

Université de Montpellier
Habilitation à Diriger des Recherches (HDR)
Ecole doctorale GAIA



A multitrophic approach to the dynamics of insect herbivores

Experiments with plants, predators and insect symbionts

Enric Frago - CIRAD CBGP

Centre de Coopération Internationale en Recherche Agronomique pour le Développement
Centre de Biologie pour la Gestion des Populations



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Defended before the jury:

Elisa Thebault (CNRS, Sorbonne Université, Paris) - Elodie Vercken (INRAE, ISA, Sophia Antipolis)
Fabrice Vavre (CNRS, Ibbe, Lyon) - Alison Duncan (CNRS, ISEM, Montpellier)
Christoph Vorburger (ETH, Zurich, Switzerland) - Christine Meynard (INRAE, CBGP, Montpellier)

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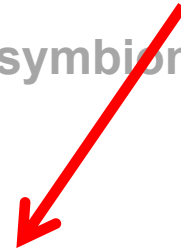
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General Context

A **multitrophic** approach to the **dynamics** of **insect herbivores**
Experiments with plants, predators and insect symbionts

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Insect herbivores:

Main players in terrestrial ecosystems

Plant diversity - soil mineralisation

General Context

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Experimental community ecology (vs observational):

A mechanistic approach to community dynamics

Long-term multigenerational dynamics

Insect diversity and extinctions

General Context

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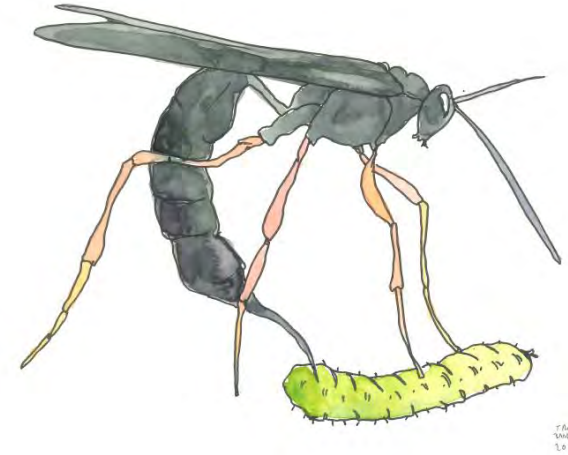
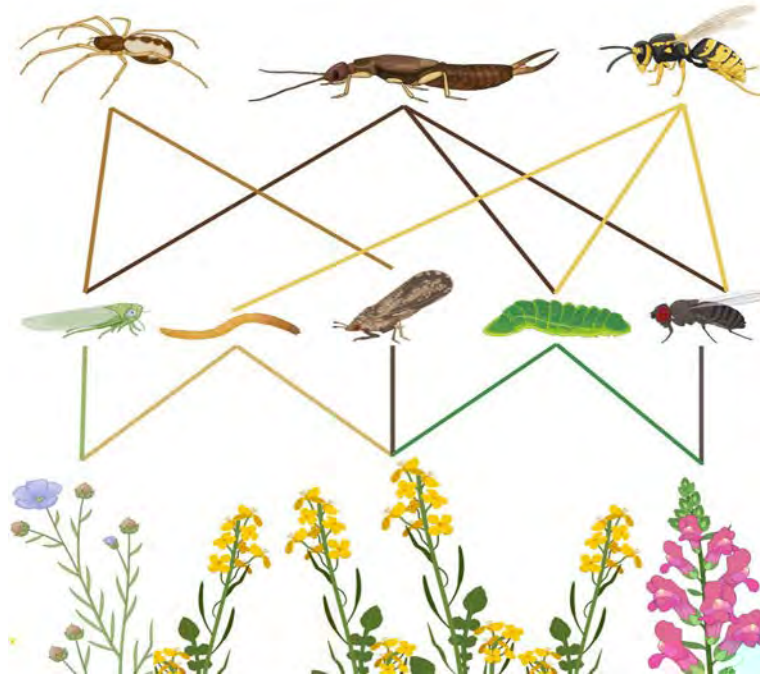


Multitrophic

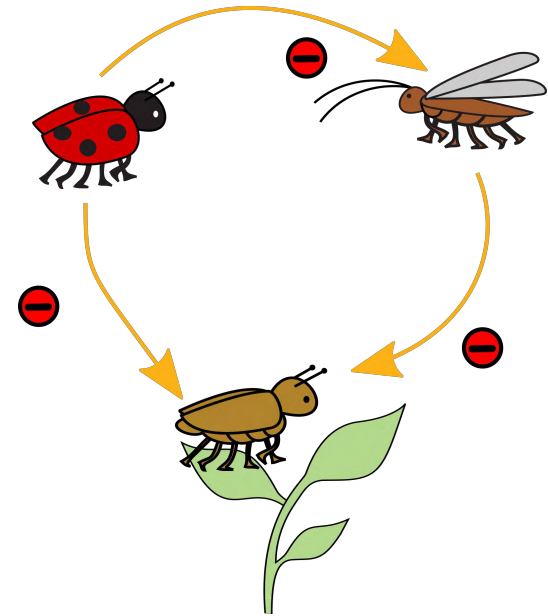
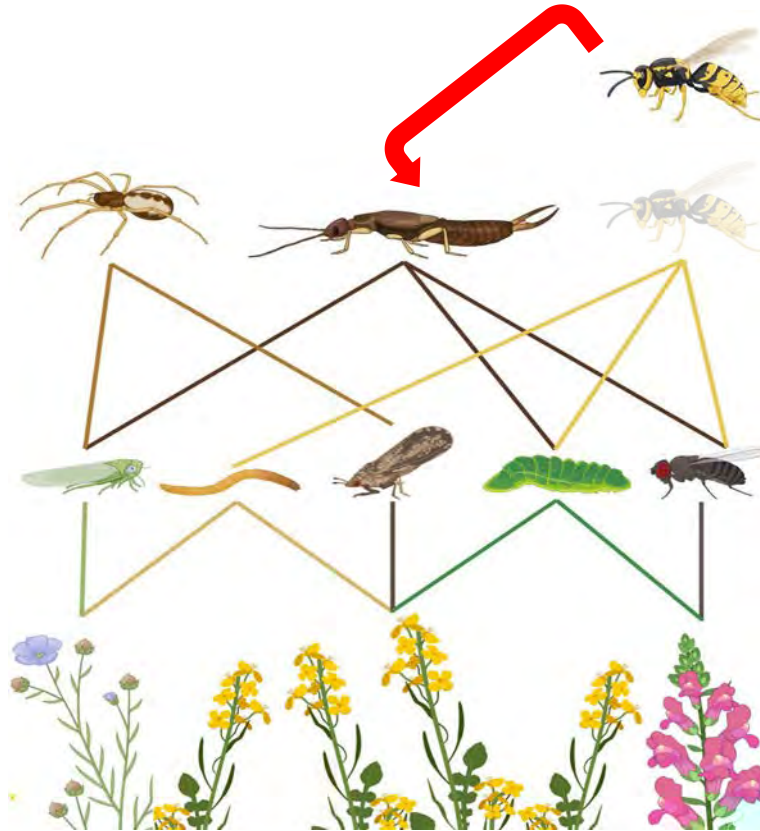
An interaction comprising more than two trophic levels

Multitrophic interactions:

The complexity behind trophic networks

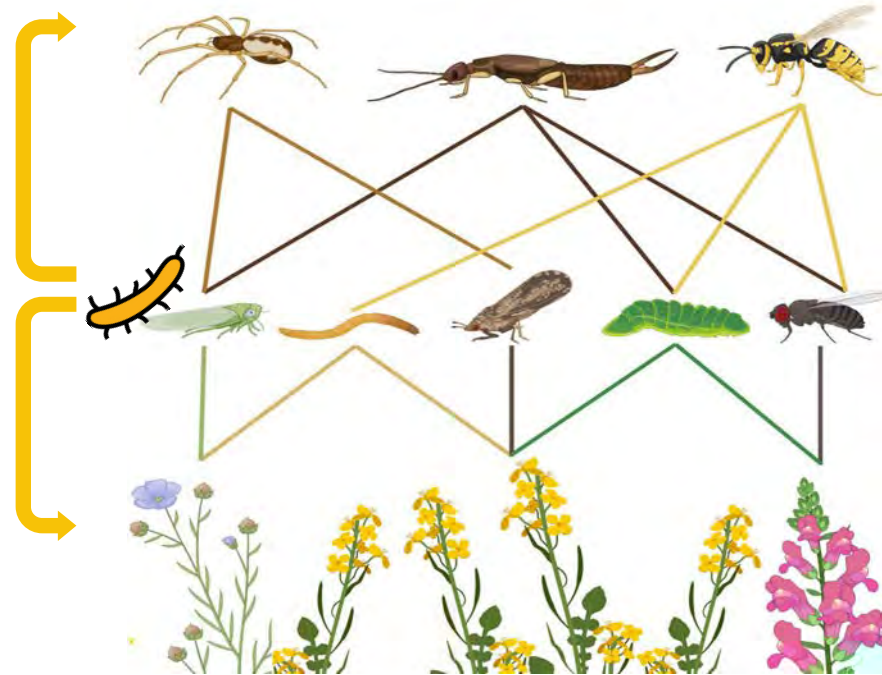


Intraguild predation



Frago (2016) Interactions between parasitoids and higher order natural enemies: intraguild predation and hyperparasitoids.
Current Opinion in Insect Science

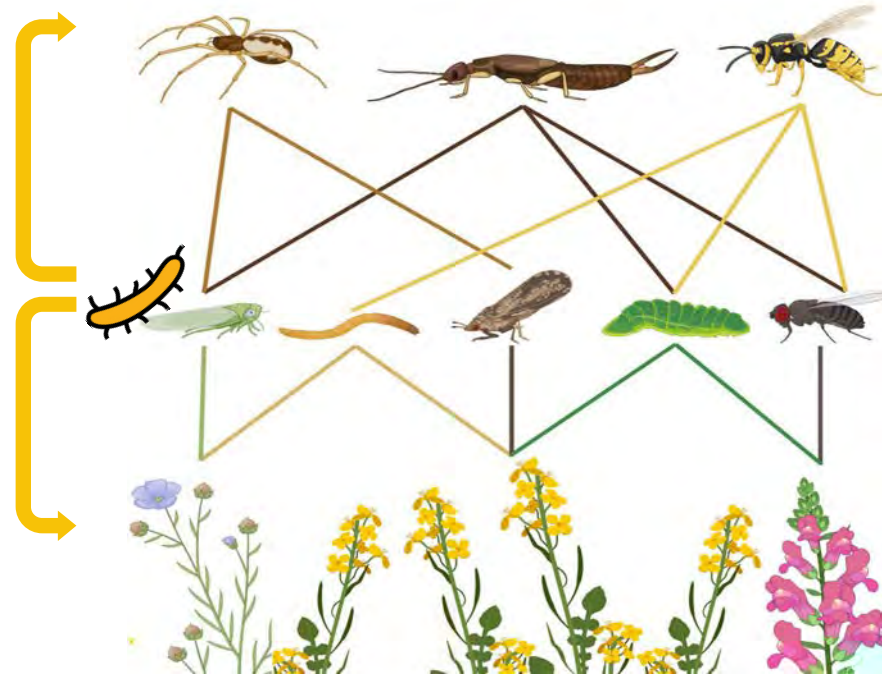
Insect symbionts



Order	Suborder	Function for host
Orthoptera	Hemimetabola	Nutrient provisioning, Behavior, Defensive symbiosis
Phasmatodea		Plant cell wall degradation
Thysanoptera		Fitness
Hemiptera	Hemimetabola	Nutrient provisioning, Plant cell wall degradation, Plant defense suppression, Defensive symbiosis
Hymenoptera	Holometabola	Nutrient provisioning, Plant cell wall degradation, Detoxification, Defensive symbiosis
Coleoptera		Nutrient provisioning, Plant cell wall degradation, Defensive symbiosis, Detoxification, Plant defense suppression
Lepidoptera		Plant defense suppression, Detoxification
Diptera		Nutrient provisioning, Behavior, Defensive symbiosis, Detoxification

Frago, Zytynska and Fatouros (2020)
 Microbial symbionts of herbivorous species across the insect tree.
Advances in Insect Physiology

Insect symbionts



		Function for host				
Hemimetabola	Orthoptera	Nutrient provisioning	Behavior	Defensive symbiosis		
	Phasmatodea	Plant cell wall degradation				
	Thysanoptera	Fitness				
Holometabola	Hemiptera	Nutrient provisioning	Plant cell wall degradation	Plant defense suppression	Defensive symbiosis	
	Hymenoptera	Nutrient provisioning	Plant cell wall degradation	Detoxification	Defensive symbiosis	
	Coleoptera	Nutrient provisioning	Plant cell wall degradation	Defensive symbiosis	Detoxification	Plant defense suppression
	Lepidoptera	Plant defense suppression	Detoxification			
	Diptera	Nutrient provisioning	Behavior	Defensive symbiosis	Detoxification	

Frago, Zytynska and Fatouros (2020)
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Thrips, aphids, spider-mites and their enemies



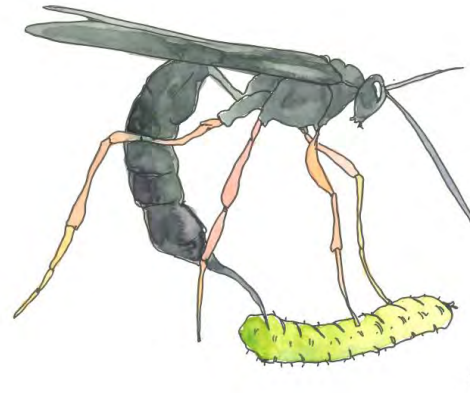
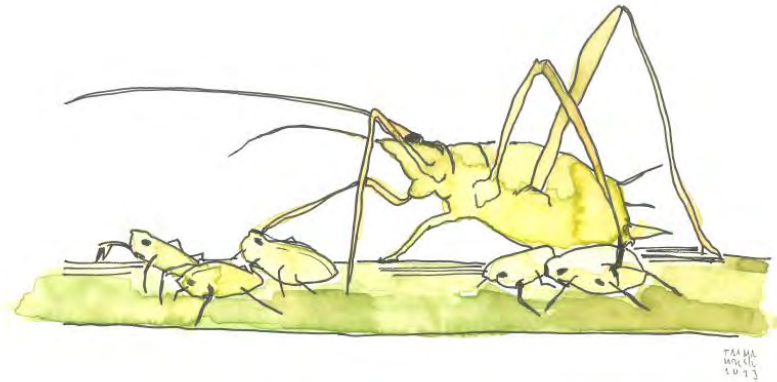
Picture credits: Antoine Franck, Bruno Michel and Alain Migeon

Three main axes:

Chapter 1: Plant-mediated interactions between insect herbivores

Chapter 2: Complex interactions among insect natural enemies

Chapter 3: Insect symbionts determine interactions with plants and natural enemies



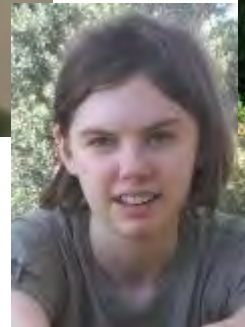
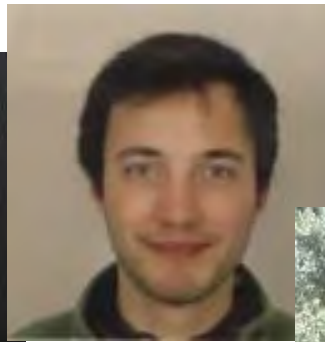
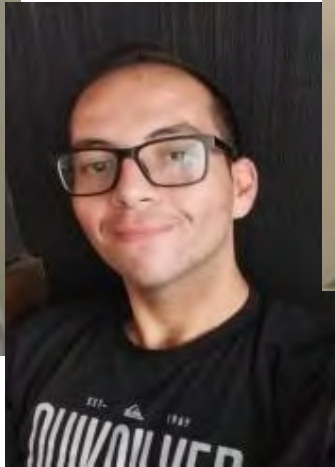
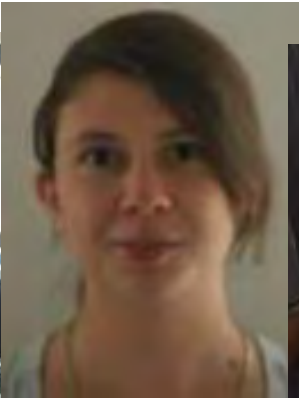
Drawing credits: Marta Barceló - 8

Three main axes:

Chapter 1: Plant-mediated interactions between insect herbivores

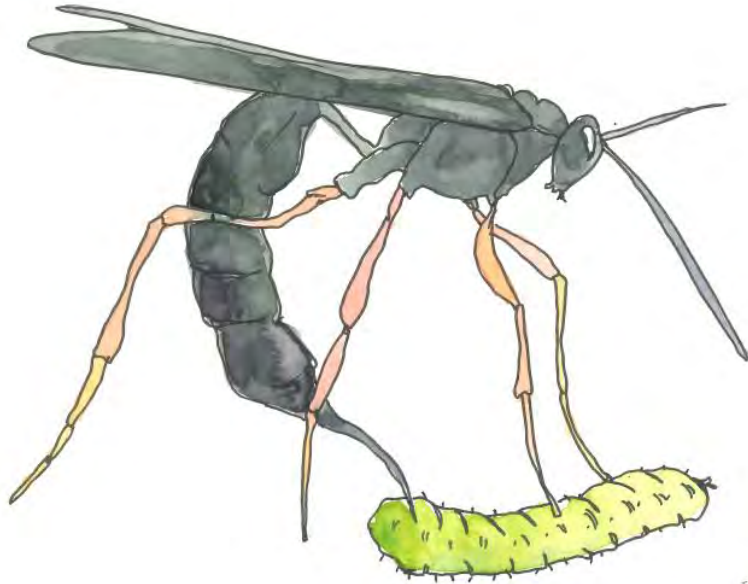
Chapter 2: Complex interactions among insect natural enemies

Chapter 3: Insect symbionts determine interactions with plants and nat. enemies



Complex interactions among insect natural enemies

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Complex interactions among insect natural enemies

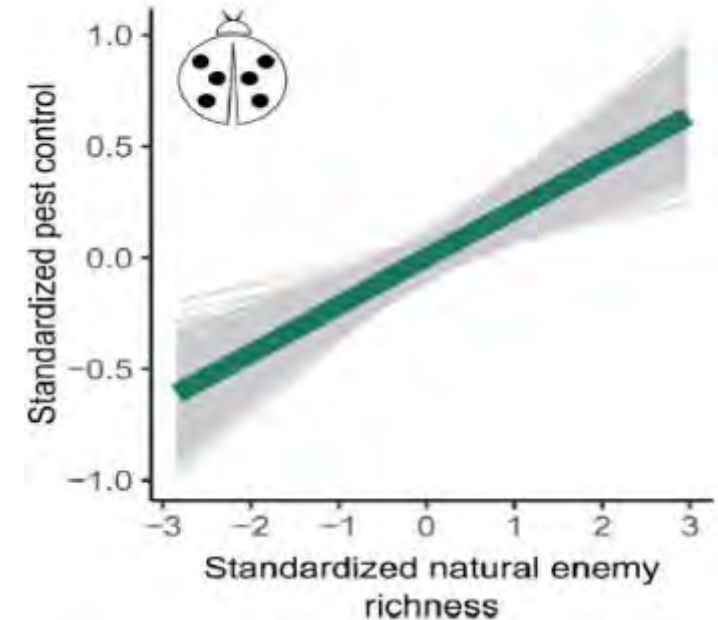
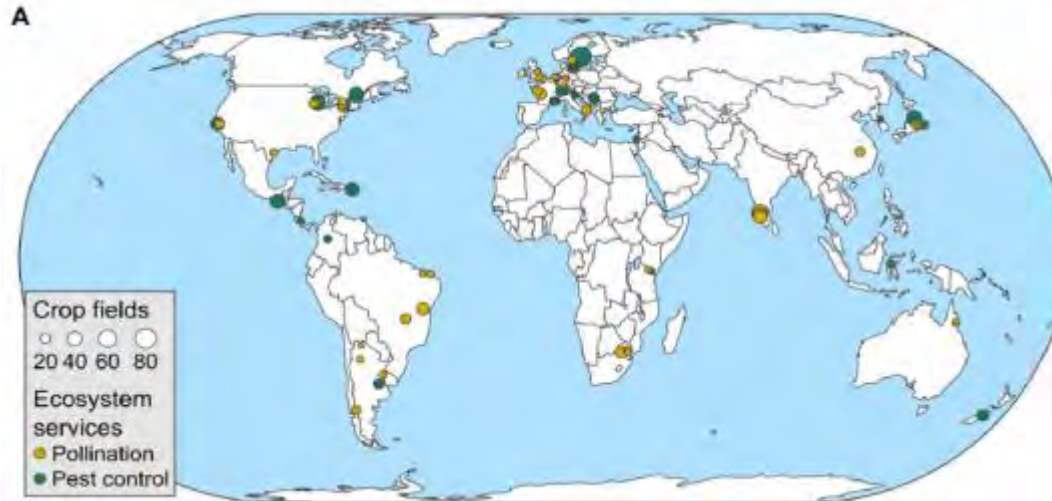
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The biodiversity-biocontrol relationship

Positive relationship between natural enemy diversity and suppression of insect herbivores

Mostly through **niche complementarity / facilitation**



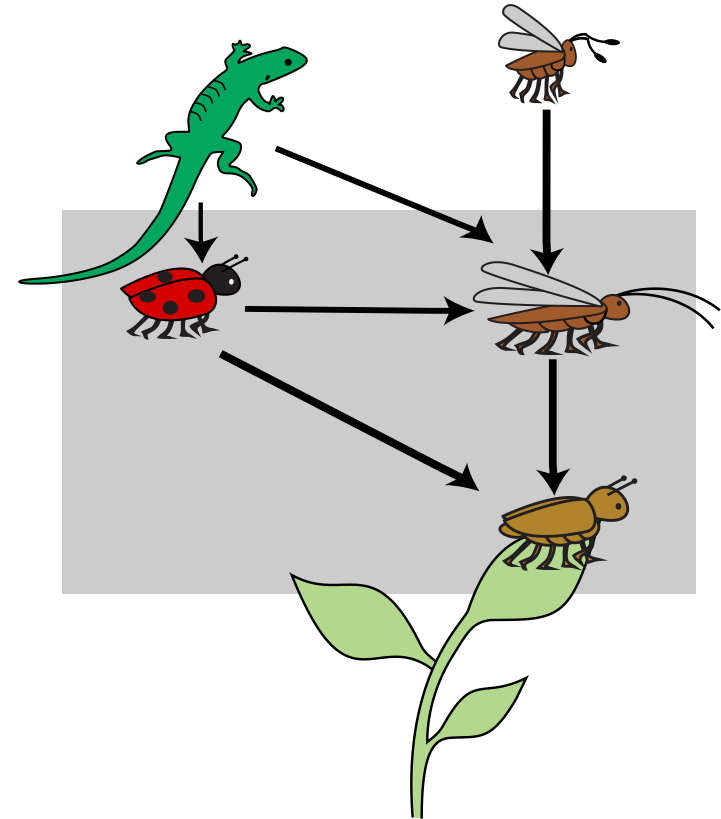
Dainese et al (2019) Science Advances

The biodiversity-biocontrol relationship

> The paradox of enemy diversity:

Positive effects of diversity may be dampened by **antagonistic interactions** among natural enemies

- Hyperparasitism
- Top predation
- **Intraguild predation**



Frago (2016) Interactions between parasitoids and higher order natural enemies: intraguild predation and hyperparasitoids.
Current Opinion in Insect Science

The biodiversity-biocontrol relationship

Balance between **positive (e.g. complementarity)** and **negative (e.g. intraguild)** interactions among natural enemies

		Complementarity	
		No	Yes
Intraguild predation	No	Intermediate biocontrol	Strong biocontrol
	Yes	Weak biocontrol	Intermediate biocontrol

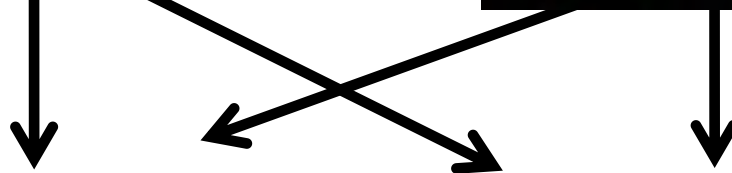
Niry Dianzinga



Amblyseius swirskii



Proprioseiopsis mexicana



Frankliniella occidentalis



Thrips parvispinus



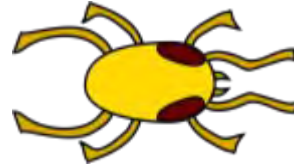
Picture credits: Antoine Franck and Manfred Ulitzka

@EnricFrago - Cirad/Cbpg - Montpellier

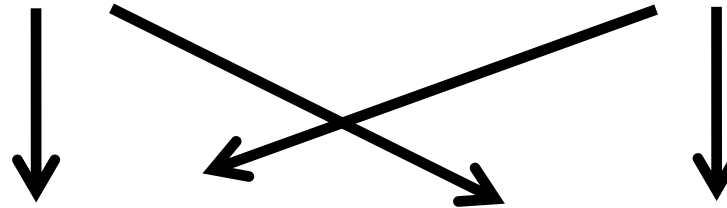
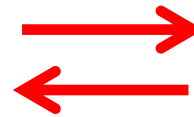
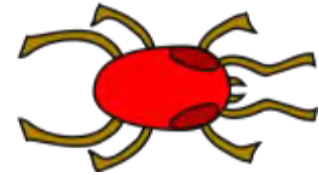
Niry Dianzinga



Amblyseius swirskii



Proprioseiopsis mexicanus

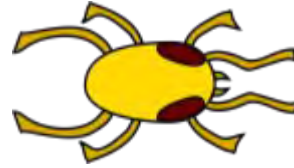


Frankliniella occidentalis

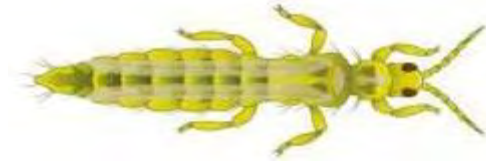
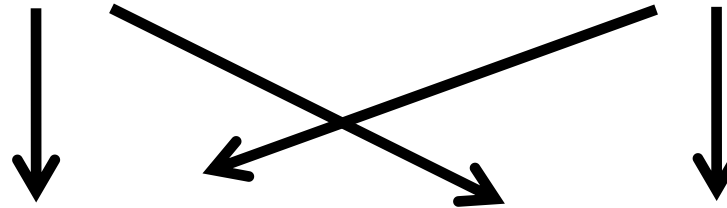
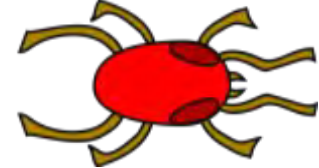


Thrips parvispinus

Amblyseius swirskii



Proprioseiopsis mexicanus



Frankliniella occidentalis

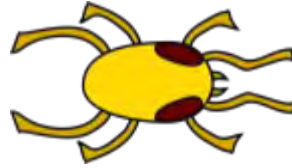


Thrips parvispinus

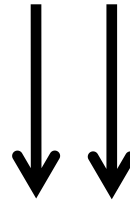
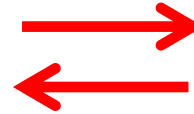
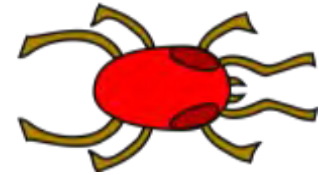
We hypothesise that:

- ▶ Herbivore suppression will be **stronger** when **both enemies** are present
- ▶ Both predators can **coexist** exploiting **alternative hosts** (i.e. **complementarity**)

Amblyseius swirskii



Proprioseiopsis mexicanus



Frankliniella occidentalis



Thrips parvispinus

We hypothesise that:

- ▶ Herbivore suppression will be **stronger** when **both enemies** are present
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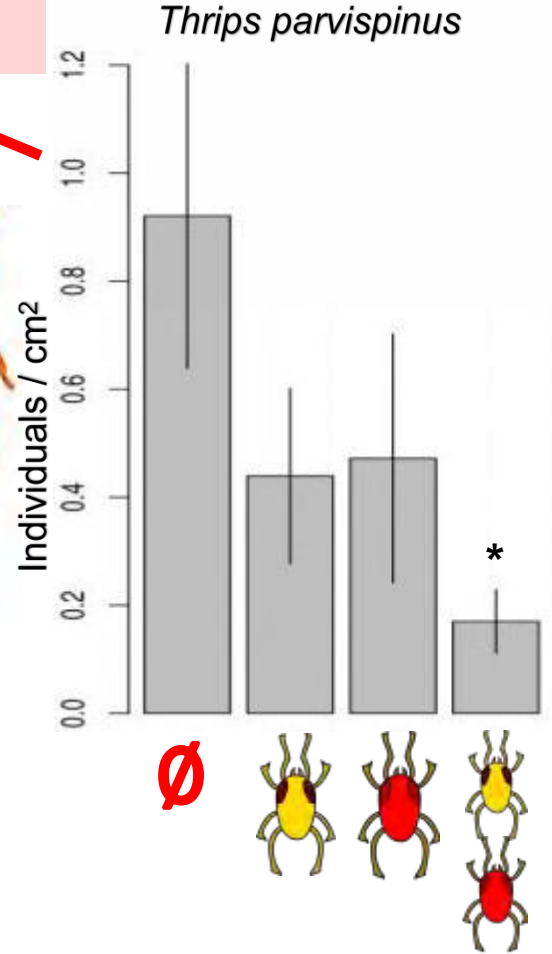
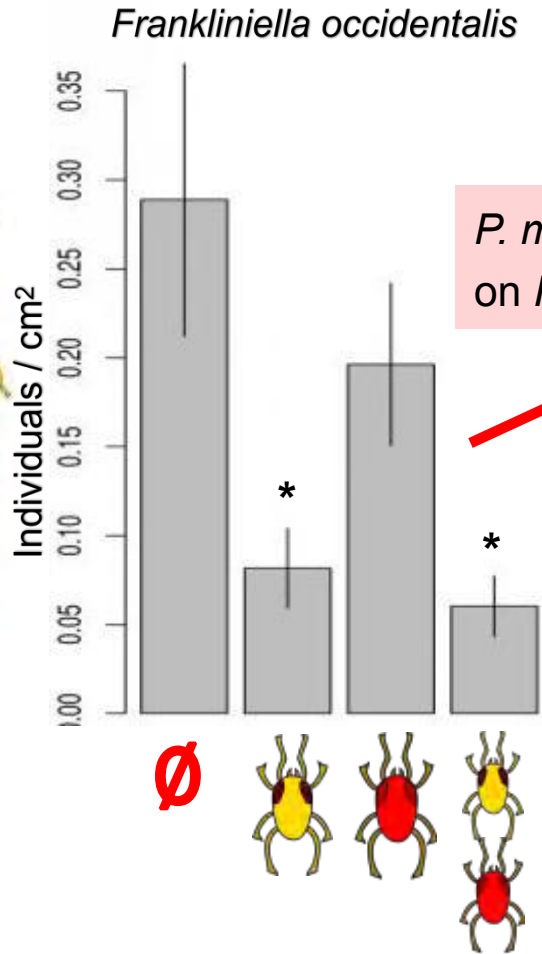
Experimental design

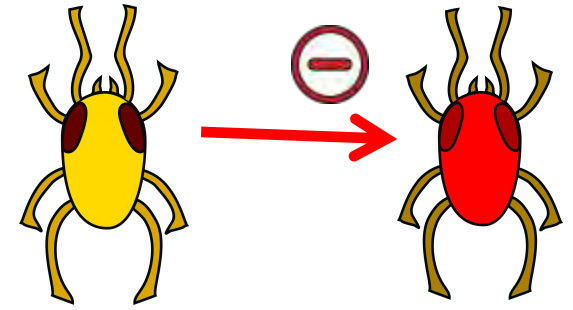
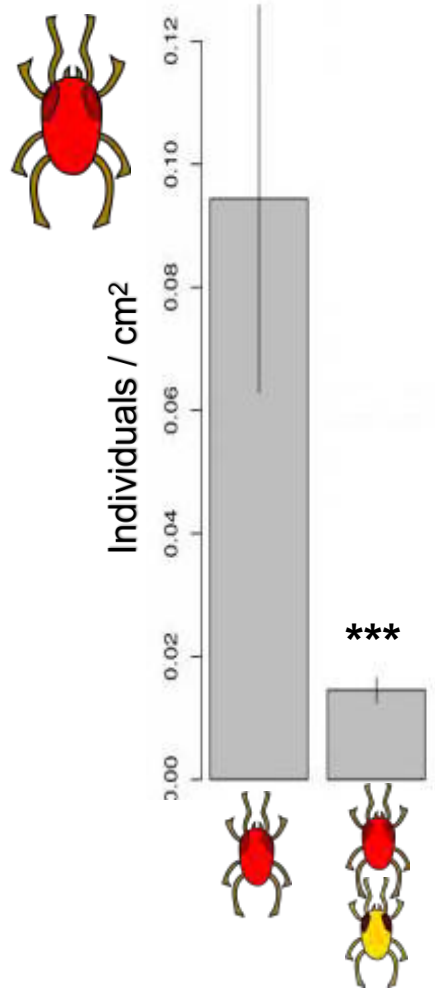
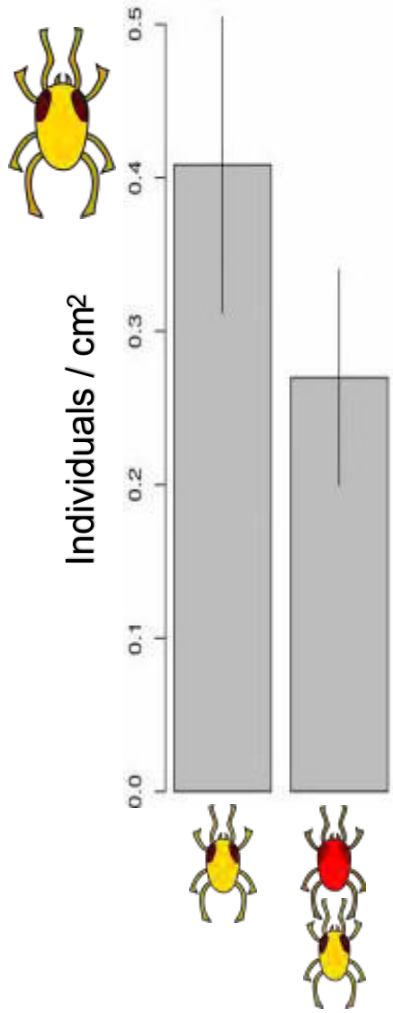
- > **4 community types** x 10 reps.
- > Host plants replaced weekly
- > Long-term dynamics (13 weeks - week counts)



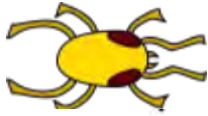
Both predators are needed to suppress *T. parvispinus*
Complementarity effect?

P. mexicanus does not feed on *F. occidentalis*

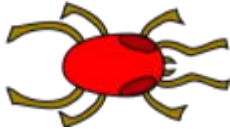




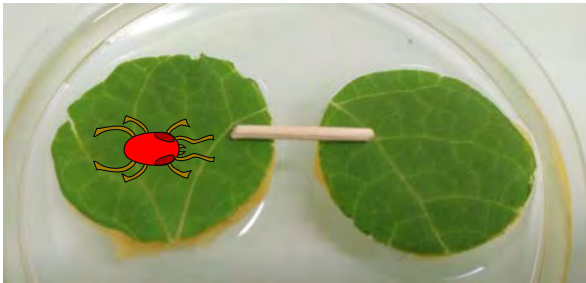
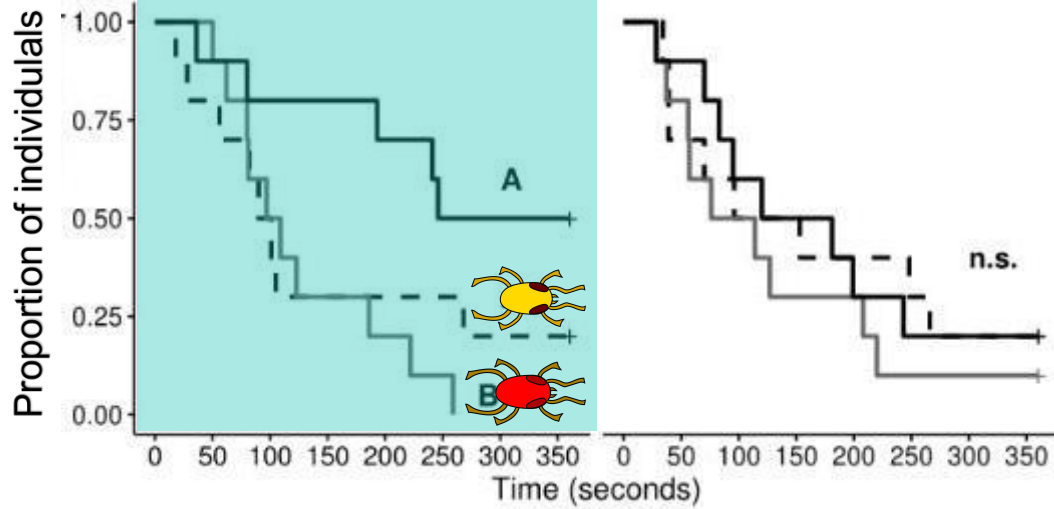
No coexistence,
P. mexicanus is lost in all cages
A. swirskii is a superior competitor



Amblyseius swirskii



Proprioseiopsis mexicana



Laura Madeleine



A. swirskii avoids competitor traces and eats its eggs

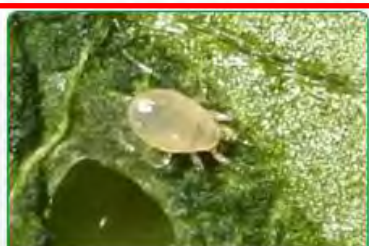
- *Proprioseiopsis mexicanus* no longer in *La Coccinelle* menu
- Optimisation of enemy use

Nos Produits



La Coccinelle

La biofabrique de La Réunion



Amblyseius swirskii

Lutte contre les Aleurodes, les araignées rouges, Les Thrips



Cheilomenes sulphurea

Lutte contre les pucerons



Aphidius colemani

Lutte contre les pucerons



Nesidiocoris volucer

Lutte contre les Aleurodes, Lutte contre les Thrips



Encarsia formosa

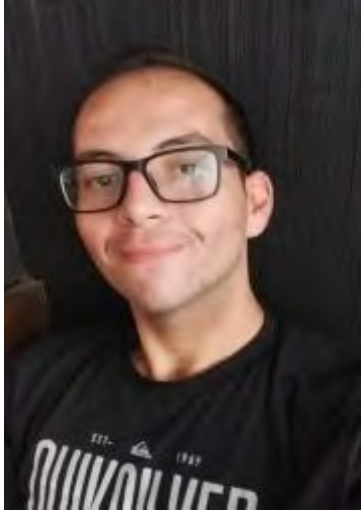
Lutte contre les Aleurodes



Eretmocerus eremicus

Lutte contre les Aleurodes

Karim Tighiouart



Pred. links: 11
IGP links: 3

*Nesidiocoris
volucer*



*Cheilomenes
sulphurea*



*Amblyseius
swirskii*



*Aphidius
colemani*



*Frankliniella
occidentalis*



*Echinothrips
americanus*



*Tetranychus
urticae*

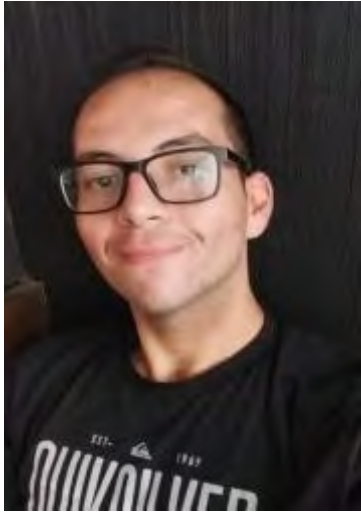


Myzus persicae

Picture credits: Antoine Franck - 20

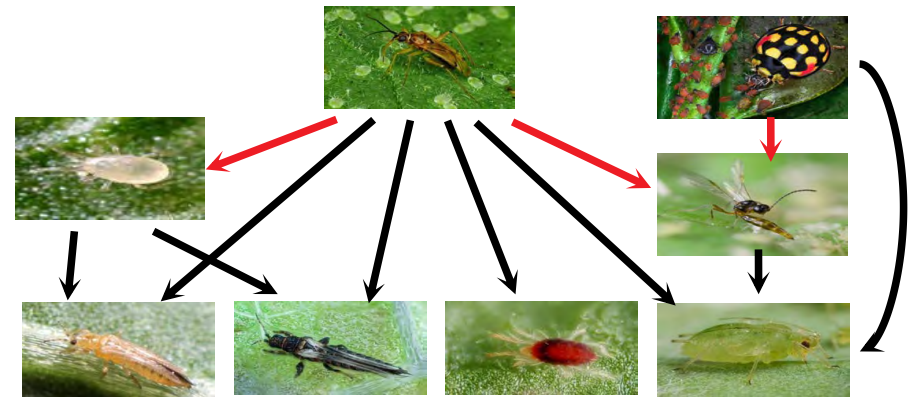


Karim Tighiouart



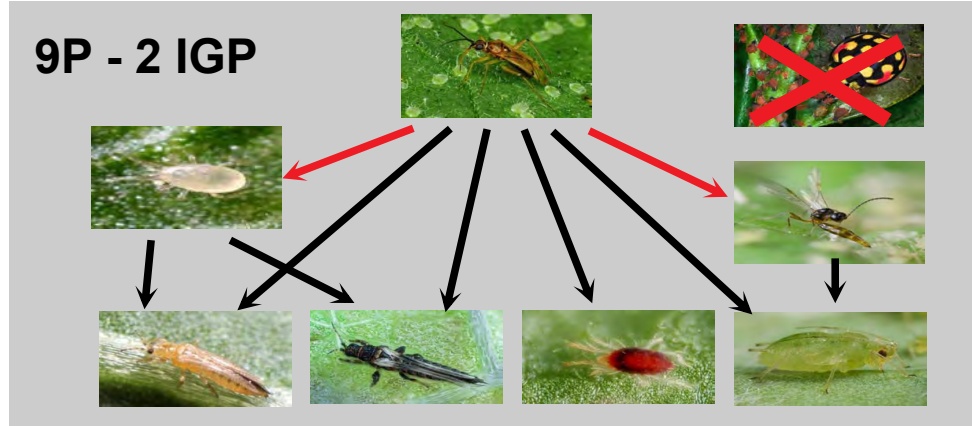
We hypothesise that that herbivore suppression will be stronger when:

- ▶ Enemies are more diverse (**more predation links**)
- ▶ Enemies engage in less antagonistic interactions (**intraguild**)

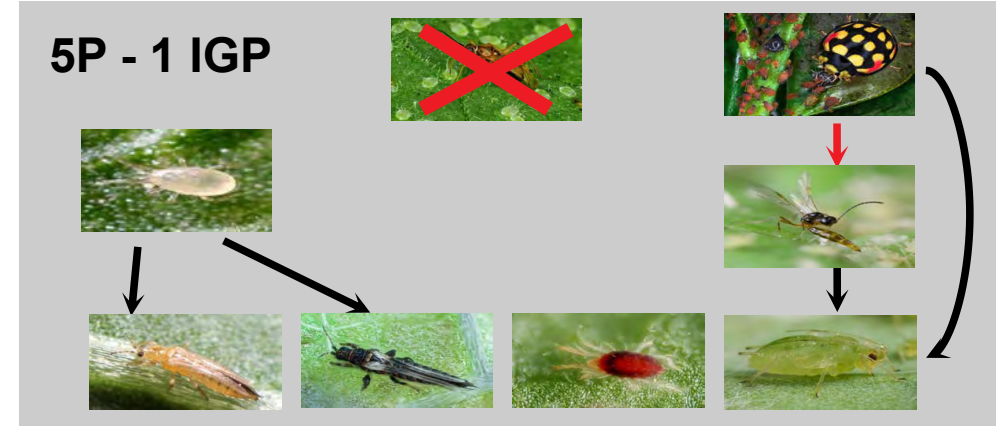


Experimental design

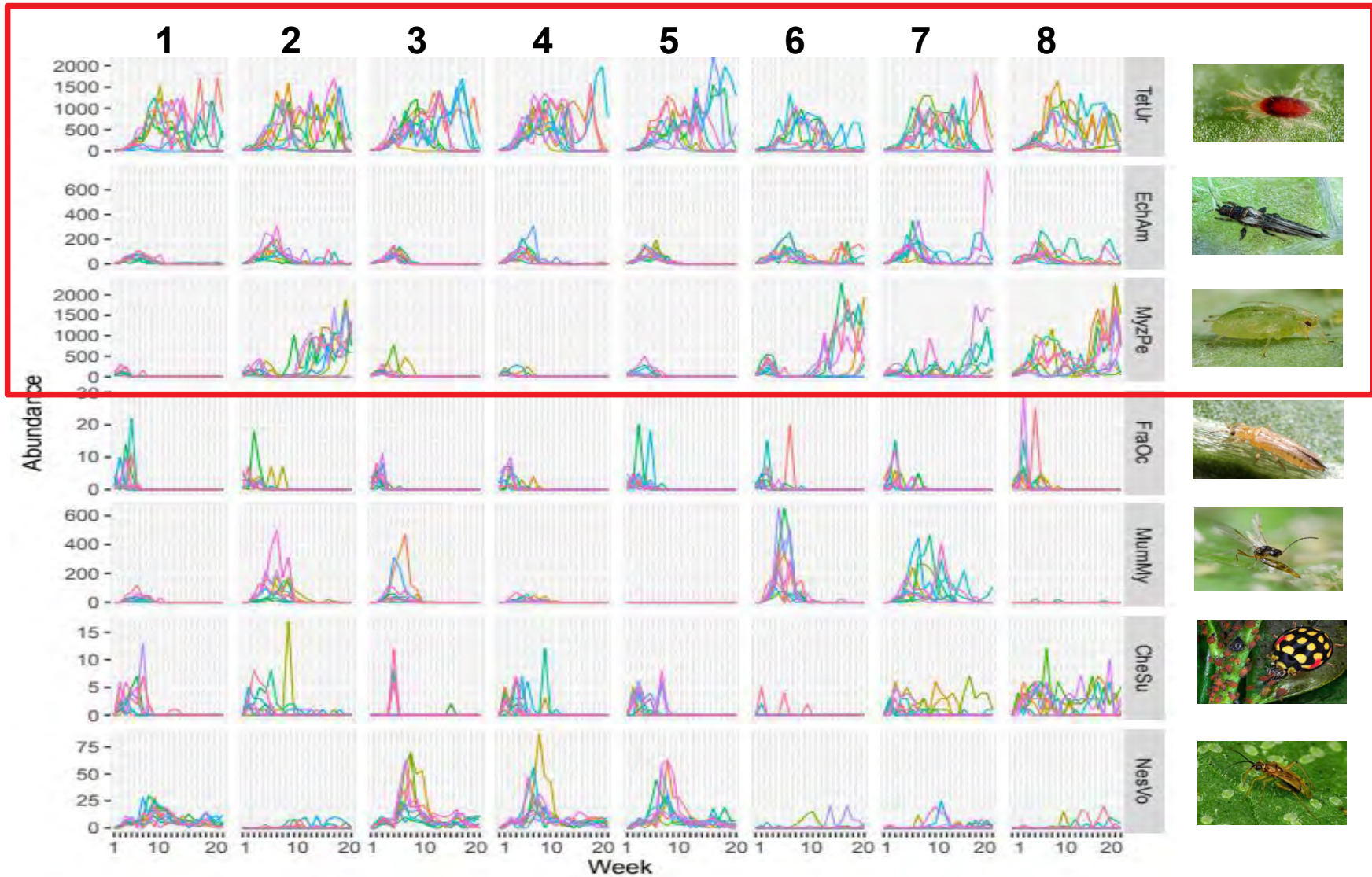
- > **8 community types** x 10 replicates = 80 experimental units
- > Host plants replaced weekly
- > Long-term dynamics (20 weeks - weekly counts)

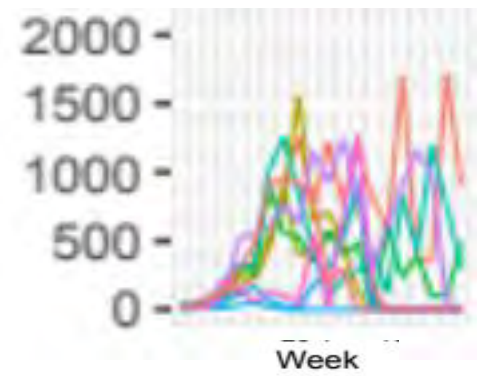
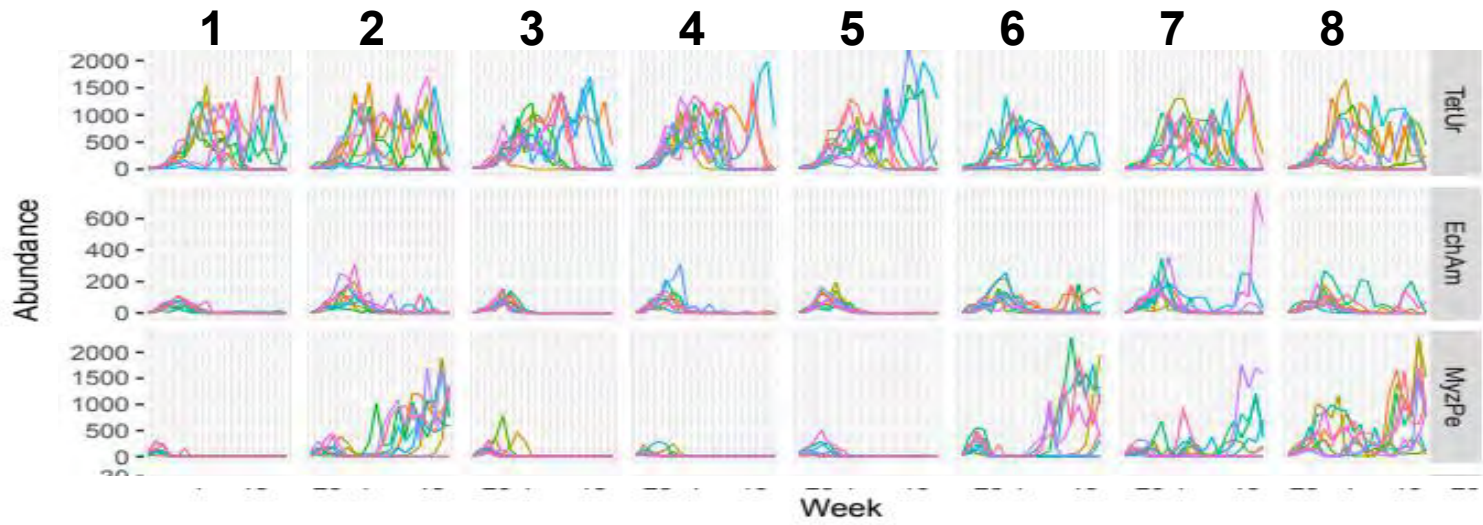


With generalist predator

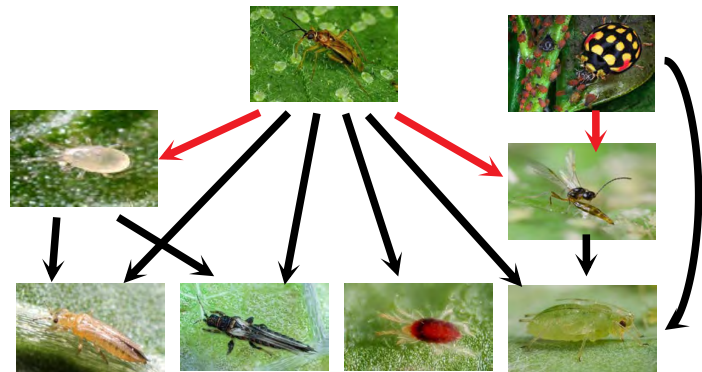


Without generalist predator





10 replicates

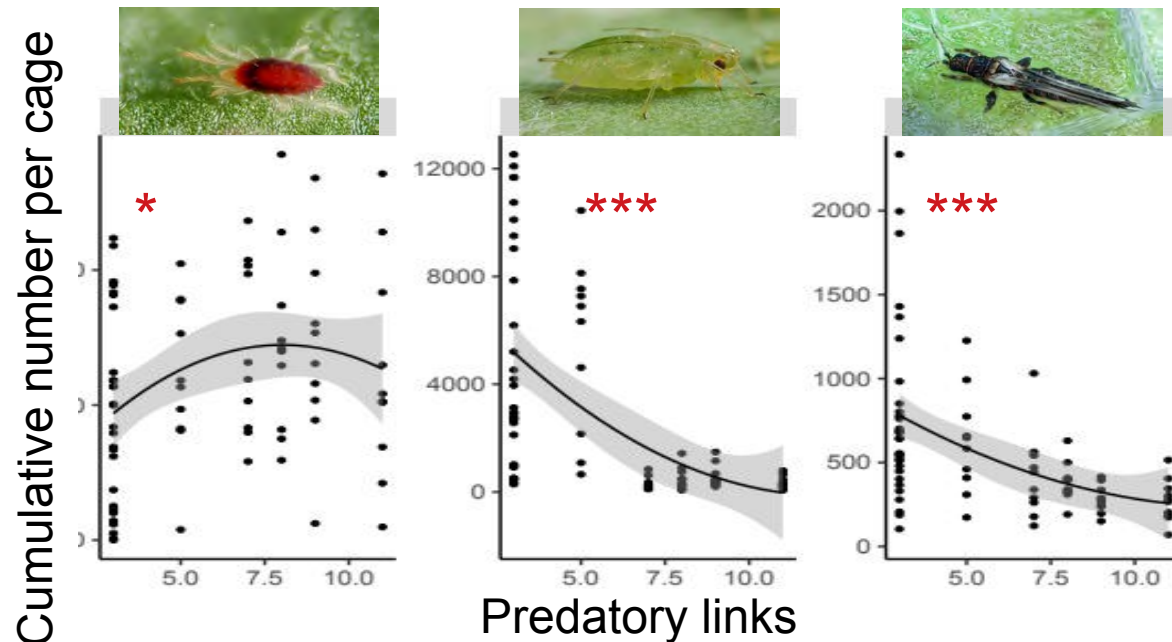


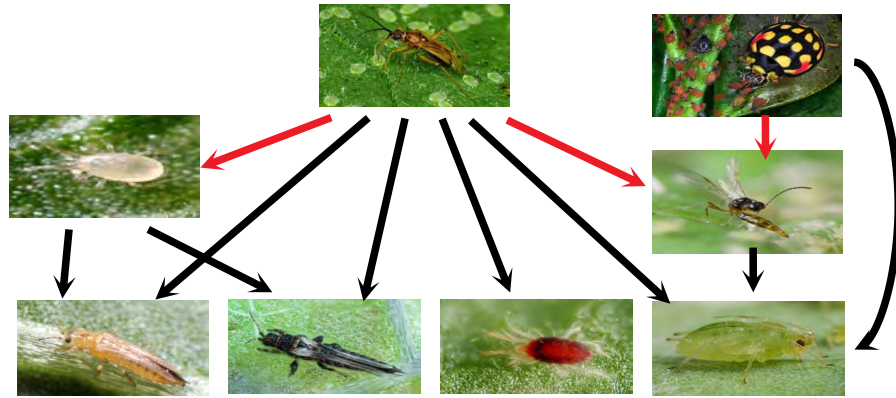
Intraguild predation links:

No effect

Predatory links:

Positive effect,
but not for the spider-mite



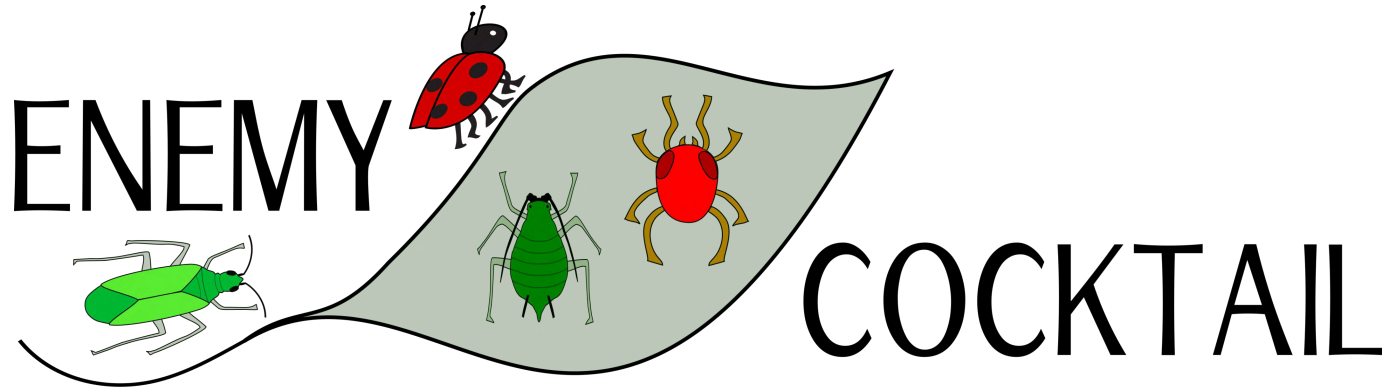


From manipulating a community to community replication

Current research:

CBGP (Plateau Serre, Elevage et Phénotypage d'Arthropodes - SEPA)

+ ISEM + Biobest + U. Exeter (ANR PRCE)



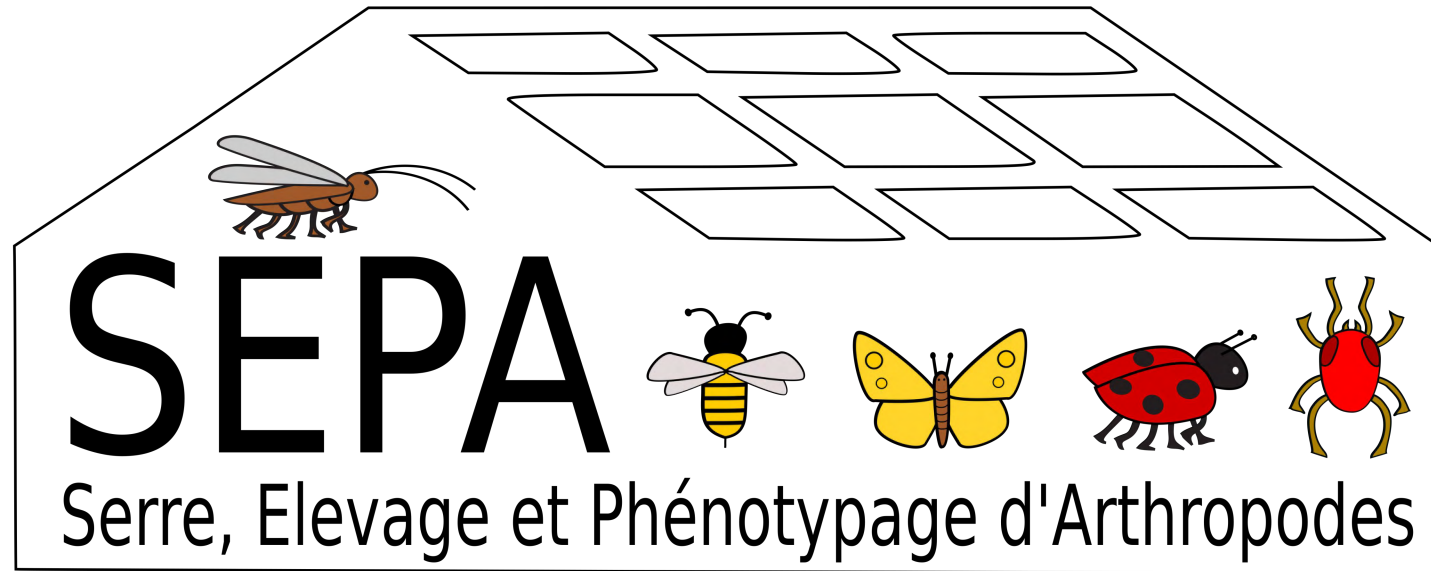
Designing natural enemy cocktails
for a better biocontrol



Current research:

CBGP (Plateau Serre, Elevage et Phénotypage d'Arthropodes - SEPA)

+ ISEM + Biobest + U. Exeter (ANR PRCE)



Research project: Enemy cocktail

Objective 1.

Experimental tests of enemy combinations in the laboratory

- > Complementarity vs intraguild predation on community dynamics

Molly
Dugan



Amandine
Raeckelboom



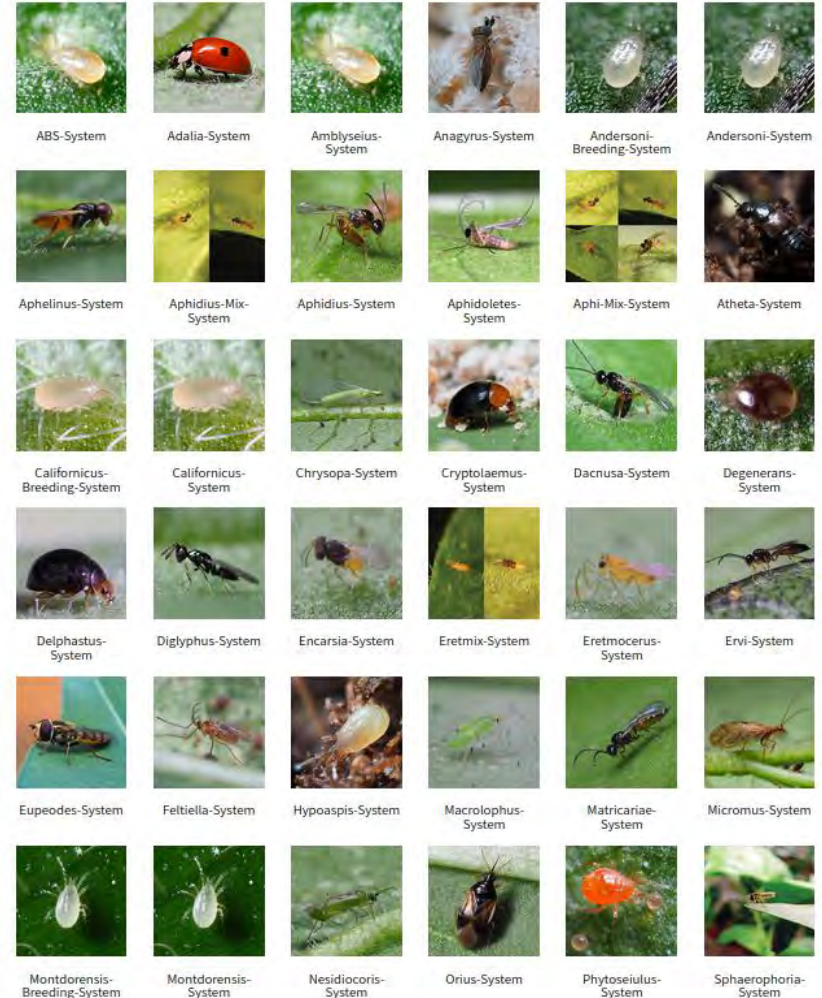
Francisco
Martínez



Research project: Enemy cocktail

Objective 1. Experimental tests of enemy combinations in the laboratory

> Complementarity vs intraguild predation on community dynamics



Research project: Enemy cocktail

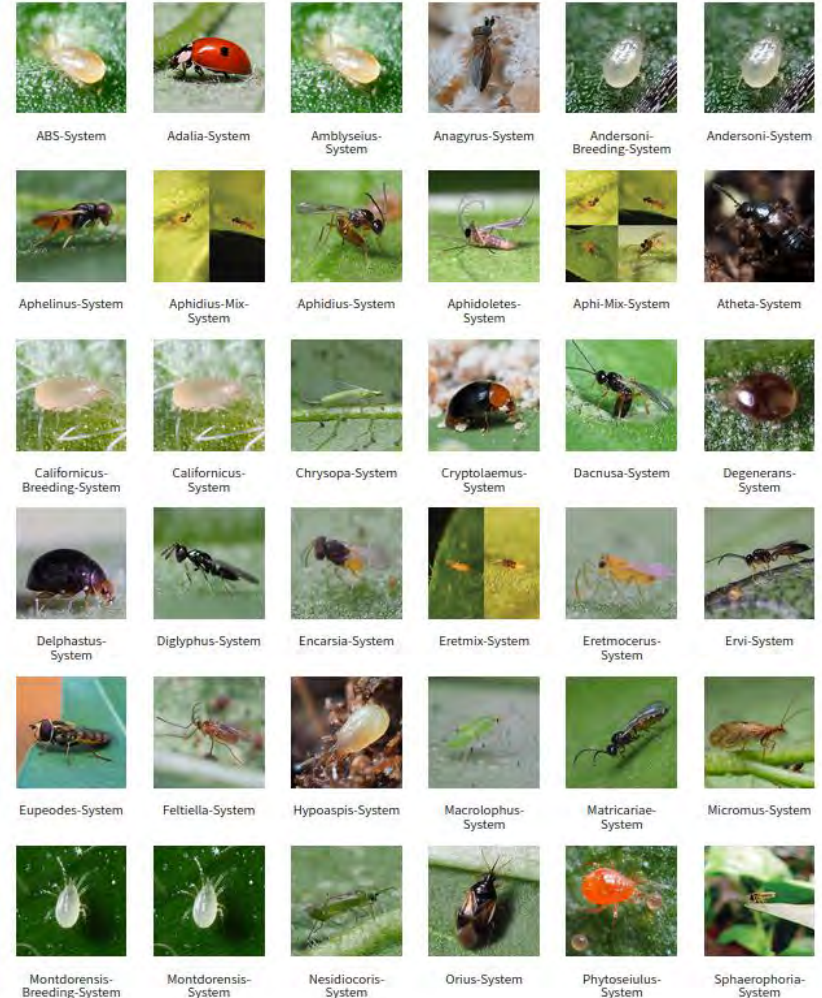
Objective 1. Experimental tests of enemy combinations in the laboratory

> Complementarity vs intraguild predation on community dynamics

Objective 2. Theoretical modelling

> Mechanistic insights into dynamics data

Selection of best cocktails

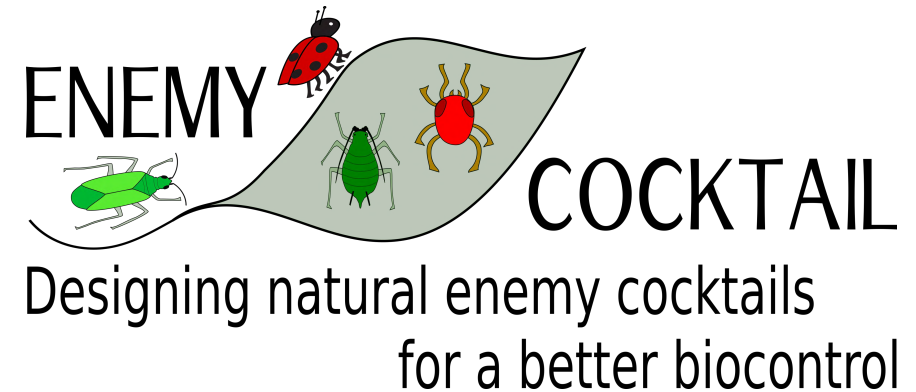


Research project: Enemy cocktail

Objective 3.

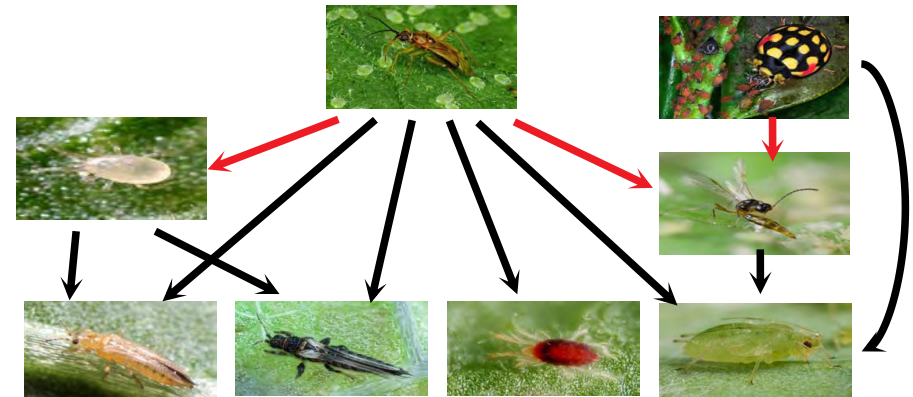
Test of enemy cocktails in commercial greenhouses

> Increase crop yield, and reduce pesticides

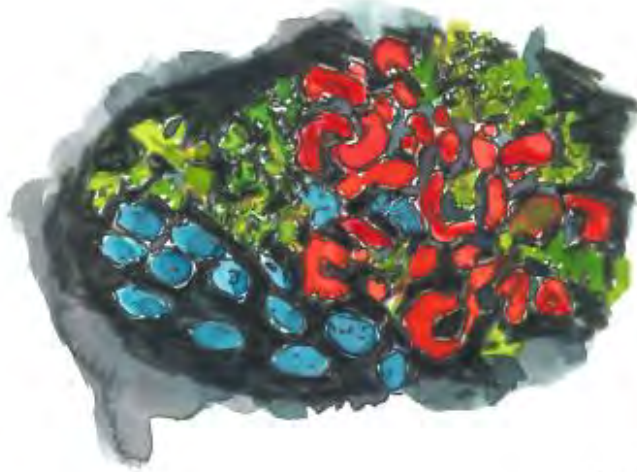


Conclusions

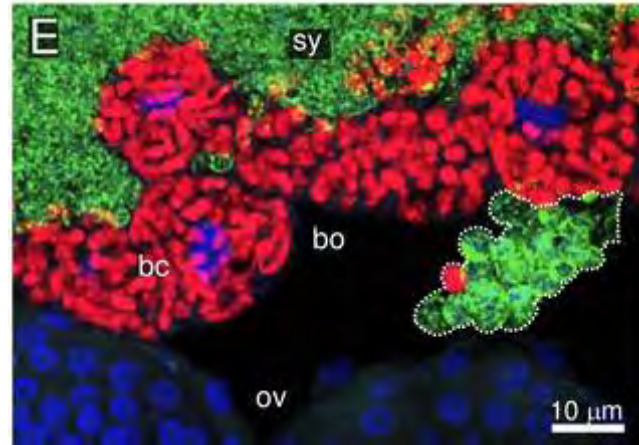
- **Intraguild predation** is not always a real problem for herbivore suppression
- **Multiple enemies** are not always needed to manage a target pest
- Generalist enemies and enemy preferences can trigger **secondary pest outbreaks**
- We will define a **roadmap for the selection of enemy combinations** in pest control



Insect symbionts determine interactions with plants and natural enemies



TNMM
2011 11
10 23



Drawing credits: Marta Barceló - 28

Plant-thrips-symbiont interaction networks along elevational gradients

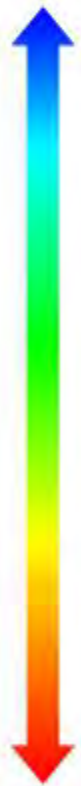


Drawing credits: Gaël Frago Barceló

Elevational gradients

To study how similar communities respond to abiotic conditions

Good proxy for global changes



At high elevation:

Low temperatures
Less resources



Harsh
conditions



Low diversity

Drawing credits: Gaël Frago Barceló

@EnricFrago - Cirad/Cbcp - Montpellier

Elevational gradients

To study how similar communities respond to abiotic conditions

Good proxy for global changes



At high elevation:

Low temperatures
Less resources



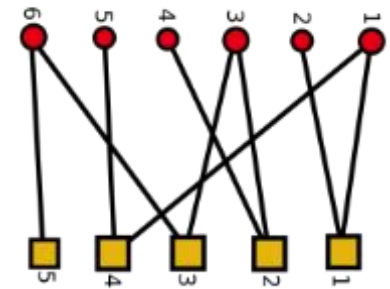
Harsh
conditions



Low diversity



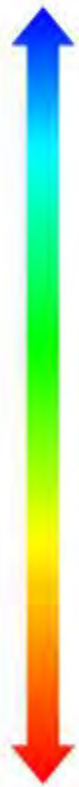
Few highly
specialised
species



Drawing credits: Gaël Frago Barceló

Elevational gradients

To study how similar communities respond to abiotic conditions
Good proxy for global changes



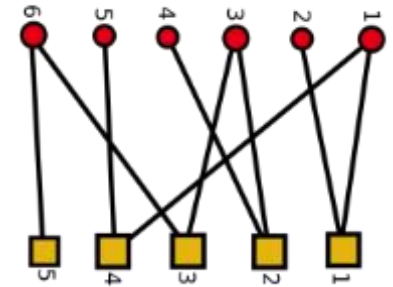
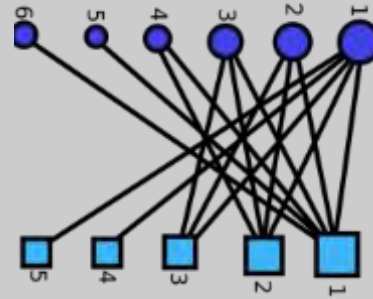
At high elevation:
Low temperatures
Less resources

Harsh conditions

Low diversity

Few highly specialised species

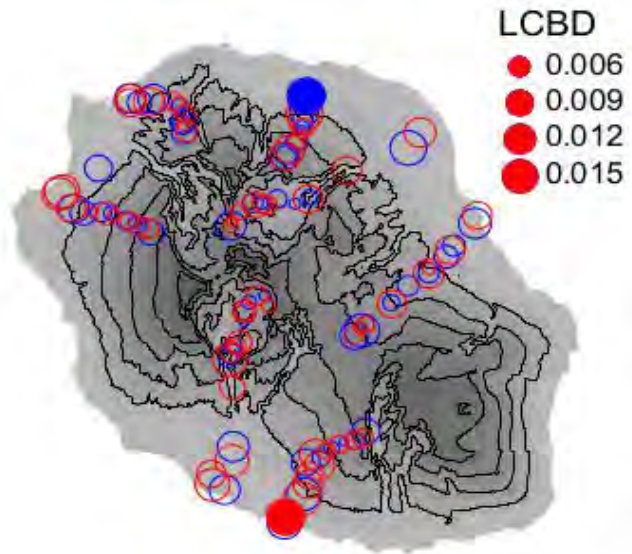
Species become generalist



Drawing credits: Gaël Frago Barceló

Thrips along elevational gradients in Reunion

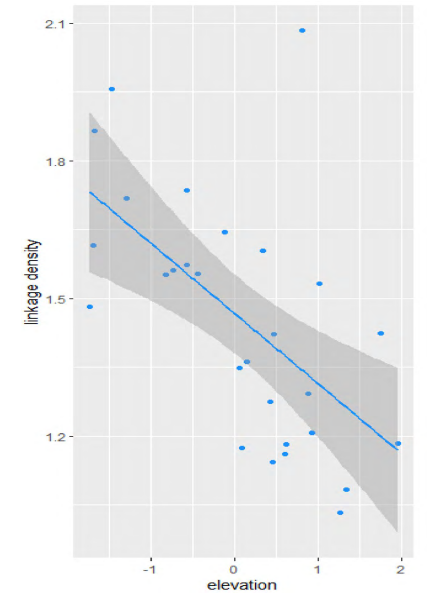
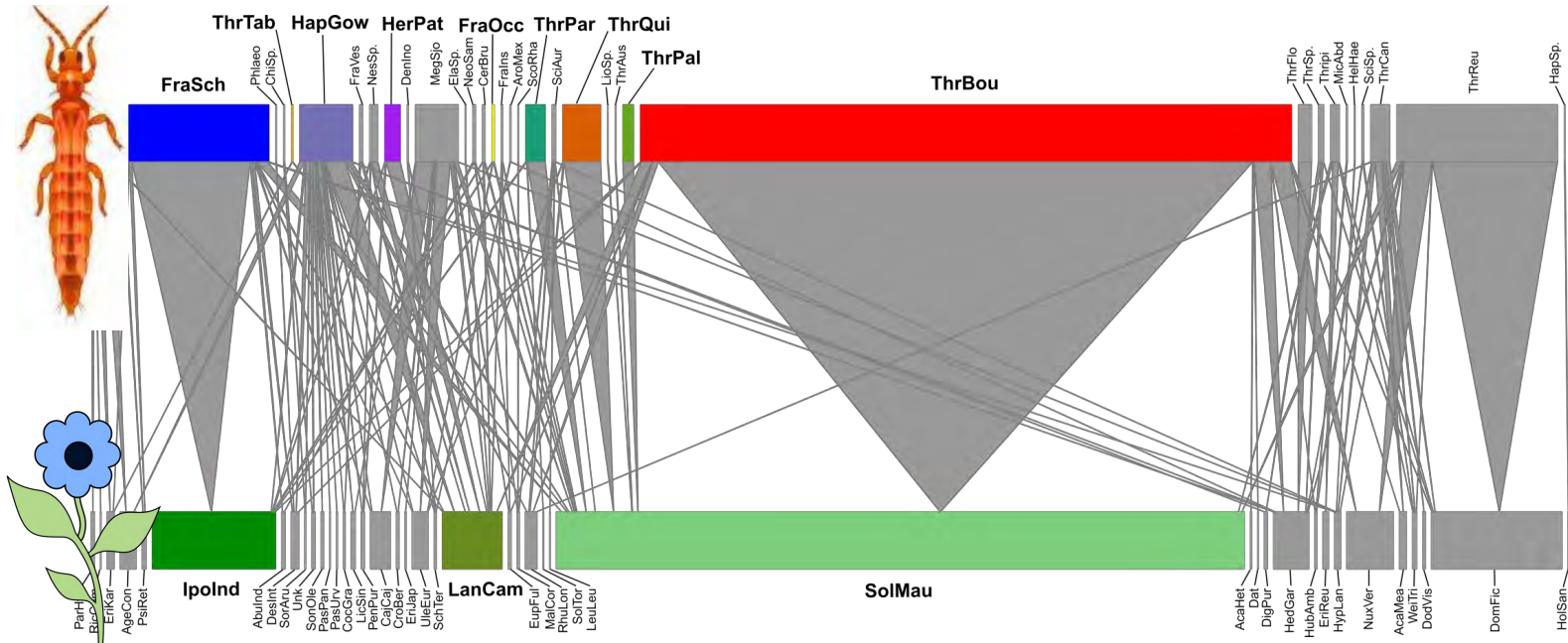
Niry Dianzinga PhD: **Thrips diversity** gradients



Dianzinga, Moutoussamy, Sadeyen, Ravaomanarivo, Frago (2020)
The interacting effect of habitat amount, habitat diversity and fragmentation on insect diversity along elevational gradients
Journal of Biogeography

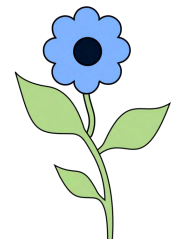
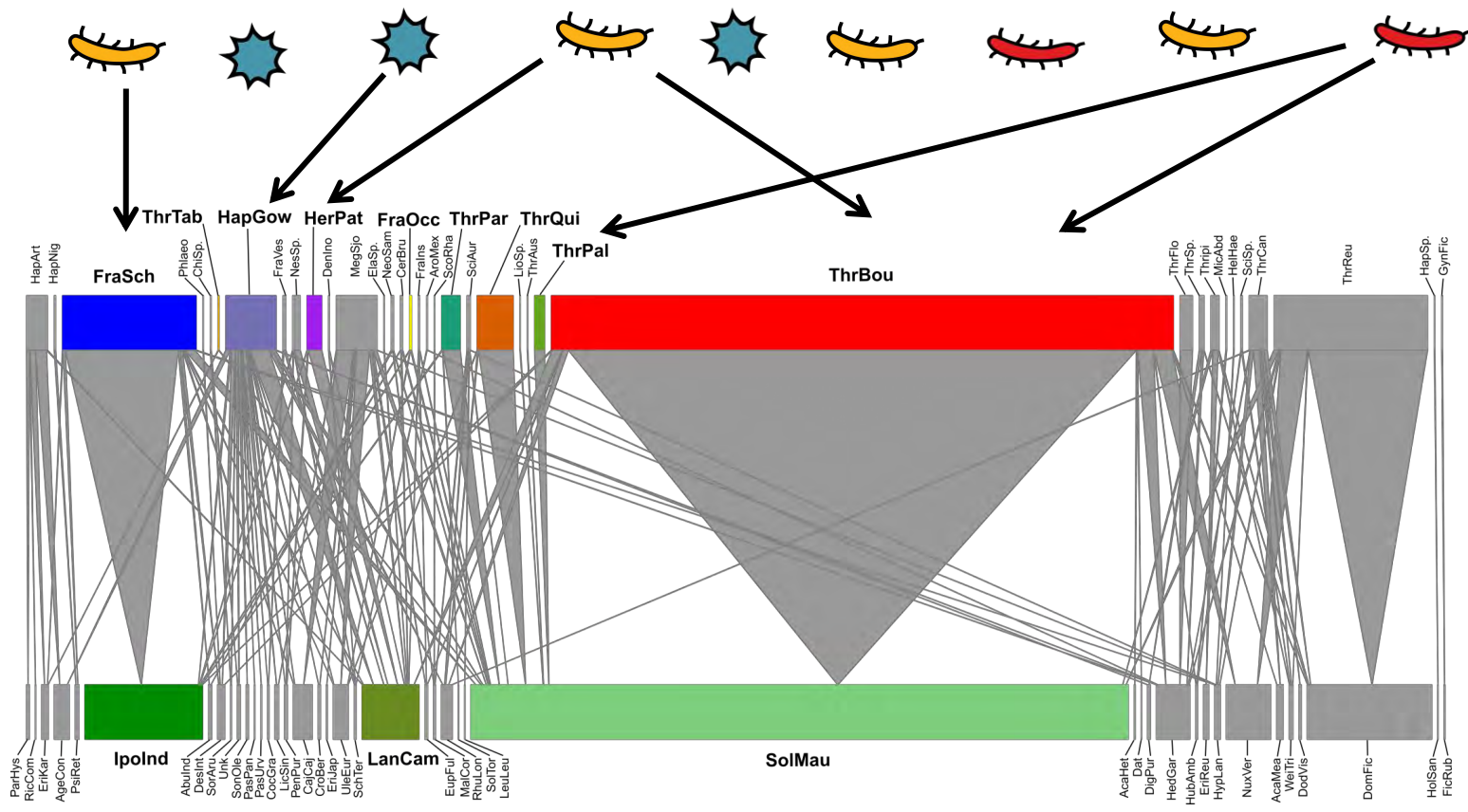
Thrips along elevational gradients

Giacomo Morassutti MSc (lockdown project):
Plant-thrips network gradients in France



Plant-thrips-bacteria networks along elevational gradients

Project DivSym - CeMEB - Emmanuelle Jousselein



Plant-thrips-bacteria networks along elevational gradients

Project DivSym - CeMEB - Emmanuelle Jouselin

CBGP (Plateau Biologie Moléculaire & Plateau Collections)

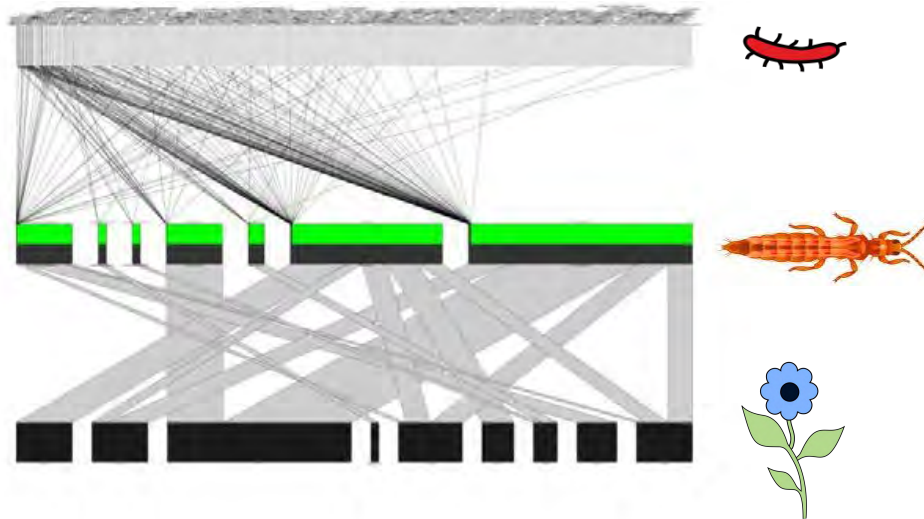


Plant-thrips-bacteria networks along elevational gradients

Project DivSym - CeMEB - Emmanuelle Jouselin

We hypothesise that:

- ▶ **Plant-thrips networks** will contain more **generalist species** at high elevation, *H2'* - weighted quantitative network specialisation index.
- ▶ The specialisation index in **thrips-bacteria networks** will vary with elevation.



Experimental design

- > 7 transects x 6 sites (0 to 1500m) x 9 plants x 5-10 thrips
- > Barcode: bacterial + insect

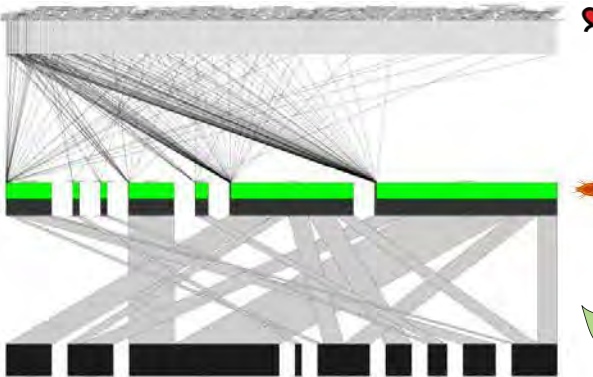
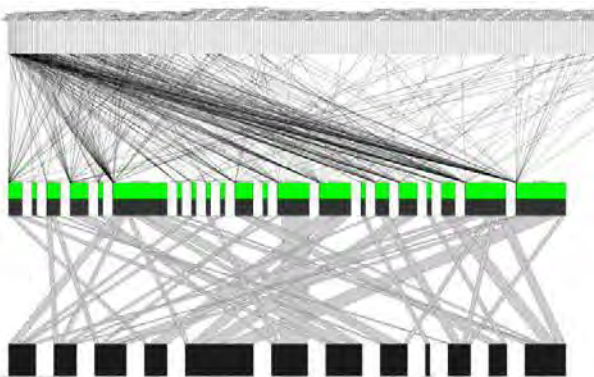
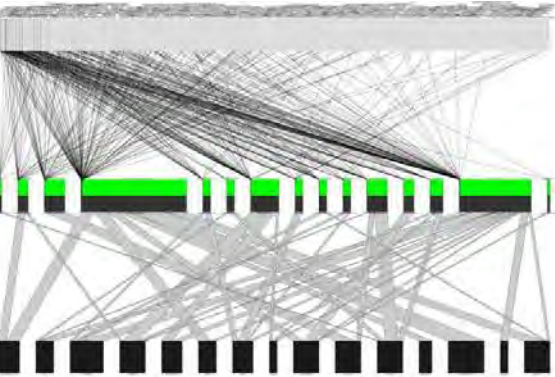


7 replicates = 7 H2' values

0 m

300m

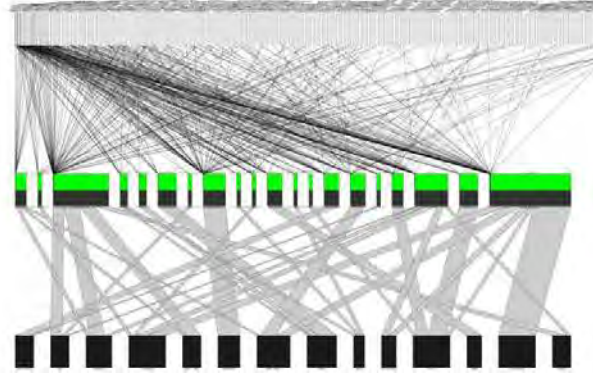
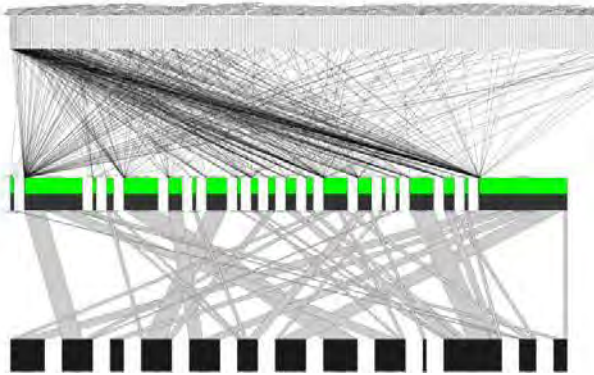
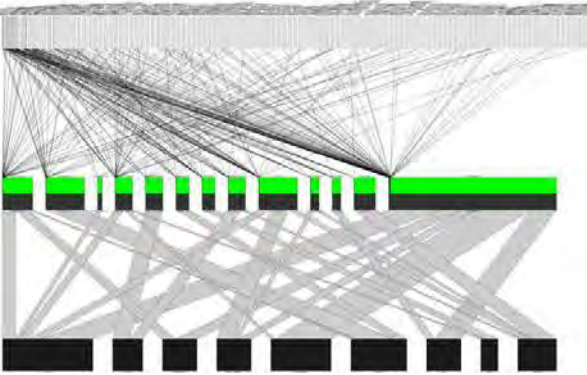
600m

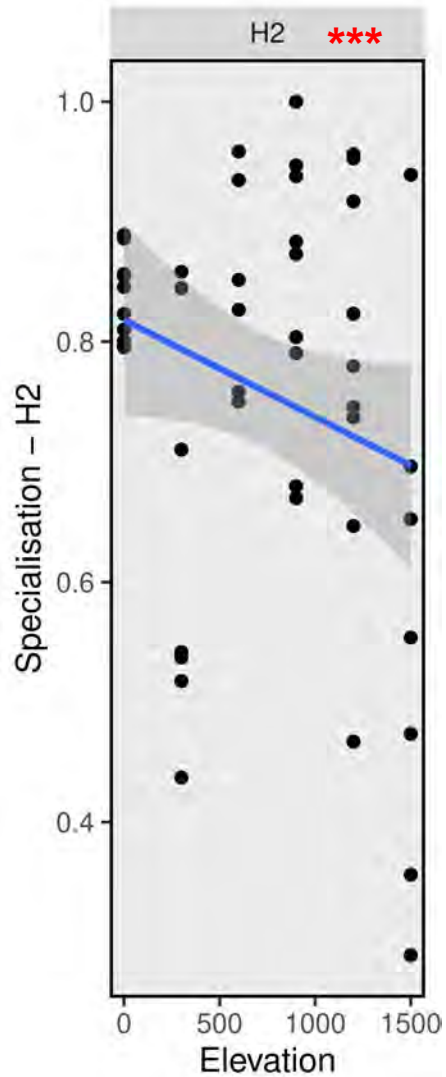


900m

1200m

1500m

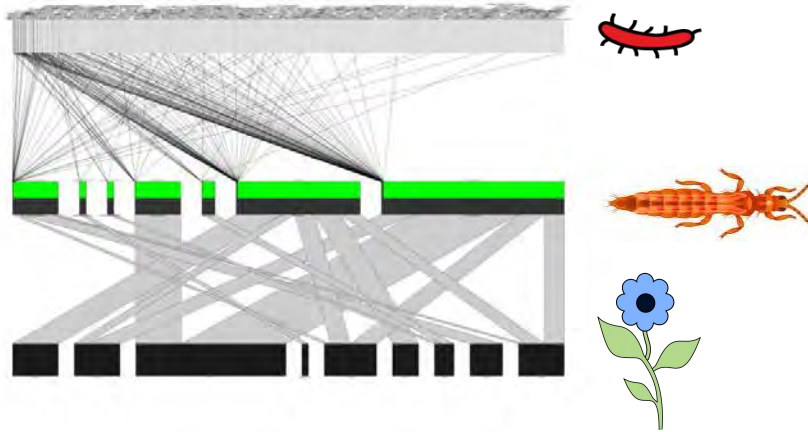




Specialist network



Generalist network

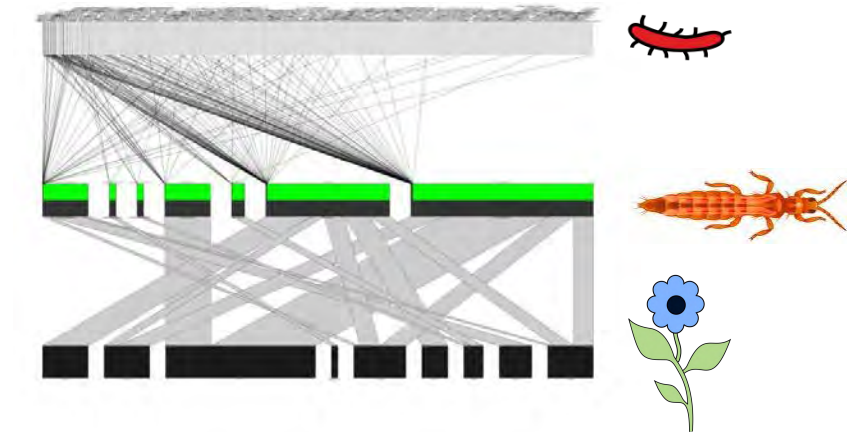


Thrips-bacteria networks:
Generalists increase with elevation

Plant-thrips networks:
Not enough data yet

Conclusions

- **Thrips are a good model system** for the study of:
 - Interaction networks** (2 weeks field work = 5000 individuals + 50 sp)
 - Insect symbiosis** (good bacterial diversity)
- Interaction networks vary with elevation, but we do not know yet if **plant-insect vs insect-bacteria interaction networks** vary differently
- We will create a **reference database** for thrips identification through barcode



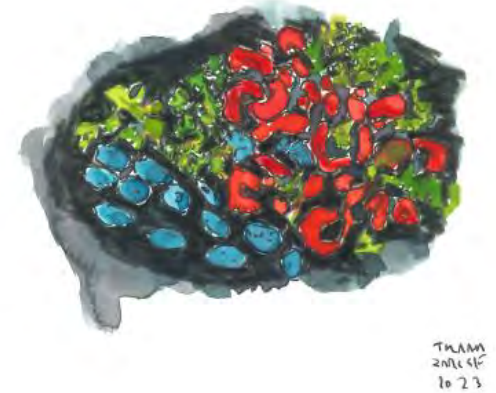
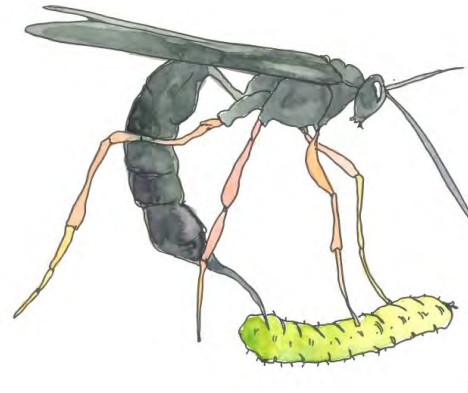
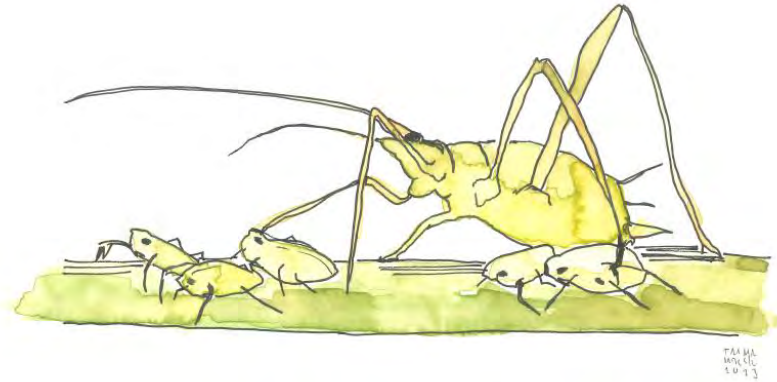
Conclusions and perspectives

Why do we need community ecology?

Mentoring young scientists

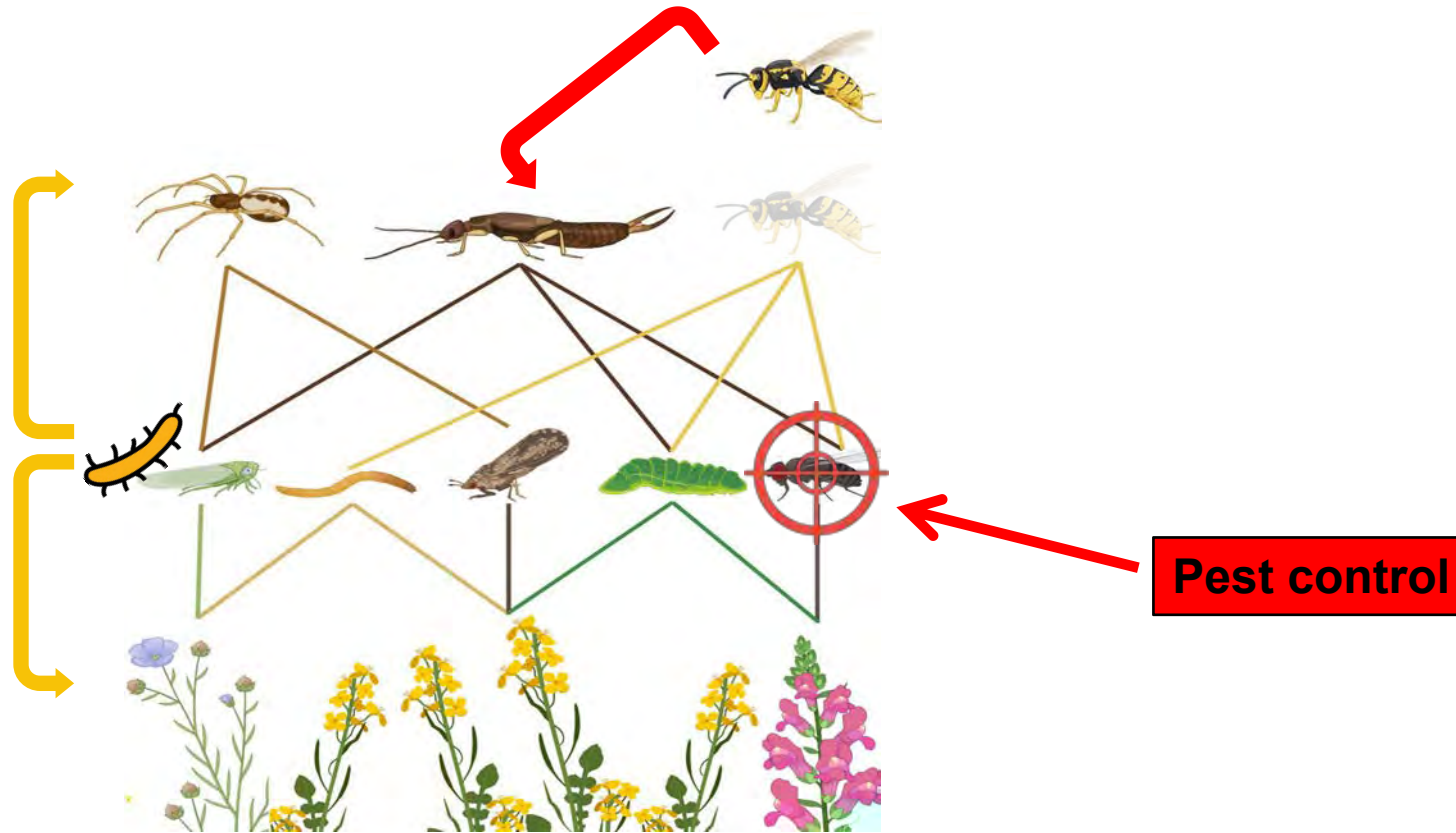
Open Access Publishing

Gender issues



Drawing credits: Marta Barceló - 37

Community ecology is needed to implement sound pest control



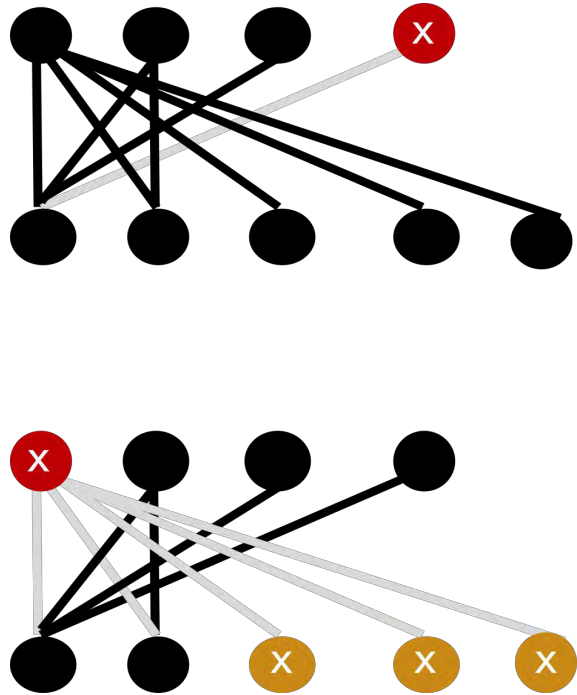
Community ecology is needed to tackle the biodiversity crisis

Cascading extinctions and insect declines

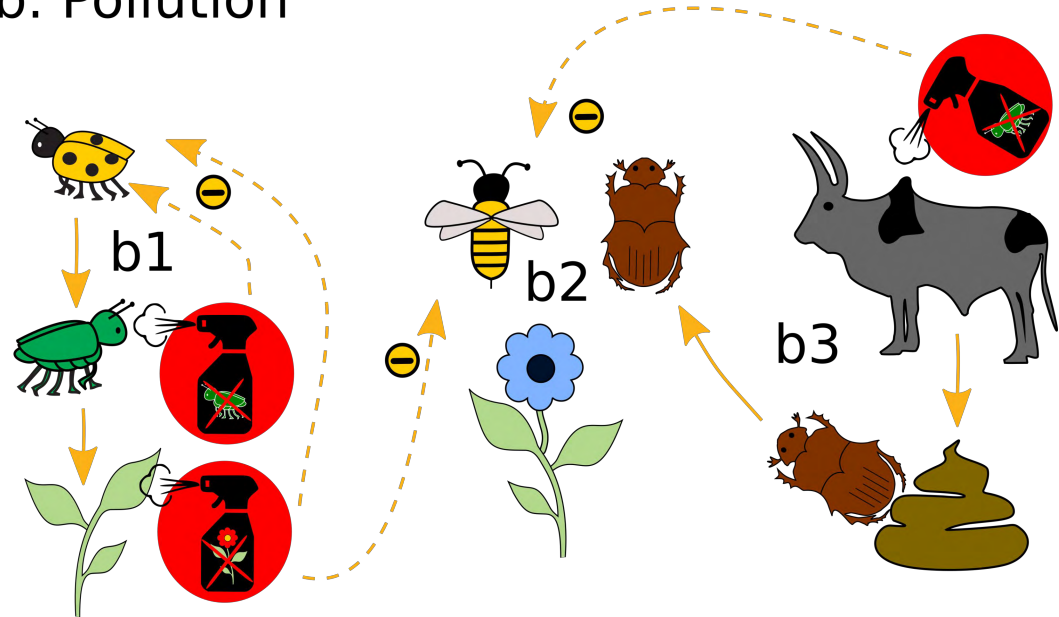


Community ecology is needed to tackle the biodiversity crisis

Cascading extinctions and insect declines



b. Pollution



Kehoe, Frago and Sanders (2020)
Cascading extinctions as a hidden driver of insect decline.
Ecological Entomology

Mentoring young scientists



Jen Heemstra @jenheemstra · 04 Aug

Genuinely caring about students should be a non-negotiable qualification for a career in academia. Full stop.

#MentorFirst

As science faculty, we are expected to produce high-quality scientific research. While this is a central goal, it is accomplished by leading teams of students, postdocs, and research staff. Thus, our success in producing research is inextricably linked to the significant role we play as mentors to the researchers in our labs.

We believe that prioritizing the needs of researchers and focusing on providing high-quality mentorship leads to greater creativity, and ultimately productivity, in our research programs.

Mentoring young scientists



Jen Heemstra @jenheemstra · 04 Aug

Genuinely caring about students should be a non-negotiable qualification for a career in academia. Full stop.

Cultivate an
inclusive environment
where everyone
feels valued

Prioritize
Professional
Development

Communicate,
Set Expectations,
and Be Transparent

Promote
self-care and
well-being

Open access publishing

DAFNEE, a Database of Academia Friendly jourNals in Ecology and Evolution

[Browse DAFNEE](#)

[Author usage index](#)

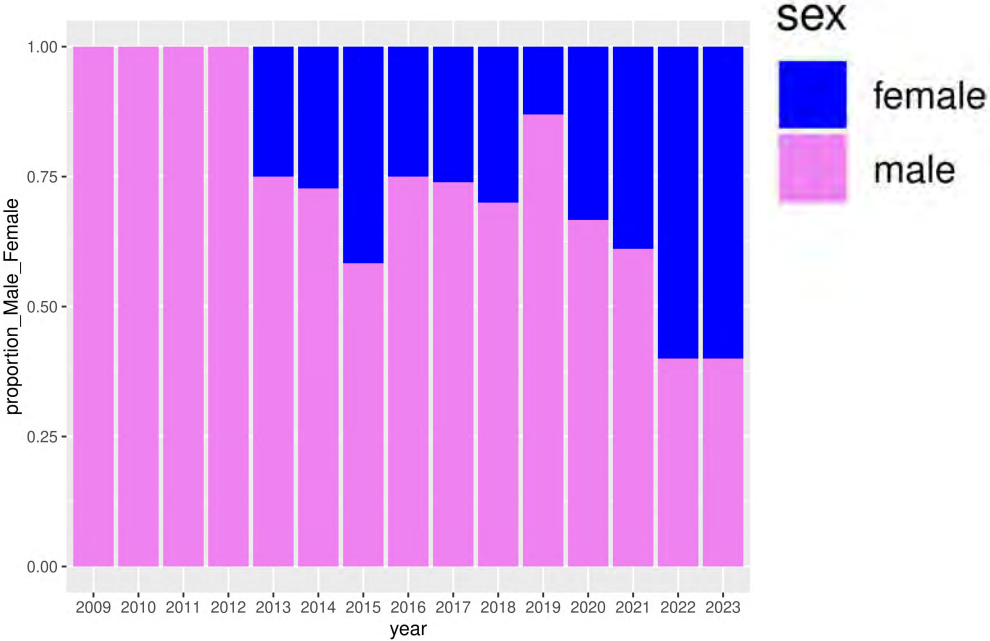
[About](#)

[Surveyed journals](#)

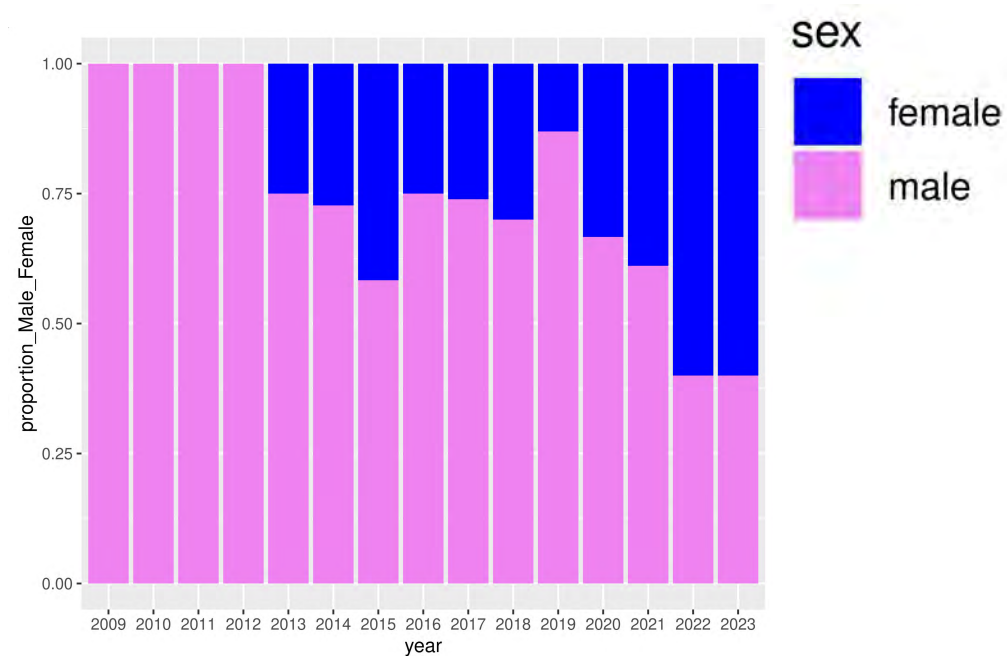
367 non-profit, learned society, or university-associated journals relevant to the field of ecology and evolutionary biology



Gender issues



Gender issues



Failure is the rule, but the intention is what matters

Alison Duncan, Elisa Thebault, Fabrice Vavre, Elodie Vercken, Christoph Vorburger, Christine Meynard, Anne Xuéreb, Nico Lemenager, Philippe Auger, Bruno Serrate, **Léo Jackson, Giacomo Morassutti, Molly Dugan, Amandine Raeckelboom, Francisco Martínez**, Laure Benoit, Anne Loiseau, Sabine Nidelet, Candice Deschamps, Guillaume Castel, Nathalie Charbonnel, Marguerite Chartois, Nathalie Vieira, Anne-Laure Clamens, Manue Jouselin, Bruno Michel, Marie-Pierre Chapuis, Benoît Facon, Simon Fellous, Diego Santos García, Svitlana Serga, Nicolas Rode, Sandra Fouchet, Julien Moulin, Samira Ouabbi-Salah, Geoffrey Thuel-Chassaigne, Jean-Marc Thuillier, Vincent Daneville, Florence Bonta, Sven Schayes, Hélène Quinonero, Antoine Foucart, Carine Brouat, Renaud Vitalis, Daniel Bathélémy, Thierry Lefrançois, Marie Bouilloud, Berenice Cariou, Émeline Charbonnel, Benoît Penel, Isis Poinas, Jess Rouil, Raphaël Leblois, Benoît Facon, Julien Foucaud, Maxime Galan, Julien Haran, Romain Gallet, Marie Vasse, Alejandro V. Cano, Philippe Auger, Vasilis Dakos, Azélie Lelong, Denise Navia, Anne-Nathalie Volkoff, Alexandre Bout, Nico Desneux, Anne-Violette Lavoire, Ludovic Mailleret, Nicolas Ris, **Oriane Lavogez**, Olivier Fontaine, Alizée Taquet, Morguen Atiama, Ludovic Dumont, Tristan Schmitt, Louis Dijoux, Stéphane Robert, Rosaire Tangama, Jean-Michel Baptiste, Nathalie Becker, Maud Charlery de la Masselière, Elodie Chapuis, Jean Philippe Deguine, Benoît Facon, Martial Grondin, Jeremy Hascoat, Maxim Jacquot, Vincent Jacob, Hélène Jourdan, Nicolas Juliet, Sylvain Lebon, Magalie Leclair, Laura Moquet, Jim Payet, Virginie Ravigné, Nicolas Talibart, Chantal Terrentroy, Antoine Franck, Marie-Ludders Moutoussamy, **Niry Dianzinga, Karim Tighiouart, Laura Madeline, Sandro Moretti**, Tolotra Ranarilalaitiana, Lala Ravaomanarivo, Apostolos Pekas, 3434, Kalliope Papadopoulou, Maria Pappas, George Broufas, Dimitrios Arrianas, Victor Flors, Paloma Sánchez Bel, Rachid Mentag, Paula Baptista, Meriem M'saad Guerfali, Salma Ben Romdhane, Benedicte Albrechtsen, Arjen Biere, Alison E. Bennett, David Giron, Thure Hauser, Eduardo De La Peña, Maria José Pozo, Ayco Tack, Charles Godfray, Marcel Dicke, Rieta Gols, **Nelson Davila, Eddie Griese, Jeny Lazebnik, Luís Paniaga Voirol, Foteini Paschalidou, Steijn Schreven, Mukta Mala**, Nina Fatourous, Ana Pineda, Rabea Schweiger, Caroline Müller, Lorenzo Marini. Giovanni. Luvi. Aleiandro Tena. **Laia Fontana**. Ace North. Piotr Łukasik, Ailsa McLean, Ciara Mann, Noel Howley, Nigel Hódar, George Boettner, Constantin Ciornei, Laurent Dor Lorenzo Marziali, Hugo Mas, Eduardo Perez Laorga, José Dirk Sanders, Sharon Zytynska, **Rachel Kehoe**, Fra el Pere, el Jonathan, la penya Puça, la penya Vino, els Voc.

cessez-le-feu immédiat et permanent

Merci de votre attention!

