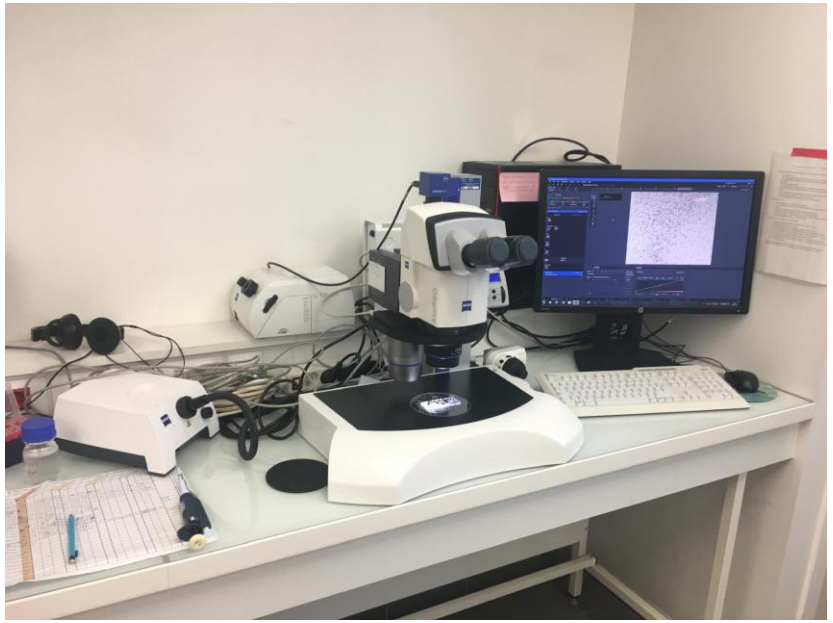
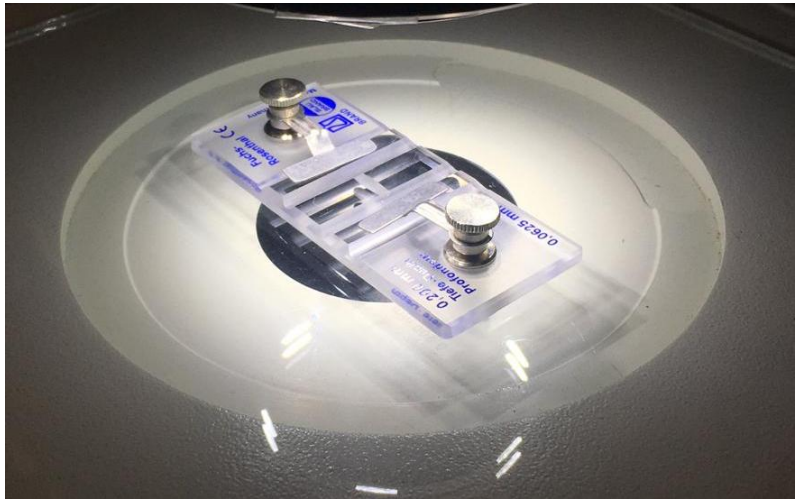


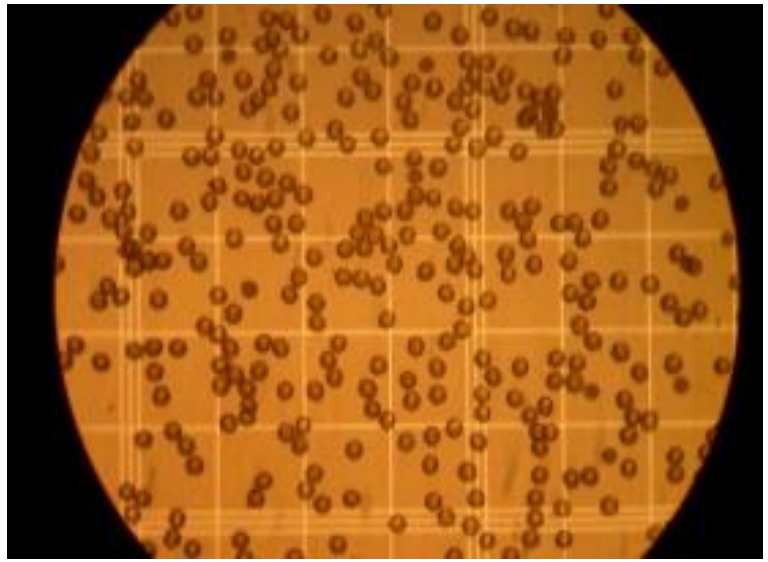
Quantify nectar sugar content



Quantify pollen volume







Nectar and pollen production per flower

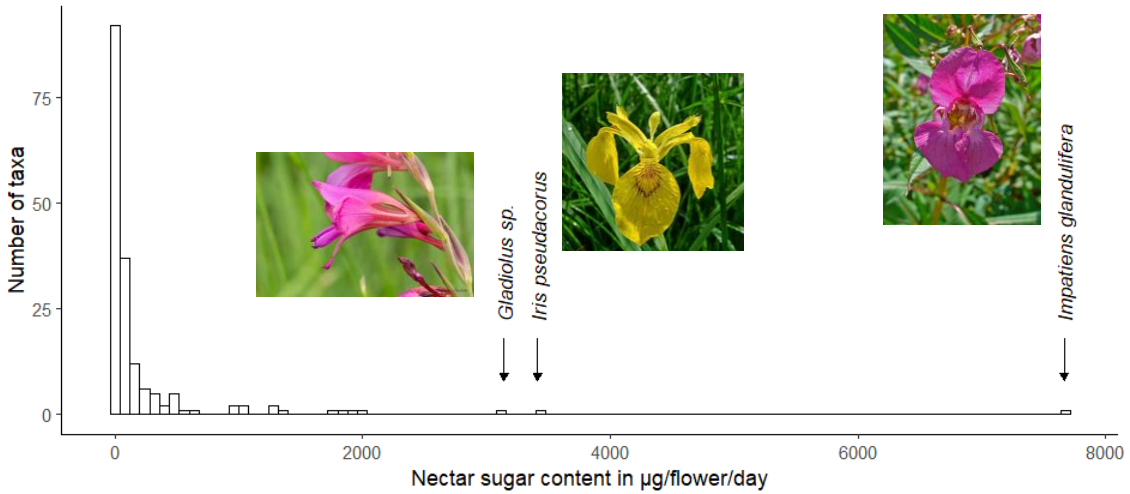
LETTER

doi:10.1038/nature16532

Historical nectar assessment reveals the fall and rise of floral resources in Britain

Mathilde Baude[1,2]†, William E. Kunin[3], Nigel D. Boatman[4], Simon Conyers[4], Nancy Davies[1,2], Mark A. K. Gillespie[3]†, R. Daniel Morton[5], Simon M. Smart[5] & Jane Memmott[1,2]

175 species



https://catalogue.ceh.ac.uk/documents/0b454d53-dfe7-48fd-9e18-b683d004b159
https://catalogue.ceh.ac.uk/documents/69402002-1676-4de9-a04e-d17e827db93c

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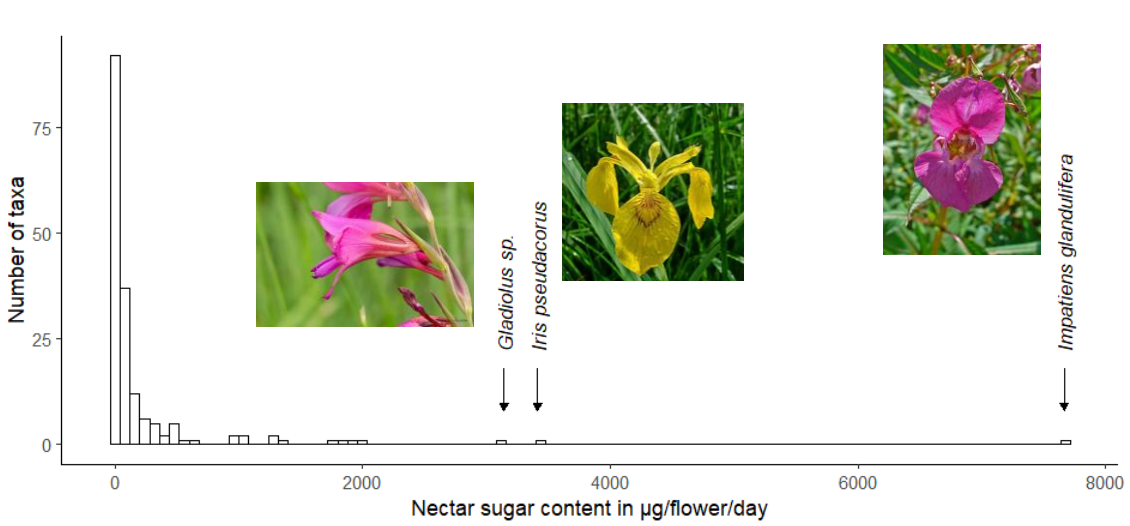


https://catalogue.ceh.ac.uk/documents/0b454d53-dfe7-48fd-9e18-b683d004b159

Received: 6 January 2025 | Accepted: 14 April 2025

DOI: 10.1002/2688-8319.70045

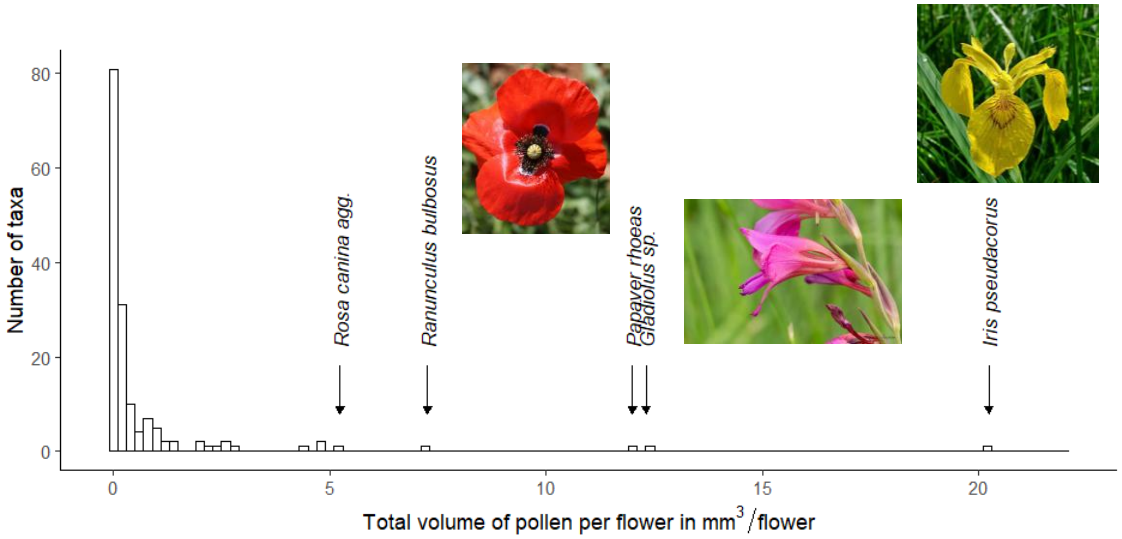
Ecological Solutions and Evidence

DATA ARTICLE

A dataset of pollen production for 168 common flowering plants in the United Kingdom

Mathilde Baude[1,2,3] | William Kunin[4] | Nancy Davies[3] | Ellen Wright[3] | Jane Memmott[3]

168 species



https://catalogue.ceh.ac.uk/documents/69402002-1676-4de9-a04e-d17e827db93c

Baude et al. 2016, Baude et al. 2025

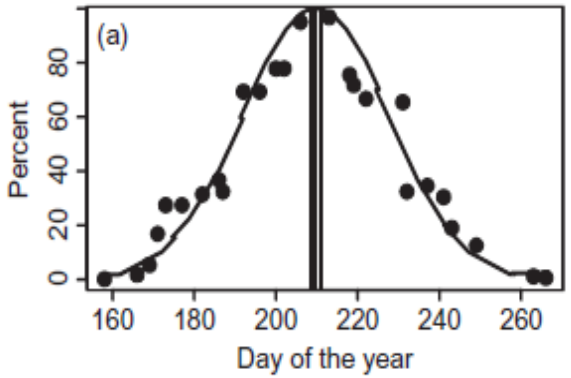
Nectar production per unit of vegetative cover

Flower Density

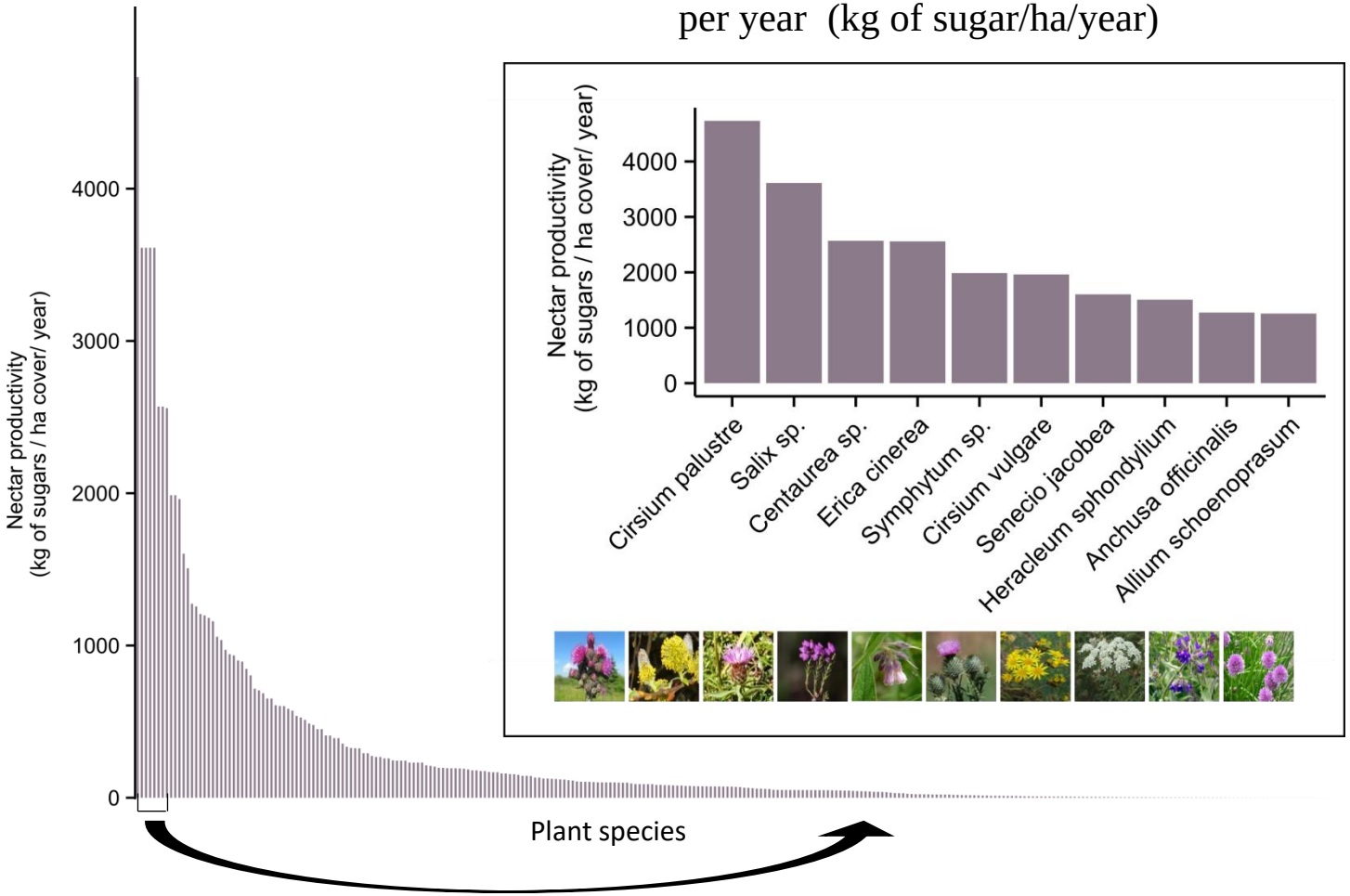
No. of flowers/m² cover (100%)

Flowering phenology

Data from the literature

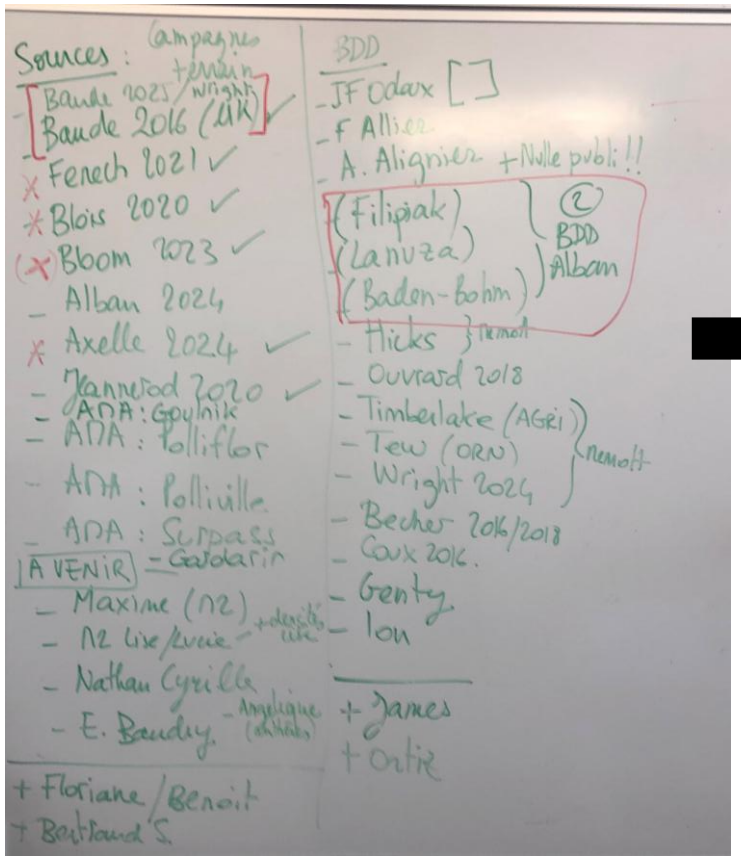


The top 10 plant species for nectar per unit cover per year (kg of sugar/ha/year)



Baude et al. 2016

The Bloom database



Bloom : data**B**ase for f**LO**ral res**O**urces of co**M**mon species

Aim: Create a database of the quantitative data on floral resources available in the literature, and gradually add any missing data with field surveys.

- Compile data
- Standardize data
- Secure backup
- Modular and upgradeable over the long term

Sarah Lemetayer CESCO/iEES

Bloom first exploration

1entry = 1 value for :

- One trait
- One taxon
- One biblio source (+ same method)
- One location
- One date

➢ **So far, we gathered :**

- **34 traits**
- **2860 taxons**
- **~ 30 000 entries**

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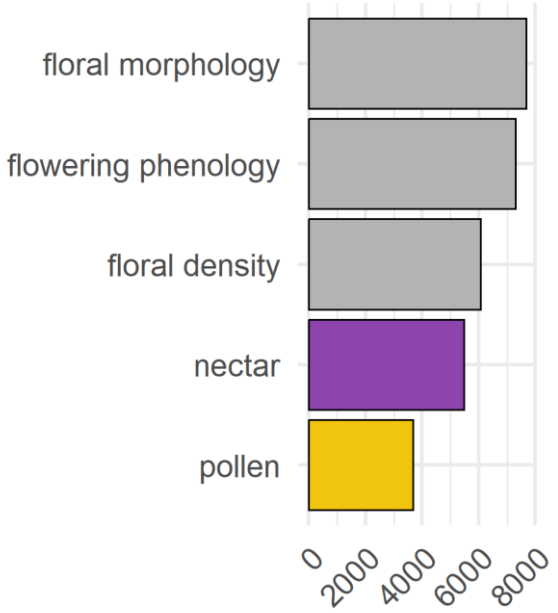
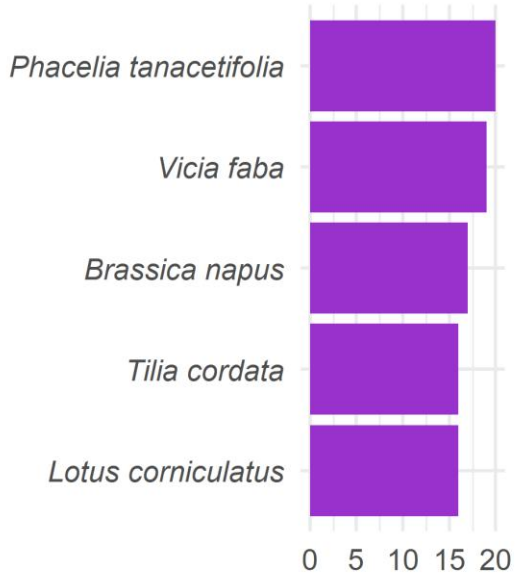
Number of ocurrence

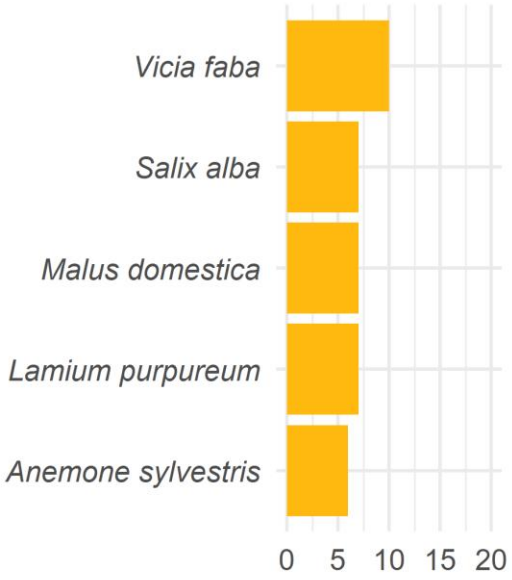


Trait

Top 5 species with the highest number of values



Nectar sugar content



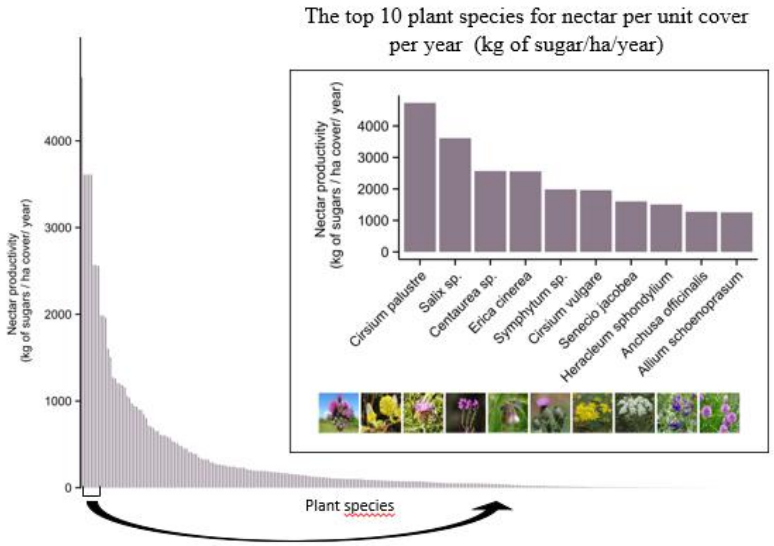
Pollen volume or mass

2 Historical dynamics of nectar and pollen production at the national scale

Did historical shifts in vegetation induce changes in floral resources?

Historical floristic data

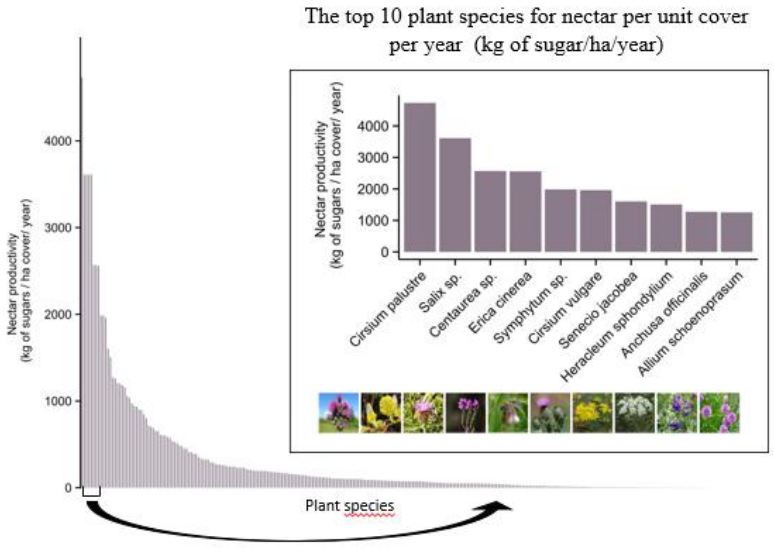
Species nectar productivity at the cover area scale



X

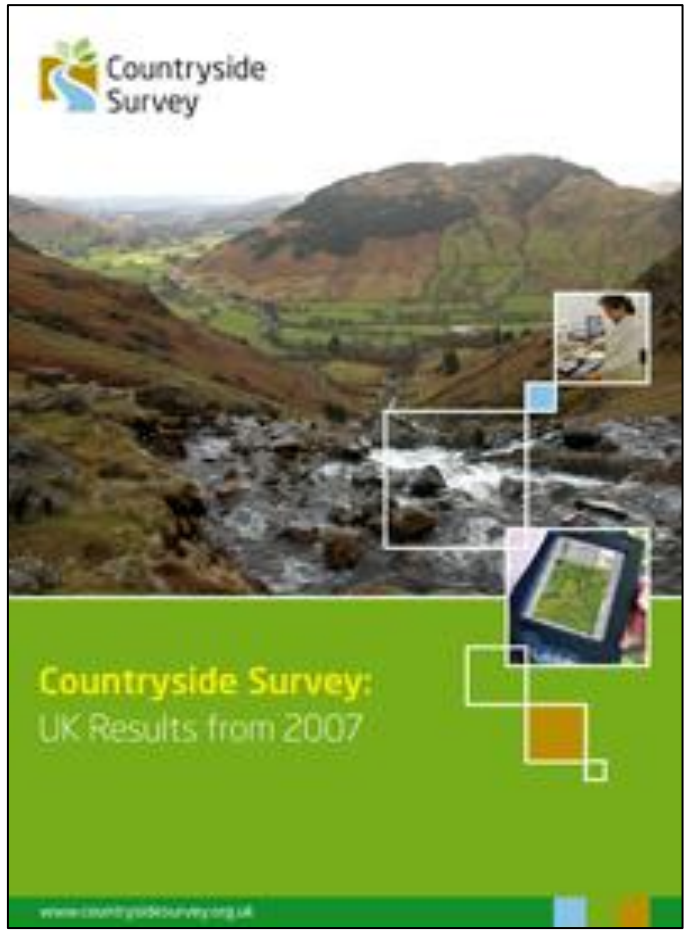
Historical floristic data

Species nectar productivity at the cover area scale



X

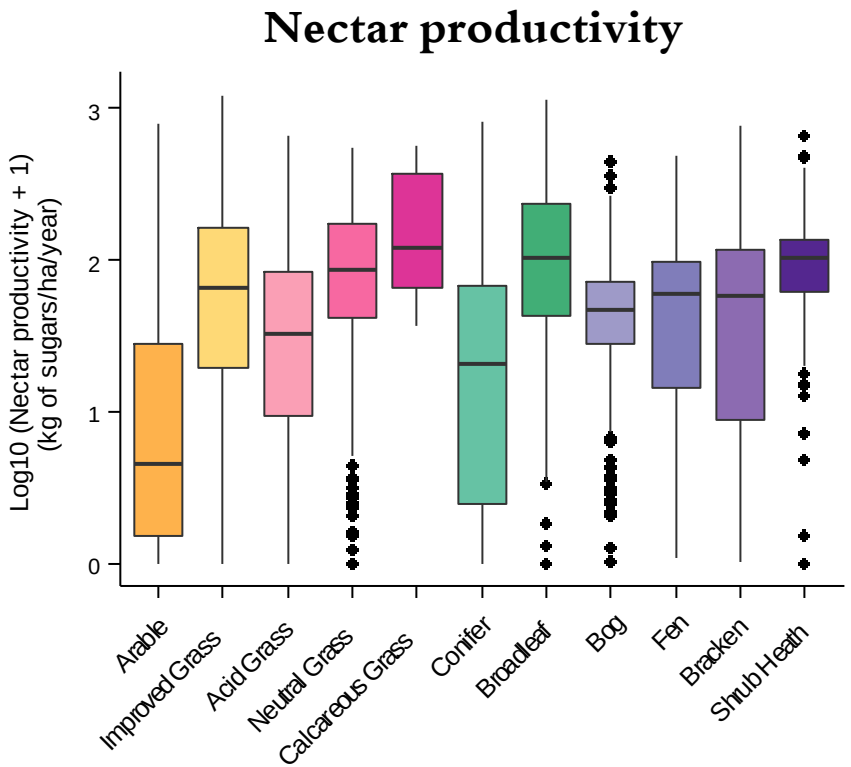
Countryside survey (UK)

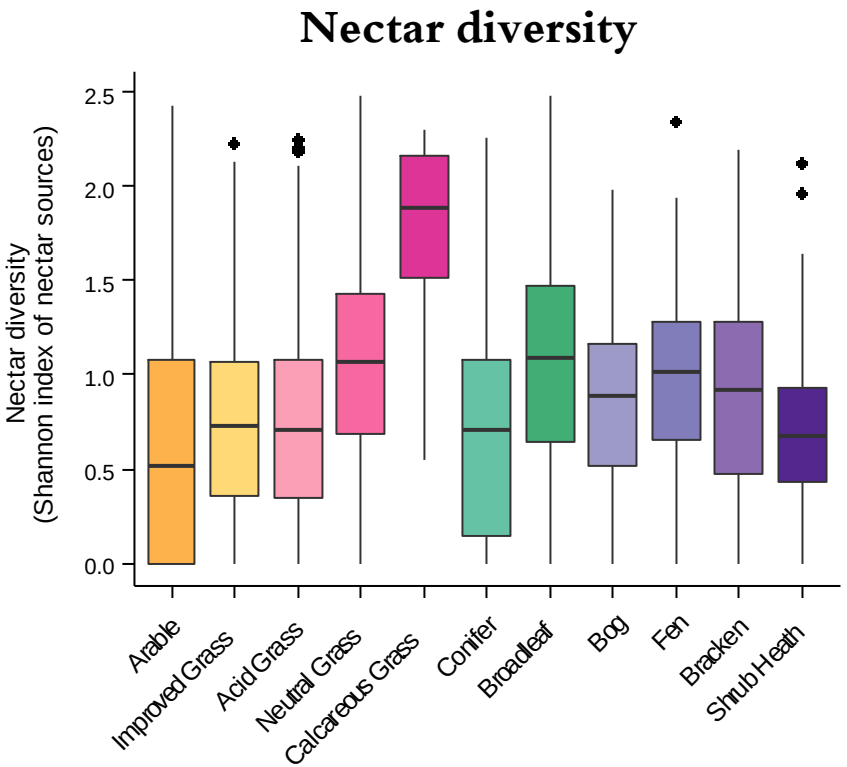


National program to monitor ecological and land use changes
2668 plots in 2007, 768 repeated across time
Plant species composition and proportional cover

1978 1990 2000 2007

Habitat nectar production



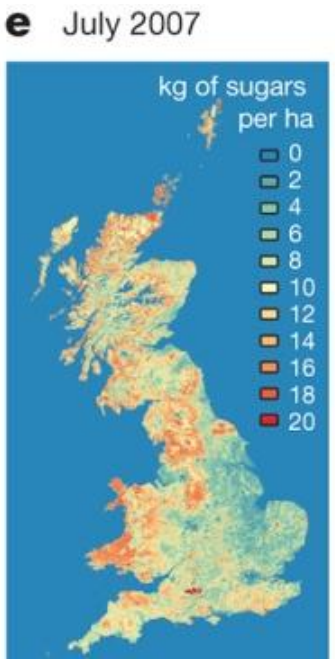


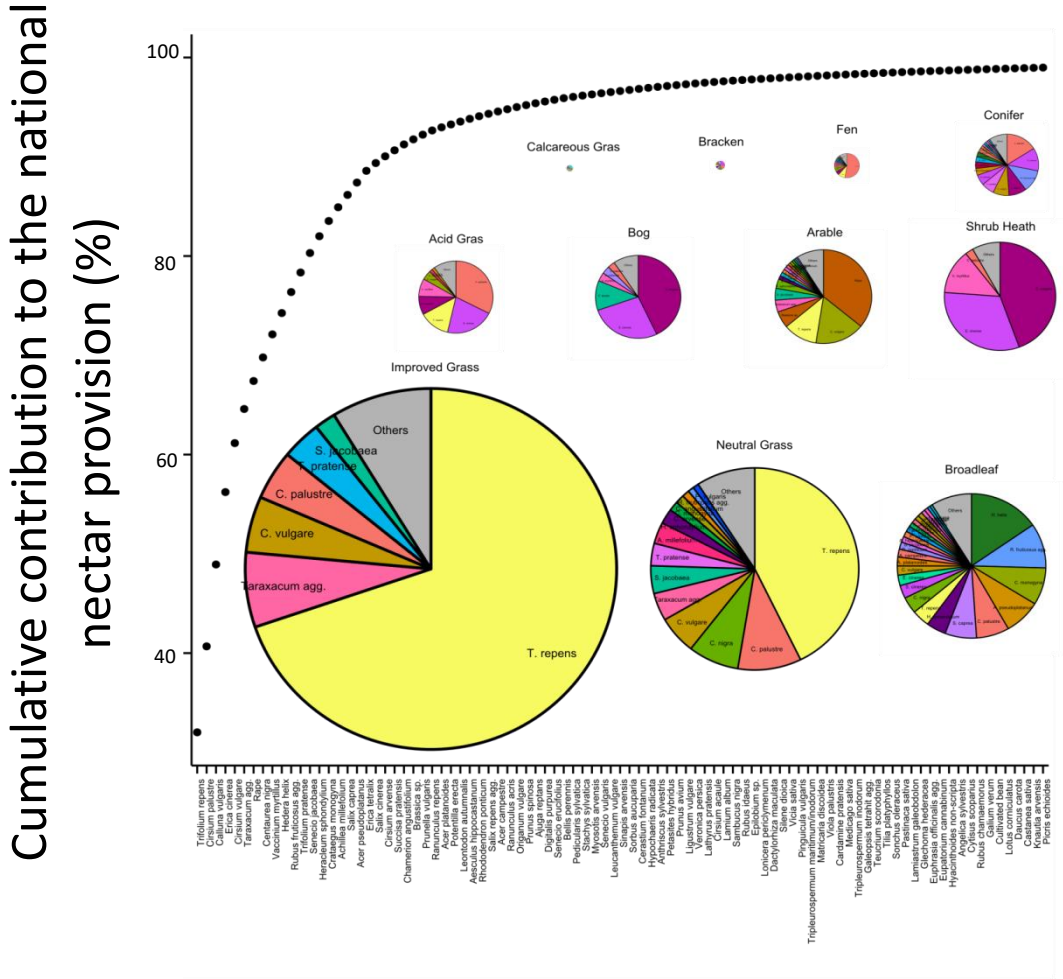
Arable | Improved grassland | Calcareous grassland | Conifer | Broadleaf | Shrub heath

Baude et al. 2016

Species and habitat contribution to the national picture

After taking into account the national land cover (CS 2007) :

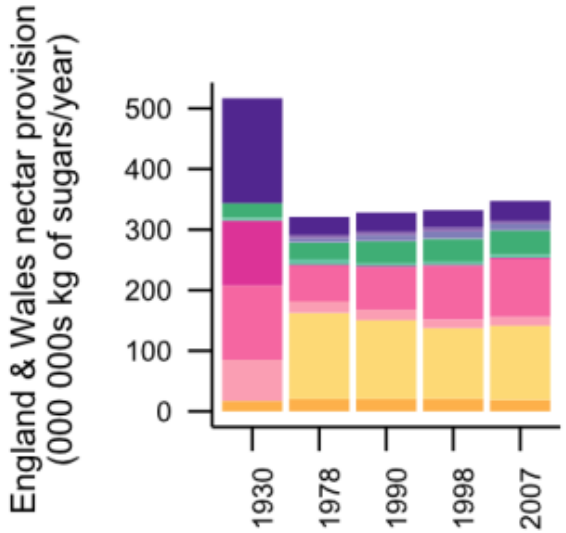




- **Improved grassland** is the habitat that has the potential to contribute the most to the national supply (32%)
- 3 species contribute almost 50% of national nectar supply: **white clover, thistle & heather**

Baude et al. 2016

Historical nectar changes

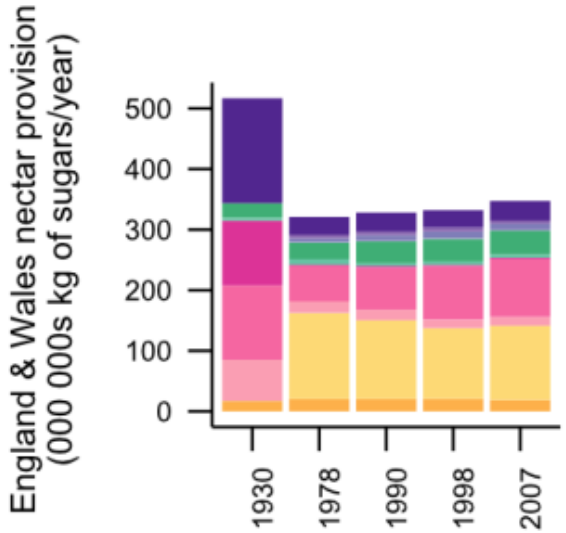


Considering changes in land cover only :

1930 – 1978 : loss of nectar supply due to the loss of grasslands & agricultural intensification

Baude et al. 2016

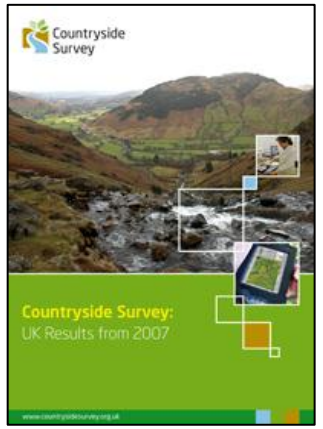
Historical nectar changes



Considering changes in land cover only :

1930 – 1978 : loss of nectar supply due to the loss of grasslands & agricultural intensification

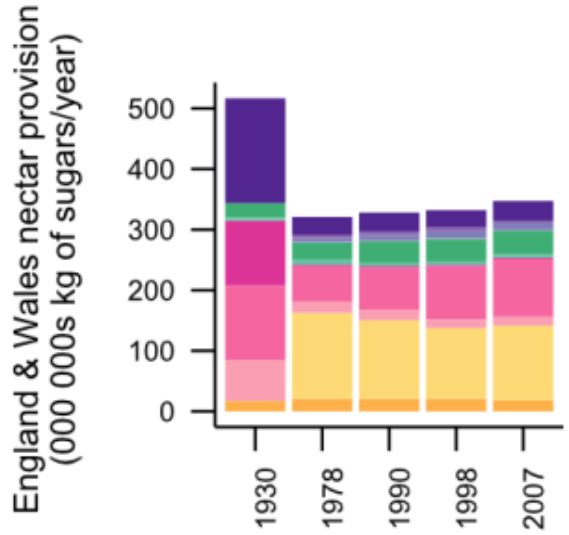
Digitalized Dudley Stamp Maps (1930s)

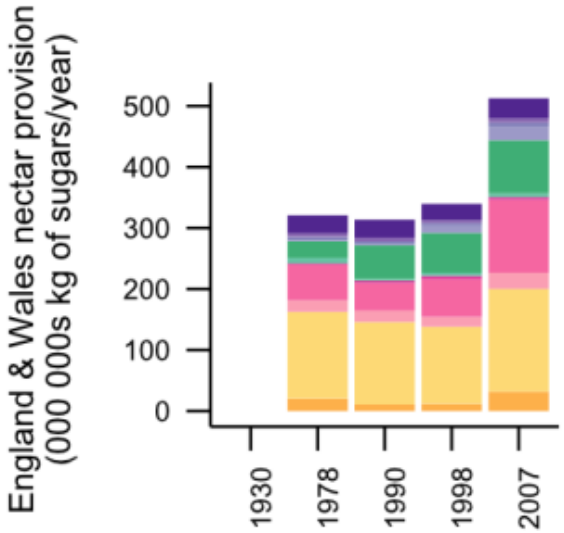


Countryside surveys (1978, 1990, 1998, 2007)

Baude et al. 2016

Historical nectar changes





<u>Considering changes in land cover only :</u>
1930 – 1978 : loss of nectar supply due to the loss of grasslands & agricultural intensification

<u>Considering changes in land cover & vegetation :</u>
1978-1998 : no change in nectar supply
1998-2007 : increase in nectar supply

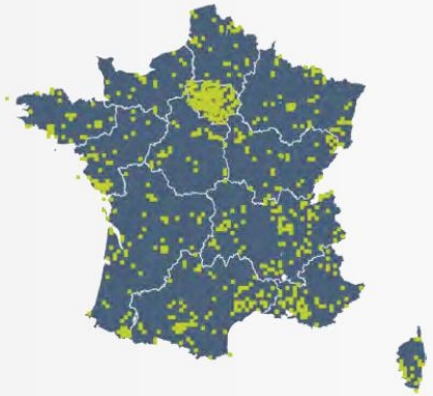
BUT the method do not allow to detect changes in actual management practices here (‘potential’)

Baude et al. 2016

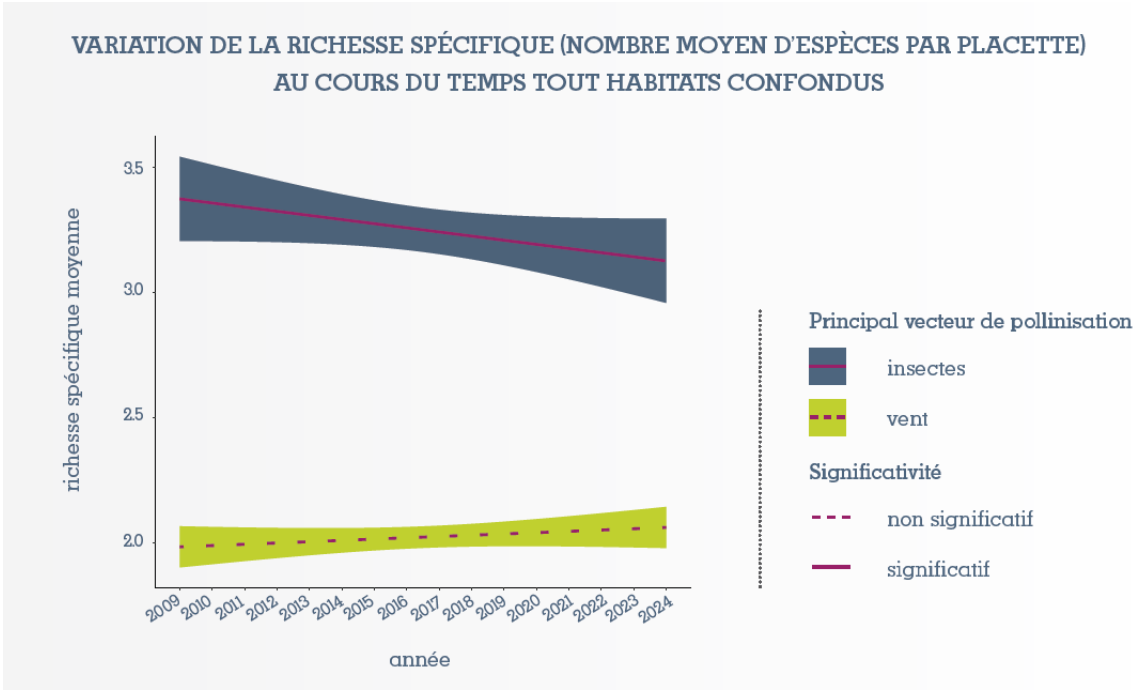
Recent nectar & pollen changes in France

Solène Agnoux
CESCO/ARB-IdF

VIGIE FLORE



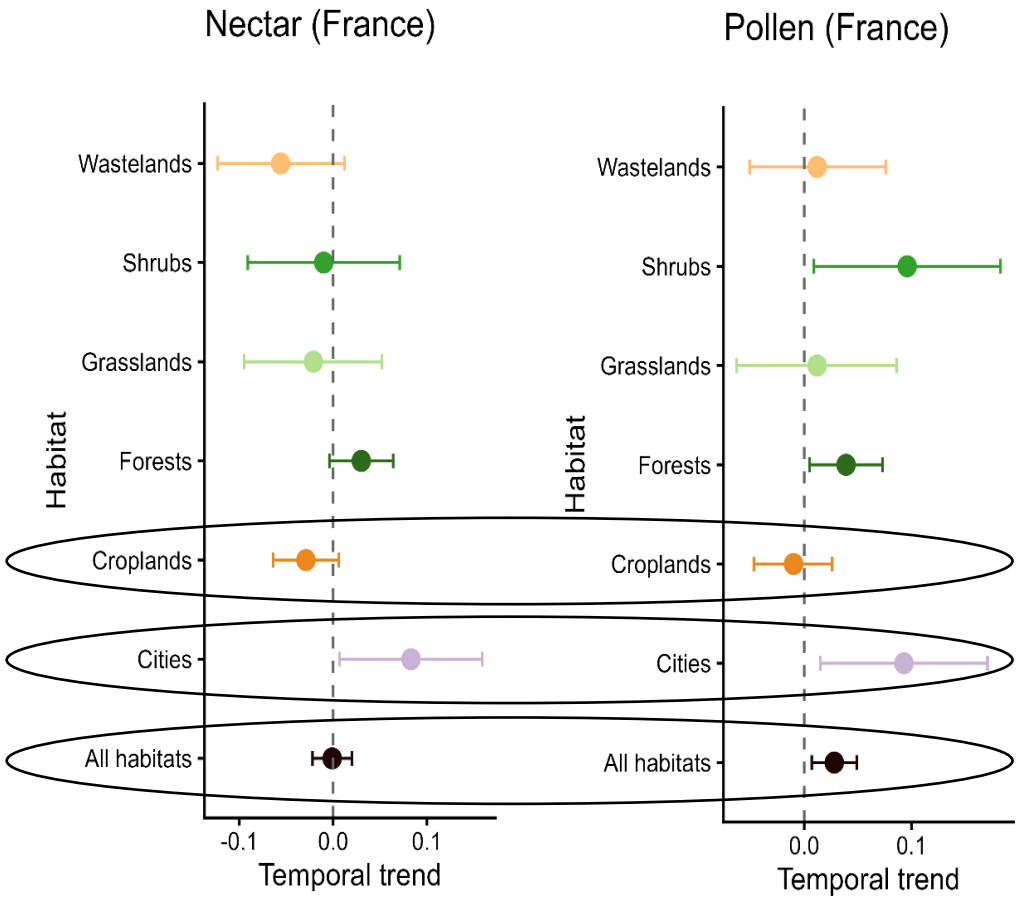
Les 762 mailles suivies au moins une année depuis le début du programme (2009)



Agnoux et al. 2025

Recent nectar & pollen changes in France

Solène Agnoux
CESCO/ARB-IdF



<u>From 2009 in France (14 years)</u> :

No overall decline in nectar & pollen detected

Decline (or trends to decline) in nectar & pollen **in agricultural landscapes**

Increase in nectar & pollen **in urban landscapes**

Agnoux et al. in prep

3

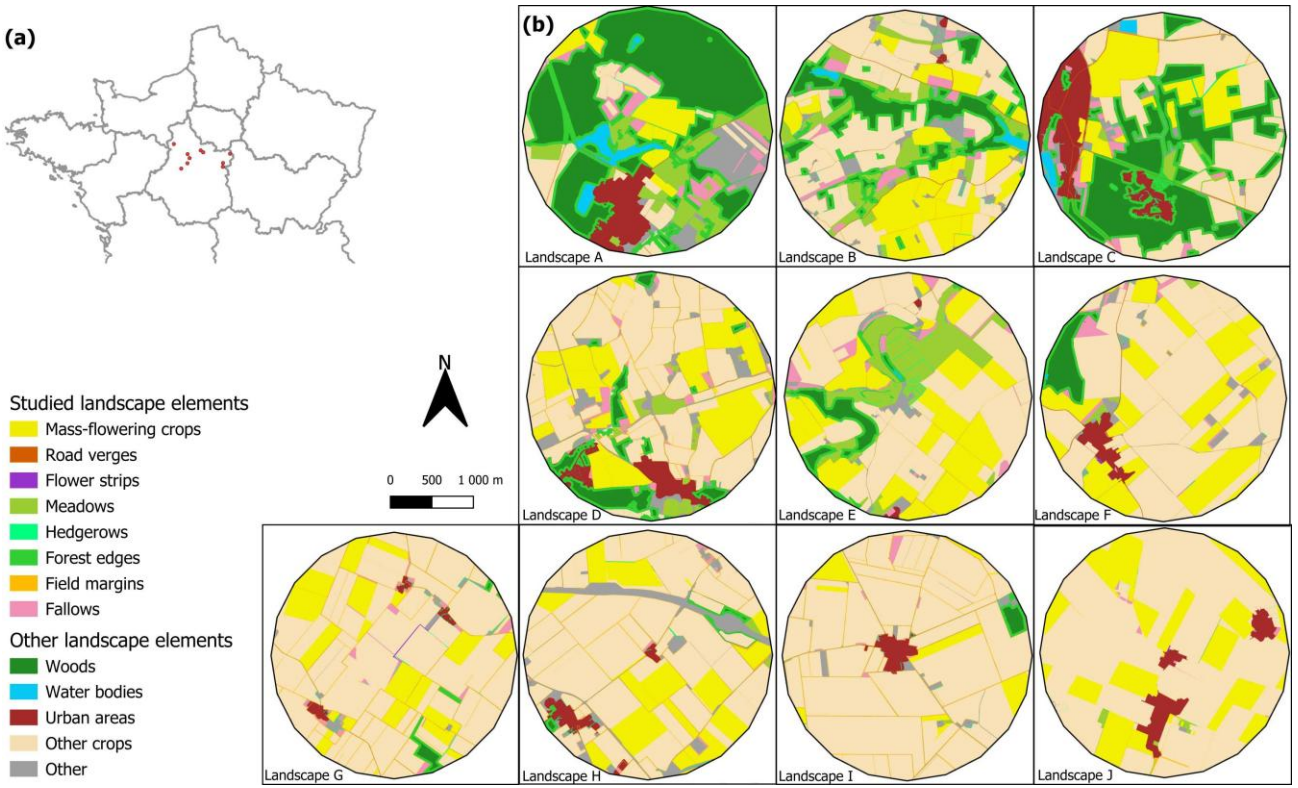
Seasonal dynamics of nectar and pollen production

What are the critical periods for floral resource availability?

Studied sites

Goal : to develop an indicator of nectar and pollen value of a farm (H&T – OFB)

Axelle Marchant, Association Hommes et Territoires



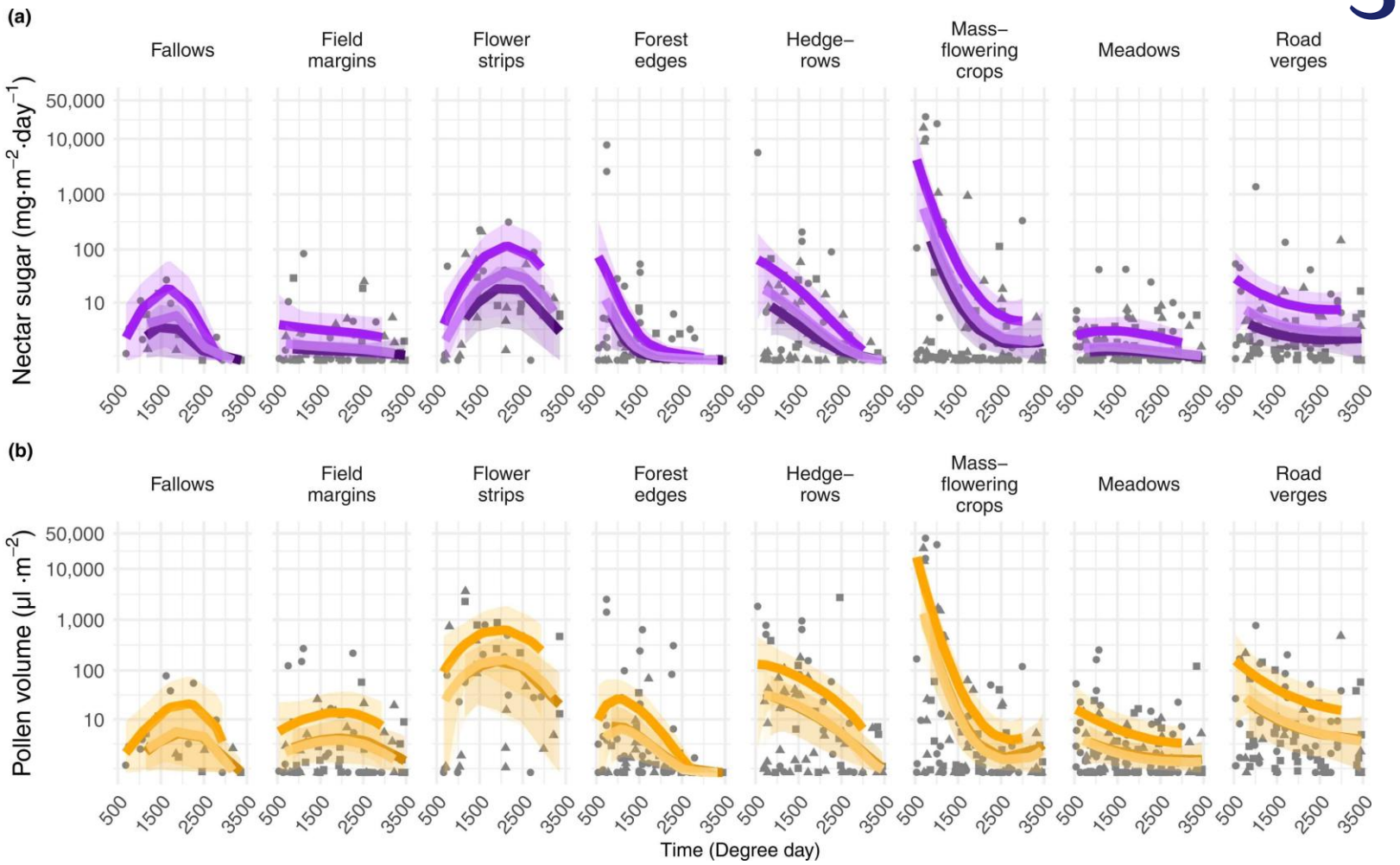
3 years (2020-2022)
10 farms
8 landscape elements
99 transects (50m²) each month from April to August
1 million of floral units counted from 280 species
5660 plant-pollinator interactions

10 farmland landscapes
Intensive agricultural practices (Région Centre Val de Loire)

Langlois et al. 2026

Seasonal dynamics of nectar and pollen production

Alban Langlois
(iEES)



nectar

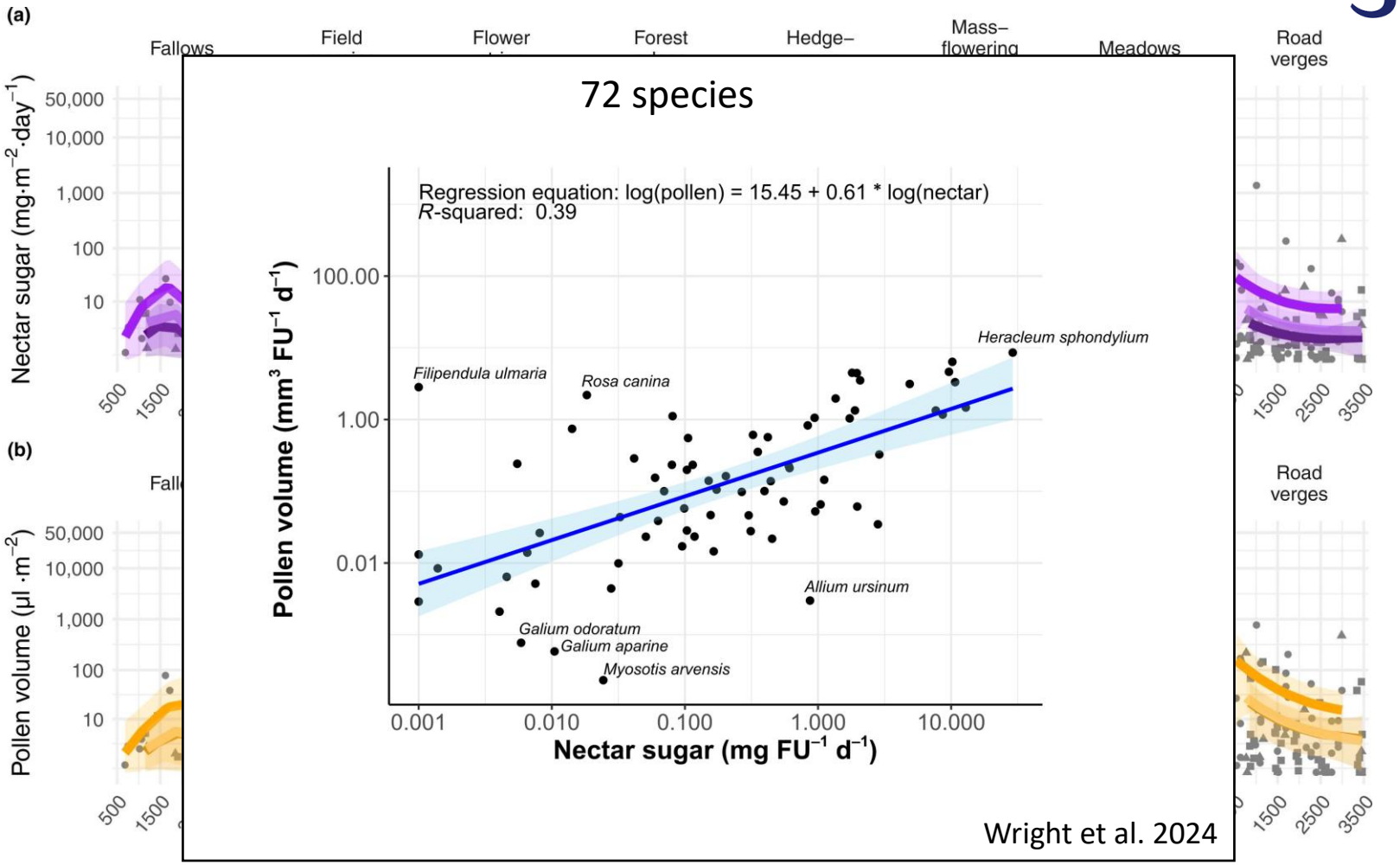
pollen

Langlois et al. 2026

Seasonal dynamics of nectar and pollen production

Alban Langlois
(iEES)

Institut de la transition environnementale
ALLIANCE SORBONNE UNIVERSITÉ



nectar

pollen

Langlois et al. 2026

Seasonal dynamics of nectar and pollen production

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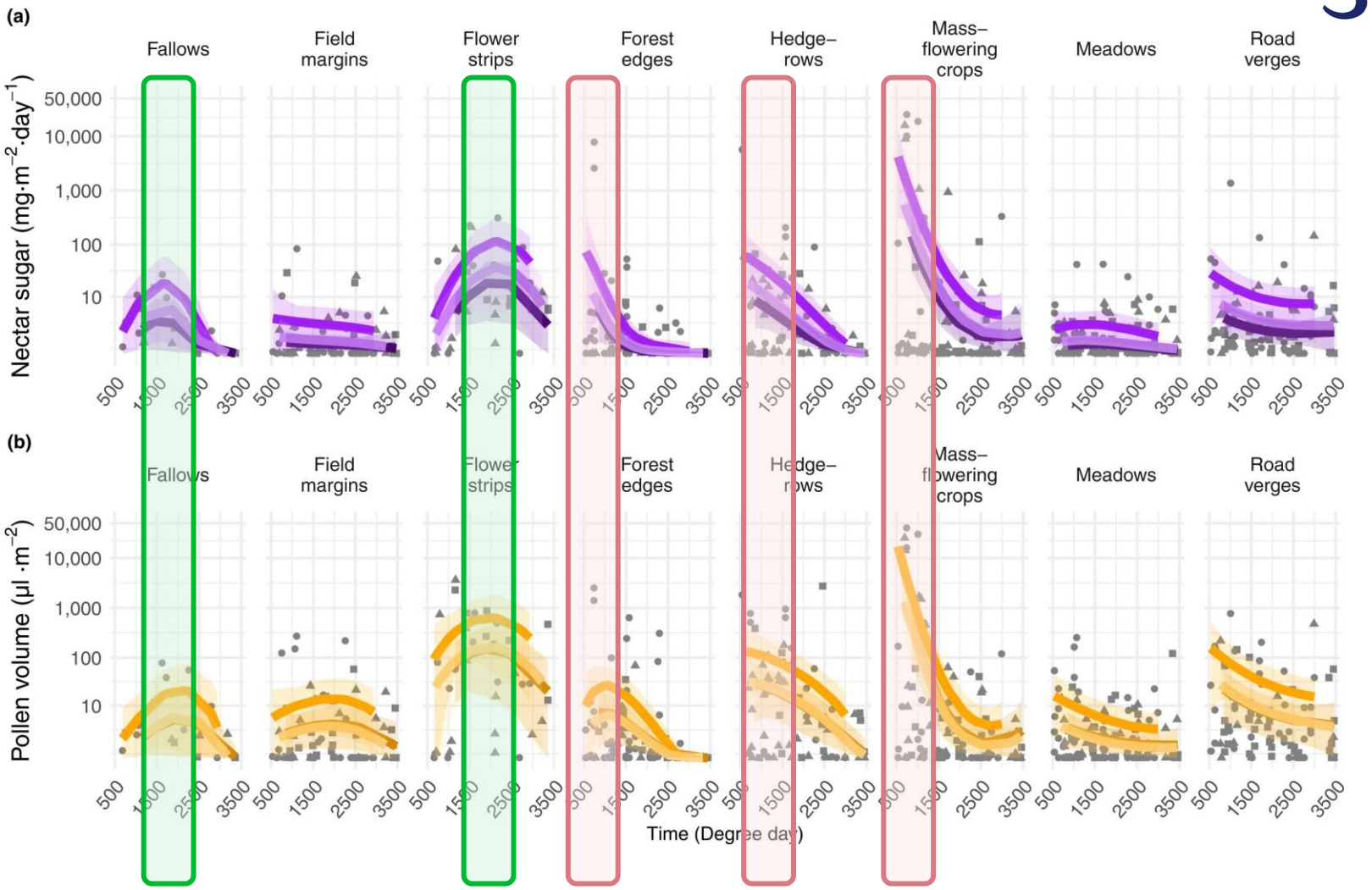


nectar

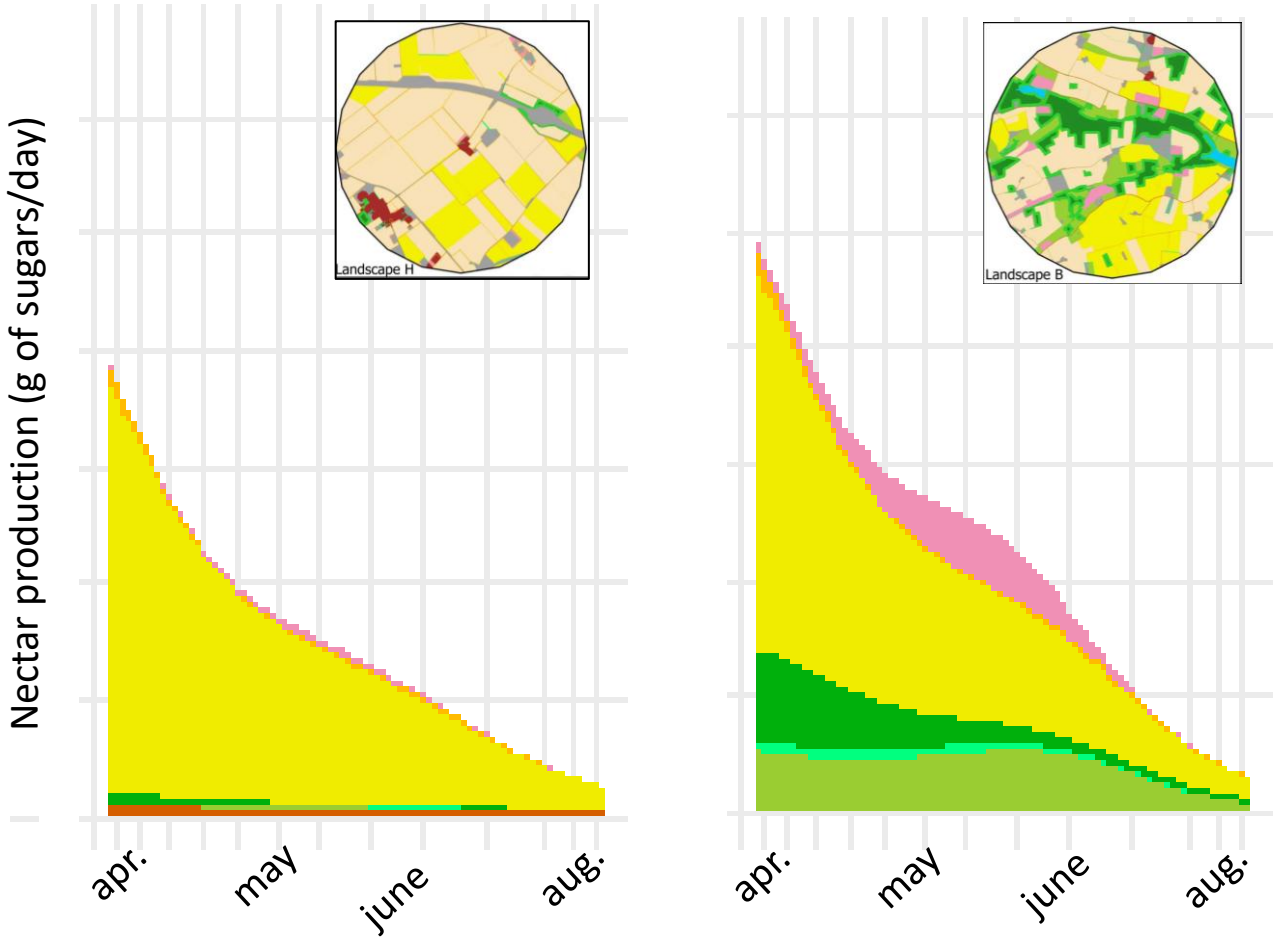
pollen

➢ Temporal complementarity in resource production among semi-natural landscape elements

Langlois et al. 2026

Habitat contribution to the landscapes

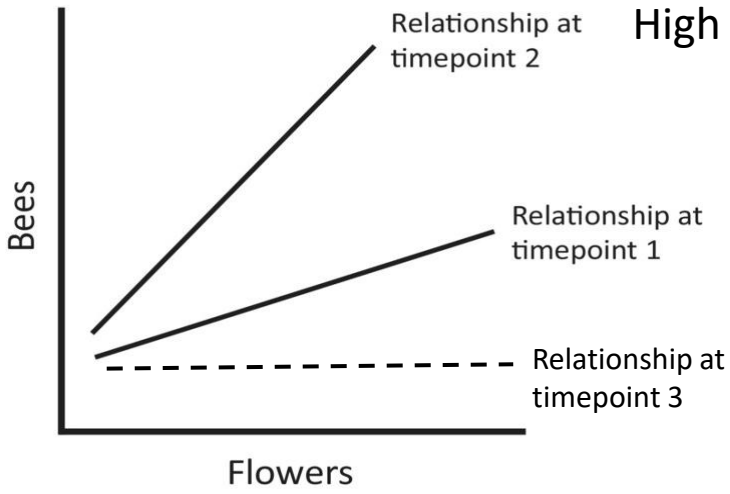
Alban Langlois
(iEES)



- Decreasing supply of floral resources across the season
- High contribution of mass flowering crops (oilseed rape)

Langlois et al. 2026

Response of pollinators to local floral resource increase



High floral resources limitation

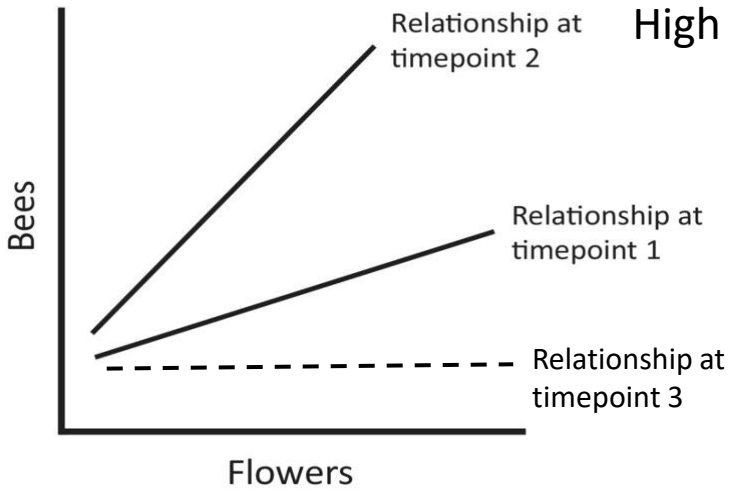
Low floral resources limitation

No floral resources limitation

Adapted from Bishop et al. 2024

Langlois et al. 2026

Response of pollinators to local floral resource increase



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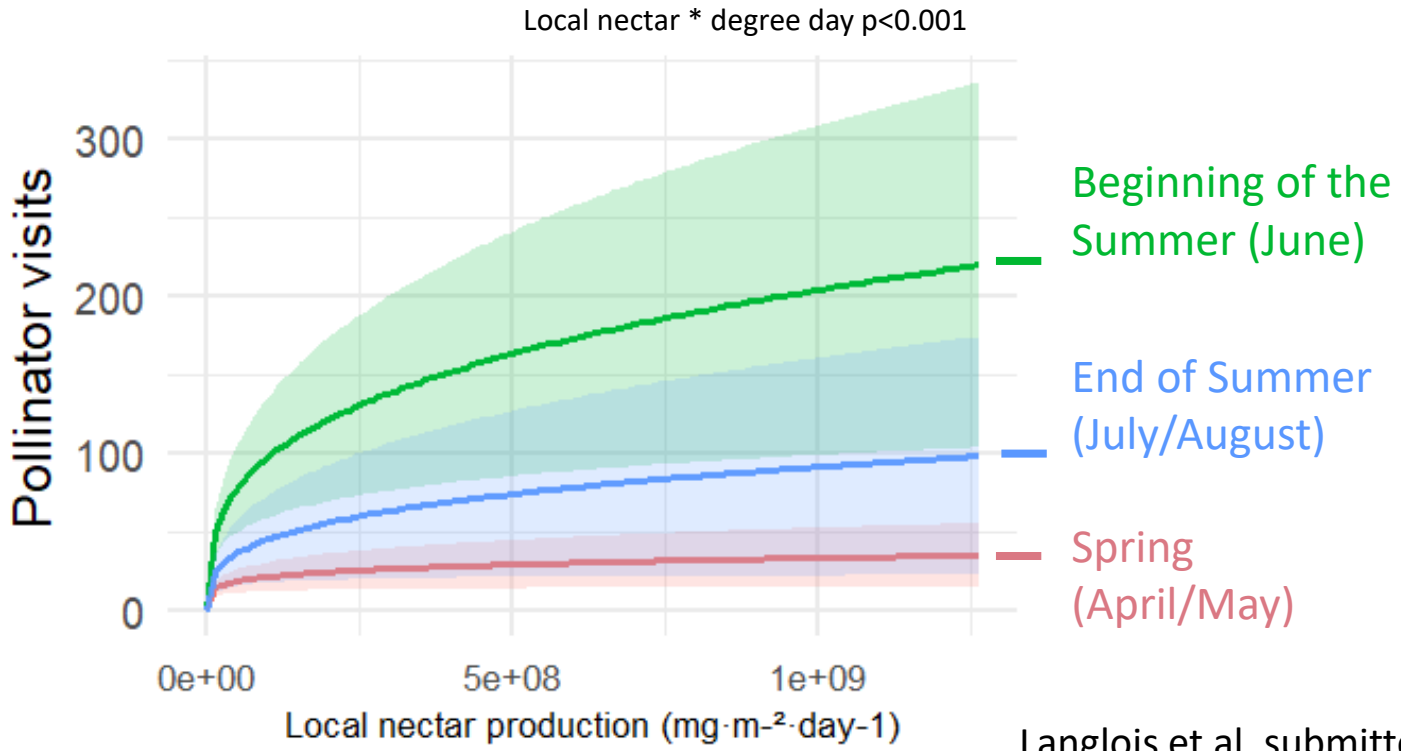


- **Critical period in June**

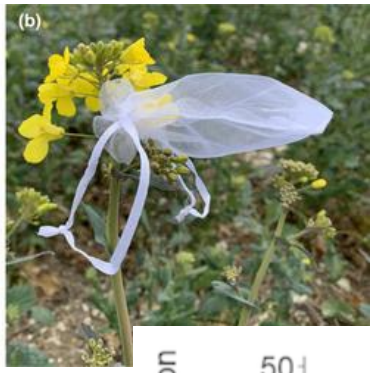
Langlois et al. submitted

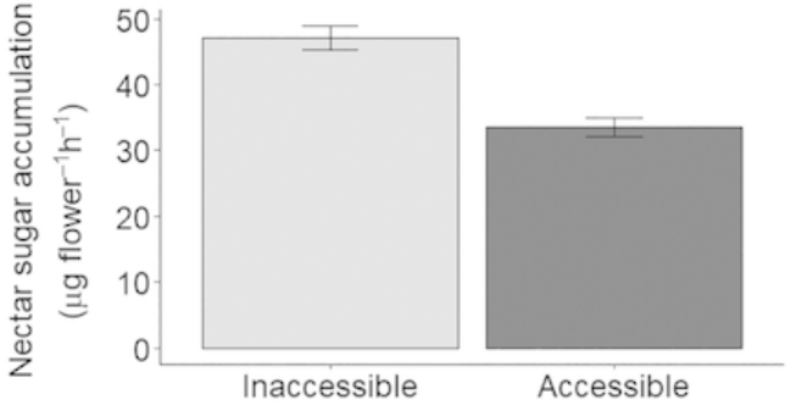
The ‘June gap’ in agricultural landscape

Floral resource wastage: Most nectar produced by the mass-flowering crop oilseed rape (*Brassica napus*) is uncollected by flower-visiting insects

Ciaran Harris, Nicholas J. Balfour, Francis L. W. Ratnieks

First published: 21 May 2024 | https://doi.org/10.1002/ece3.11453 | Citations: 1

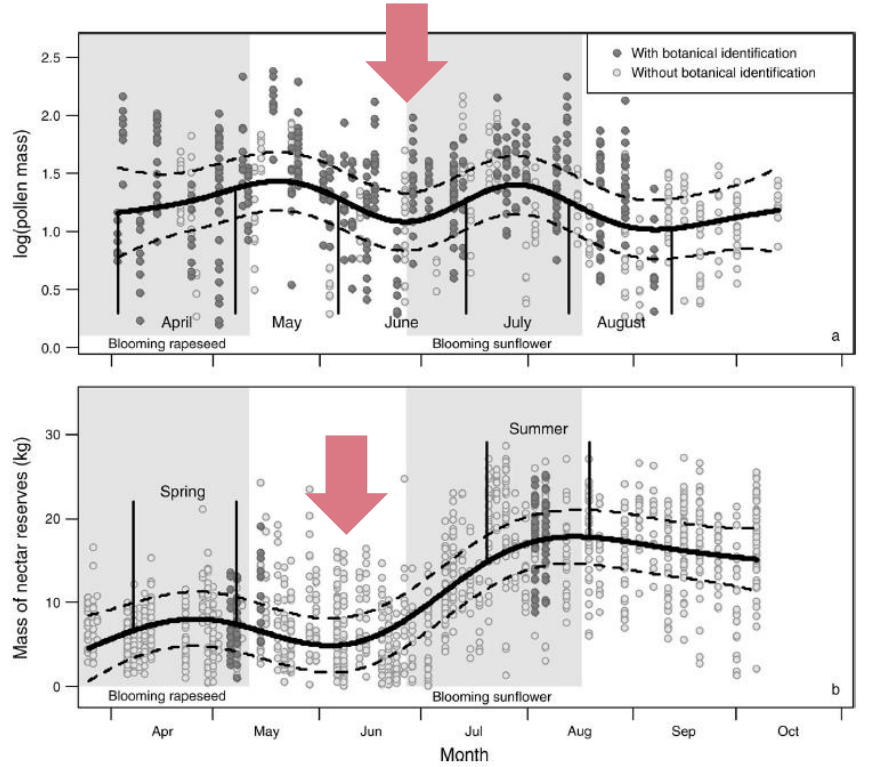




Harris et al. 2024

Honey bee diet in intensive farmland habitats reveals an unexpectedly high flower richness and a major role of weeds

Fabrice Requier,[1,2,9] Jean-François Odoux,[1] Thierry Tamic,[1] Nathalie Moreau,[3] Mickaël Henry,[4,5] Axel Decourtye,[5,6,7] and Vincent Bretagnolle[2,8]



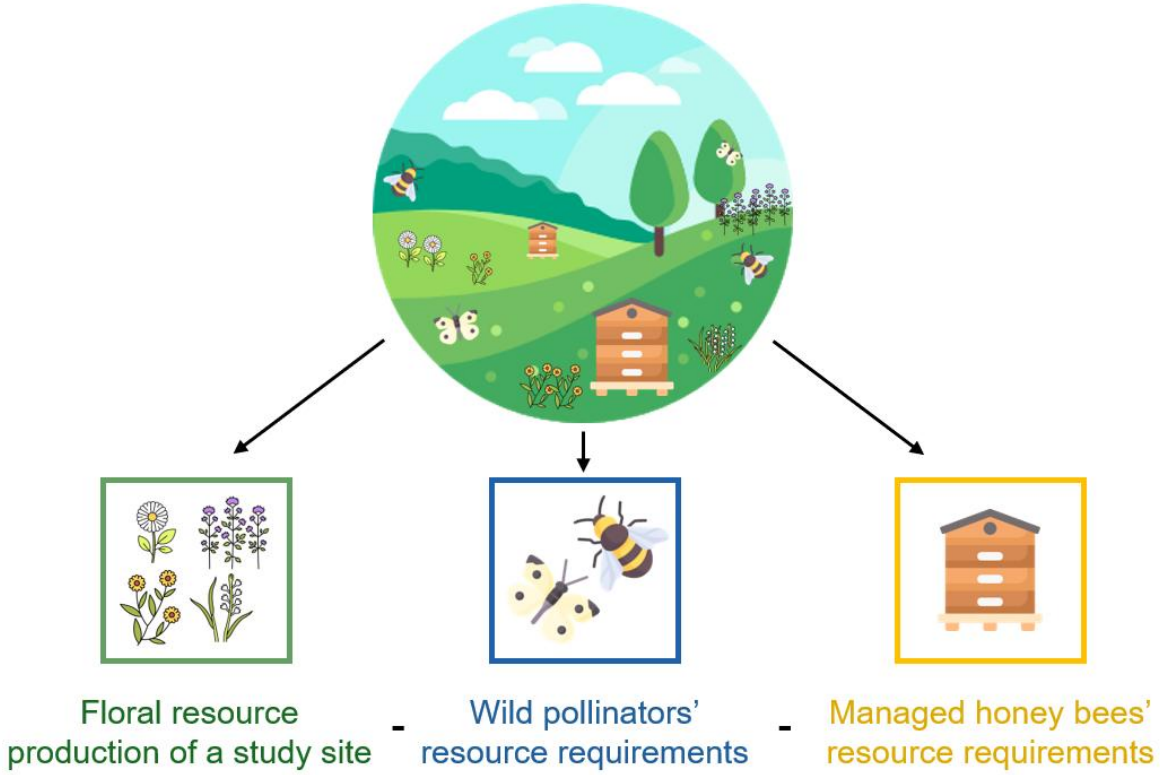
- Importance of fallows, meadows & adventices to fill this gap.

Requier et al. 2015

Balance between resources supply and demand

Malena Sibaja Leyton
EGCE

Competition risks between
honeybees & wild pollinators

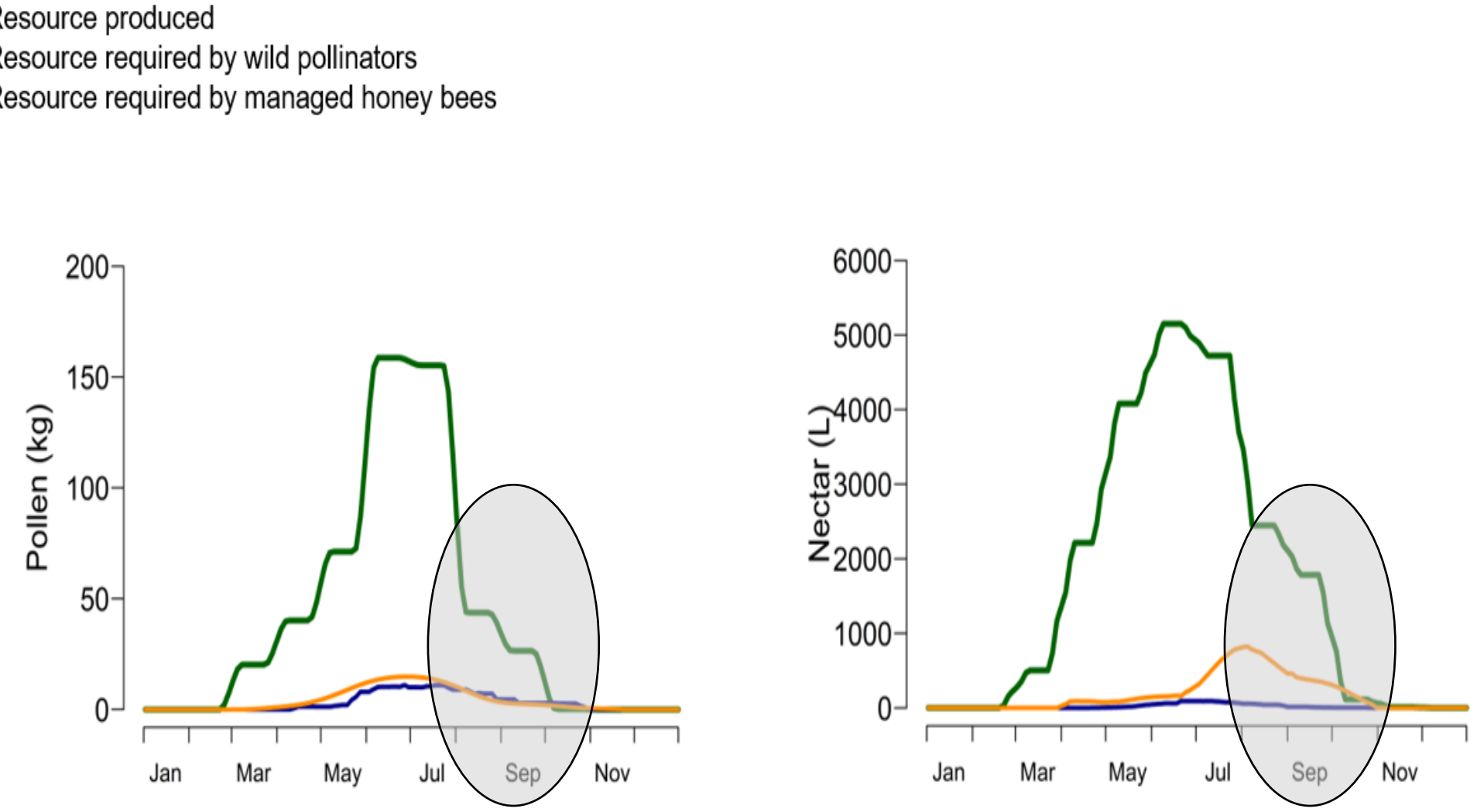


Natural reserve
Lac de Remoray (Jura, FR)

340 ha (woodland, westland, grasslands)
298 hives recorded surrounding
70 effective hives

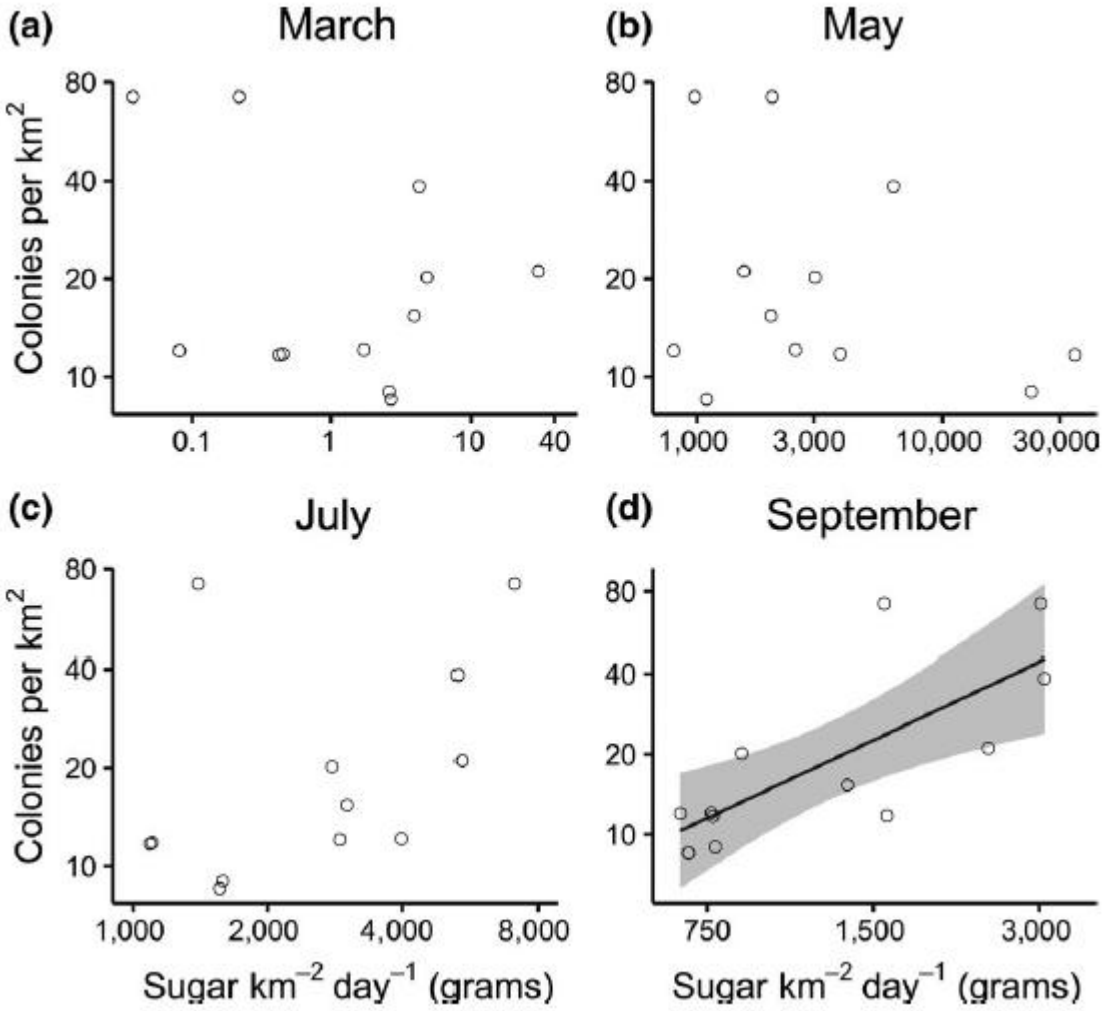
Balance between resources supply and demand

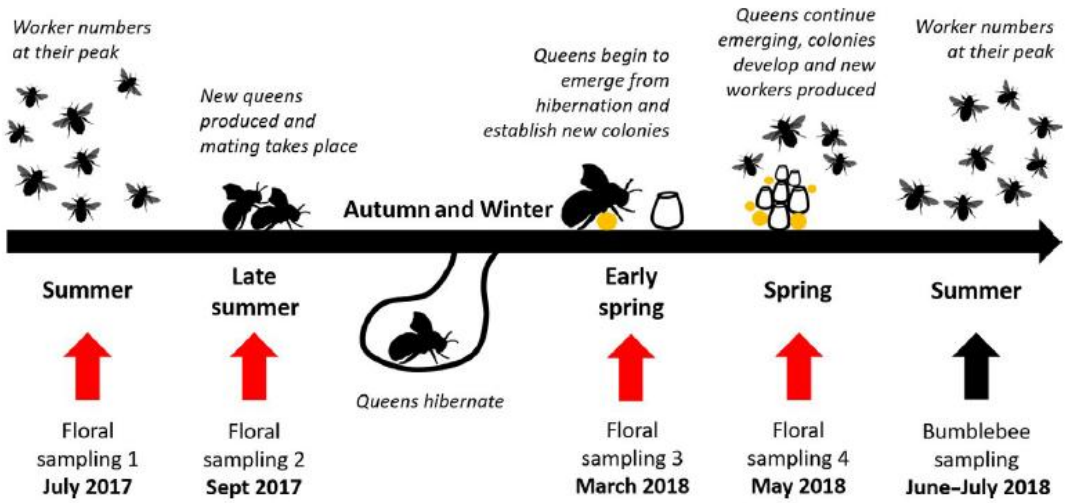
Malena Sibaja Leyton
EGCE



- Risk of competition at the end of the season in the natural reserve

Response of pollinator populations to the landscape floral resources of the previous year





Positive relationship between *Bombus terrestris* colony density with floral resource production in September of the previous year.

- **Limiting period in September**

Timberlake et al. 2021

Conclusion : review of critical periods in Europe

➢Periods of floral resources shortage is dependent of the landscape

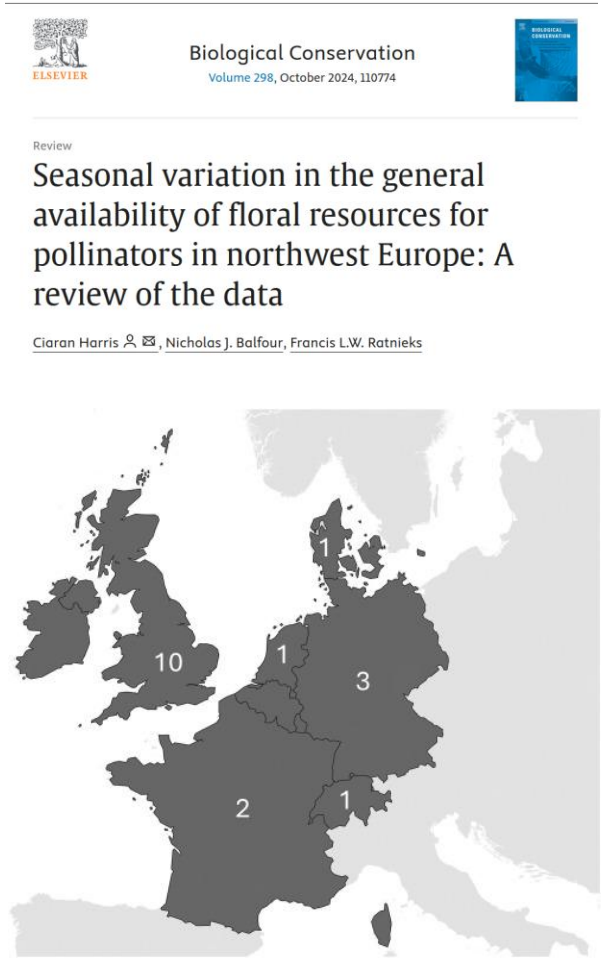
- June is the critical period in intensive agricultural landscape
- Competition risk between wild pollinators and honeybees at the end of the season in a natural reserve
- Late floral resources of the year n shape bumblebee population the year n+1

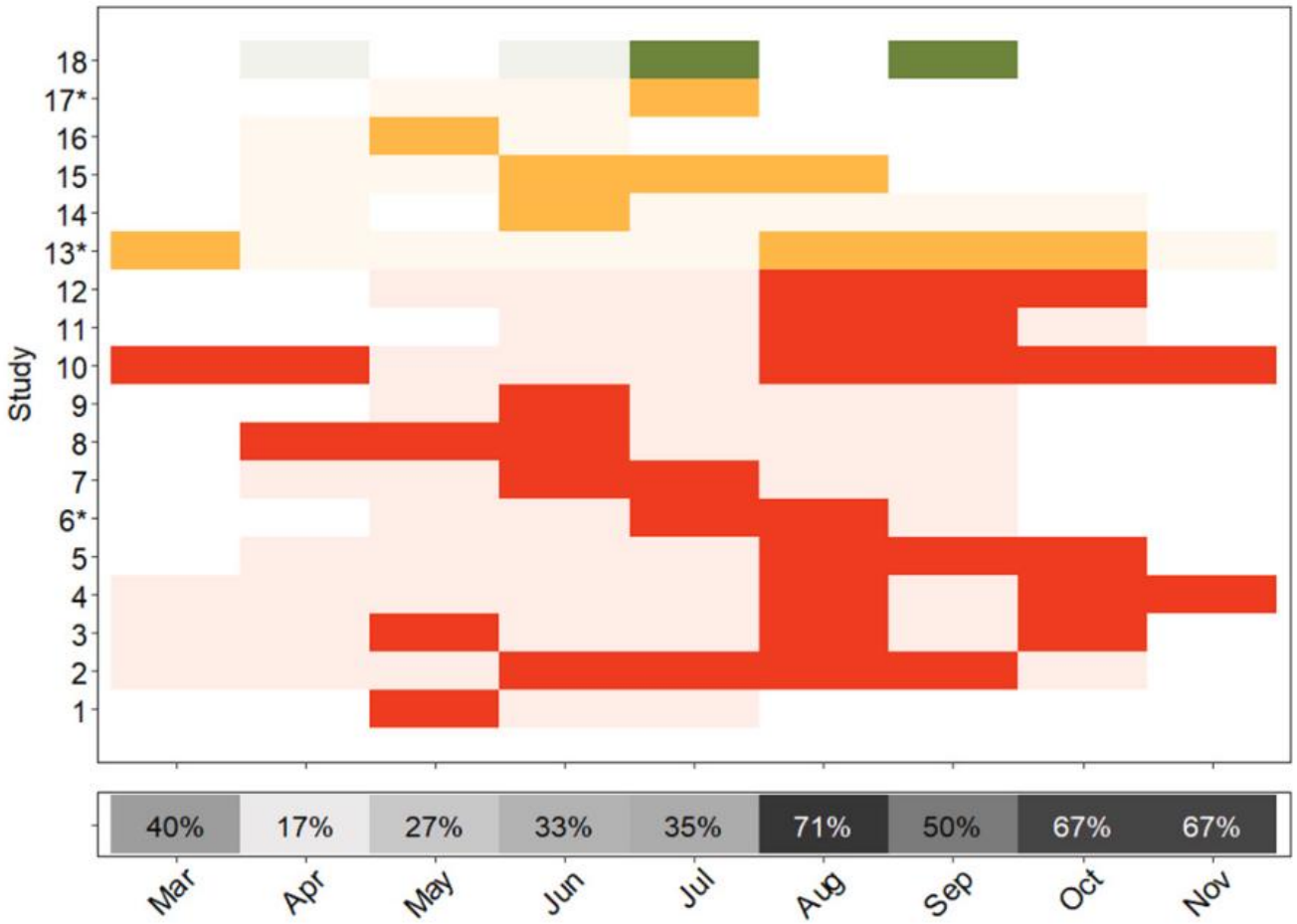
Sweet world hypothesis

(Sponsler et al. 2023)

➢Different from herbivory. Why?

Conclusion : review of critical periods in Europe

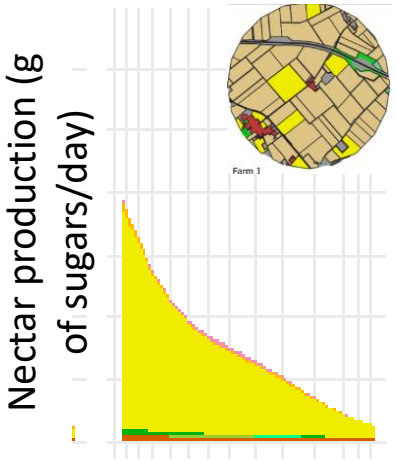




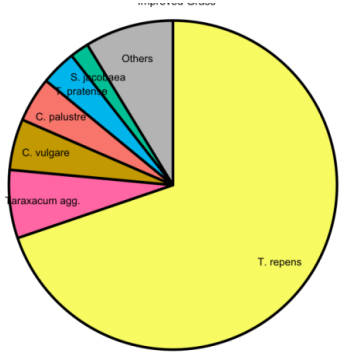
Harris et al. 2024

Conclusion : high contribution of dominated human landscapes

➢ High contribution of dominated human landscapes in floral resource production due to their large areas in the landscape/country



Mass flowering crops (oilseed rape)



Improved grasslands in the UK (potential)

- Appropriate biodiversity management in these cultivated areas can have a significant impact in the wider landscape
- Low diversity of resource supply in these landscapes
- The quality of the floral resource is not investigated (composition, pesticides)

- iEES-Paris (Equipe DYNECO)
- RT Pollineco (FlowerPower)
- Sarah Lemetayer, Alban Langlois, Cassandre Murail, Solène Agnoux, Malena Sibaja Leyton