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Elodie Le Souchu, Guilhem Parmain, Stéphanie Bankhead-Dronnet, Mathias Brand, Sébastien Damoiseau, Christian Sallé, Christophe Bouget, Aurélien Sallé

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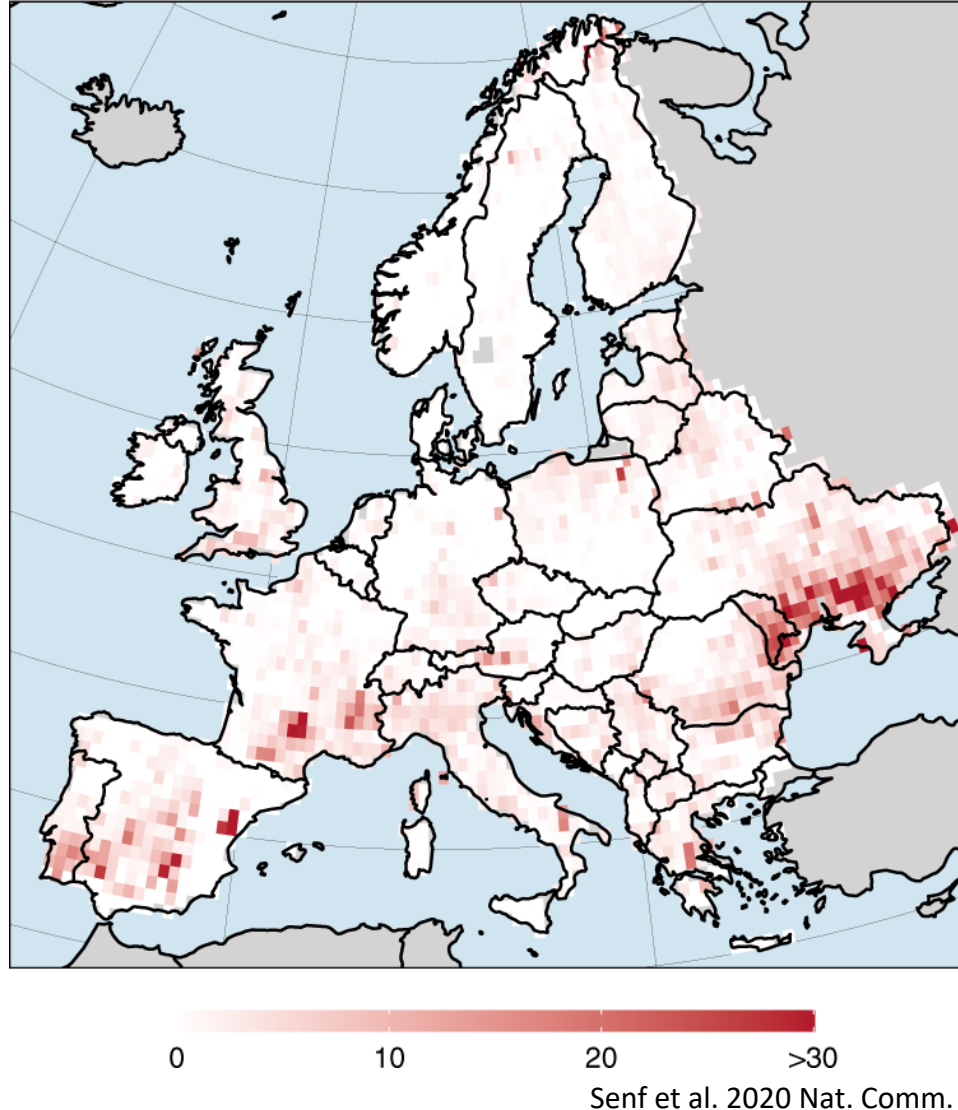


Contrasting responses of trophic guilds to forest decline reshape canopy insect community

E. Le Souchu, G. Parmain, S. Bankhead-Dronnet, M. Brand, S. Damoiseau, C. Sallé, C. Bouget & A. Sallé



Percent of total mortality attributable to drought



Climate change: increased severity and frequency of droughts & heatwaves (Allen et al. 2010)

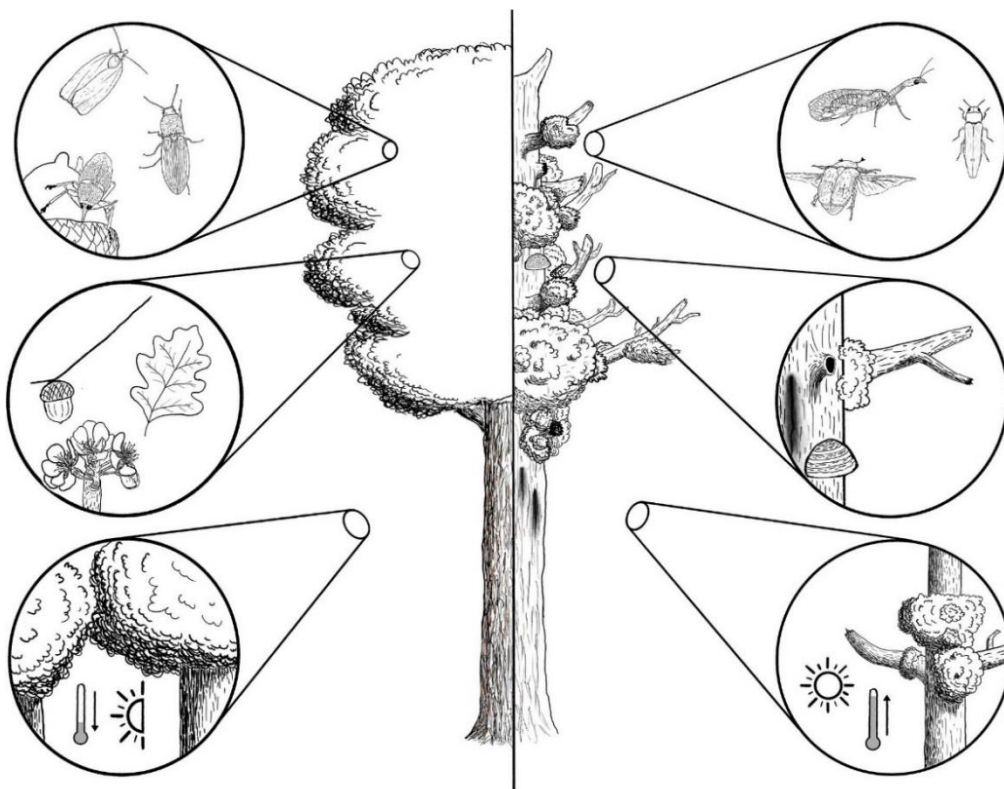
- Large-scale forest disturbances
- Large-scale forest declines and diebacks
- **Large-scale degradation of forest canopies**



Declining oaks – © A. Sallé

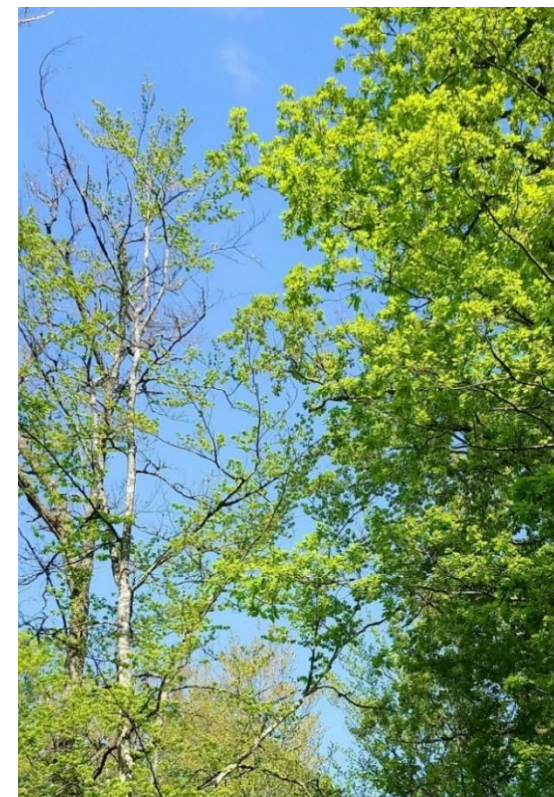
Forest decline: gradual degradation of forest health leading to tree death after several years. Leads to **collapses and pulses of microhabitats and trophic resources.**

- **Collapses:** Rapid crown alteration with loss of foliage & change in foliage quality and microclimates.
- Deleterious effects on foliage-feeding species (phyllophagous, gall-inducer, ...)?



Overview of decline-induced changes in arthropod communities (upper insets), resources and habitats (medium insets), and microclimates (lower insets) in forest canopies.

Sallé et al. 2021 Front. For. Glob. Change



Declining tree (left) & healthy tree (right)

© A. Sallé

→ **Pulses:** Positive effects on saproxylic species (mycophagous, xylophagous, ...) and flower-dependent taxa ?



Quantity and diversity of dead wood

Sap flow

Opportunistic fungi



Trunk cavities

Soil resources

Floral resources

- **Question:**

What are the effects of oak decline on the functional structure of the community of canopy-dwelling insects ?

- **Objectives:**

To characterize the community of canopy insects.

To assess the effects of decline on this community and its trophic guilds.

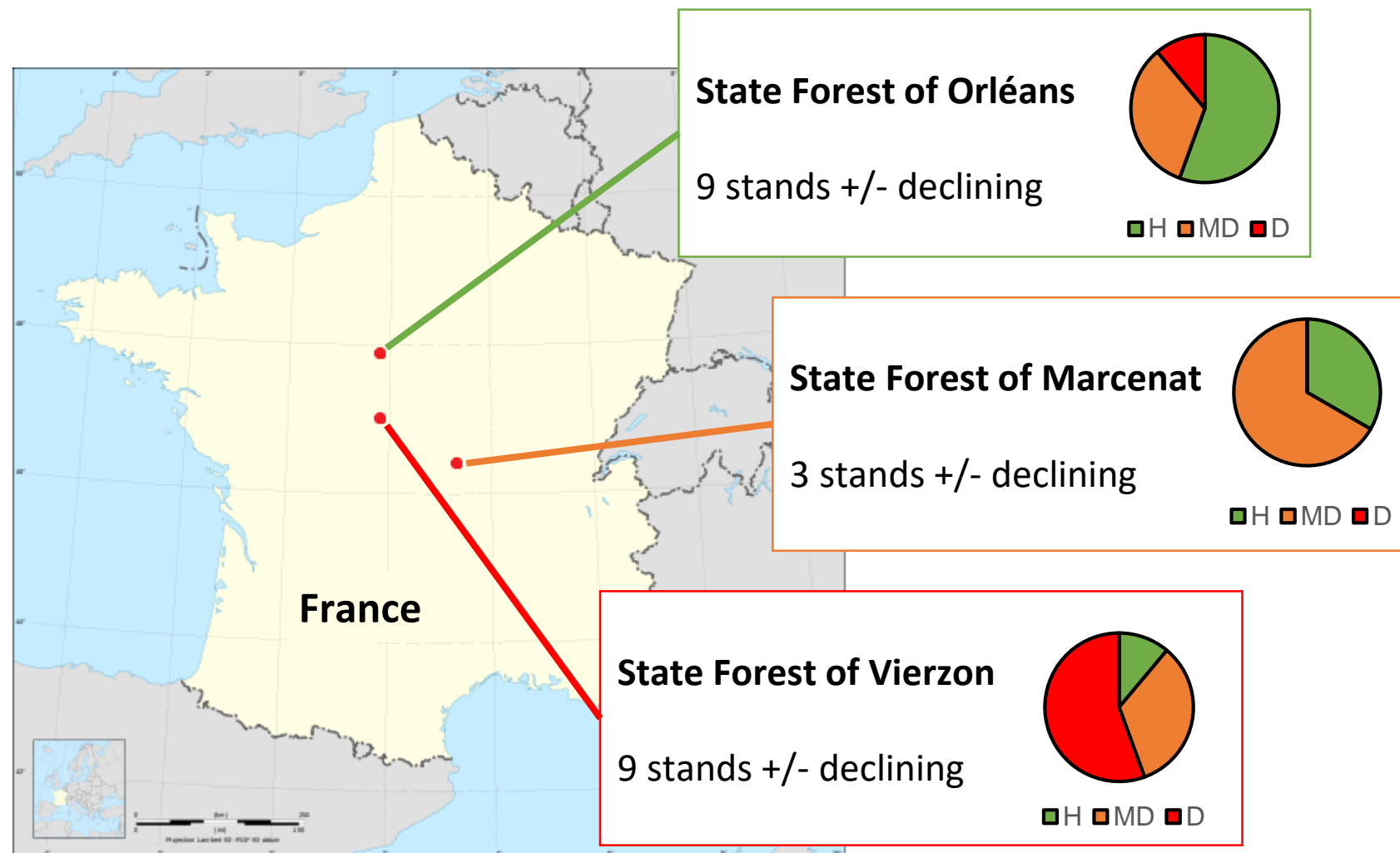
- **Hypotheses:**

- I. The level of decline influences the species composition, due to species turnover
- II. Contrasting effects of forest decline on abundance and species richness of larval trophic guilds



Study areas in 2019: Oak dominated forests.

H: Healthy stand - MD: Moderately declining stand - D: Declining stand



Dieback surveys in 2019 and 2020:

Quantification of crown degradation (DEPERIS protocol) on 10 trees/plot and 30 trees/stand



MB = 0
MR = 0
DEPERIS = 0/A



MB = 1
MR = 2
DEPERIS = 2,6/C



MB = 1
MR = 3
DEPERIS = 3,4/D



MB = 2
MR = 3
DEPERIS = 3,8/E

Sampling: 2 trees/stand, with **one green multi-funnel trap + one flight-interception trap** on each.

→ 1 plot = 1 tree with the two types of traps + 9 trees around the trap tree

Traps hanged in the **oak canopy** (10-15 m).

Sampling performed over the **activity period of insects** (from April to September 2019).

Identification: At the **lowest taxonomic level**.

Analysis: Data were pooled at the plot level



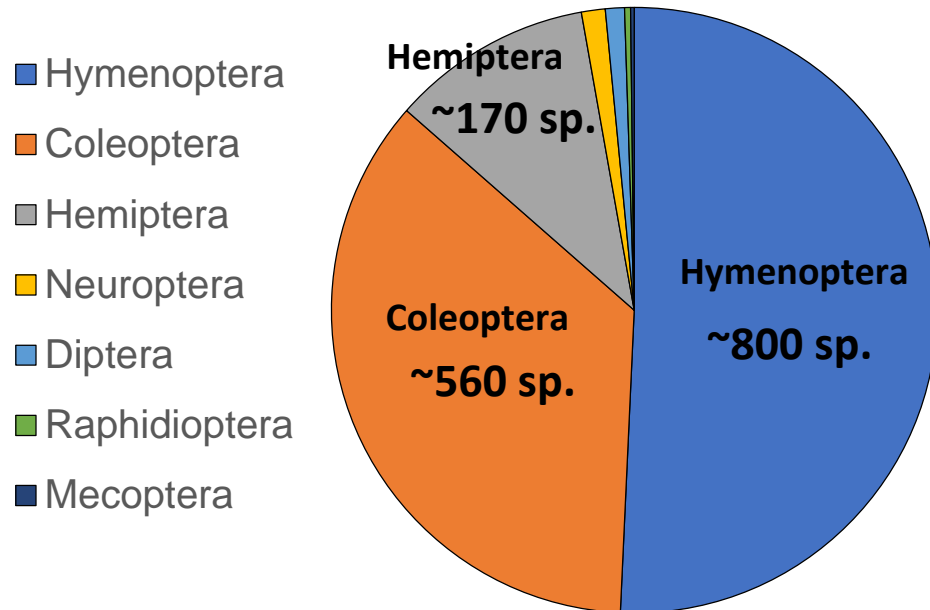
Oak canopy (left) with green multi-funnel trap (middle) & flight-interception trap (right). © E. Le Souchu

Community overview

Approx. **132,000 indiv.** for **1,569 species.**

Divided into **7 orders**, **127 families** and **16 larval trophic guilds.**

Species richness of sampled orders



Larval trophic guilds

Plant-based diet

Gall-inducer
Rhizophagous
Seminiphagous
Phyllophagous
Sap-feeder

Flower-dependent

Anthophagous
Pollinivorous/Nectarivorous

Wood-based diet

Saproxylophagous
Xylophagous

Polyphagous

Social polyphagous
Polyphagous

Prey/host-dependent

Parasitoid
Zoophagous
Zoophyllophagous

Others

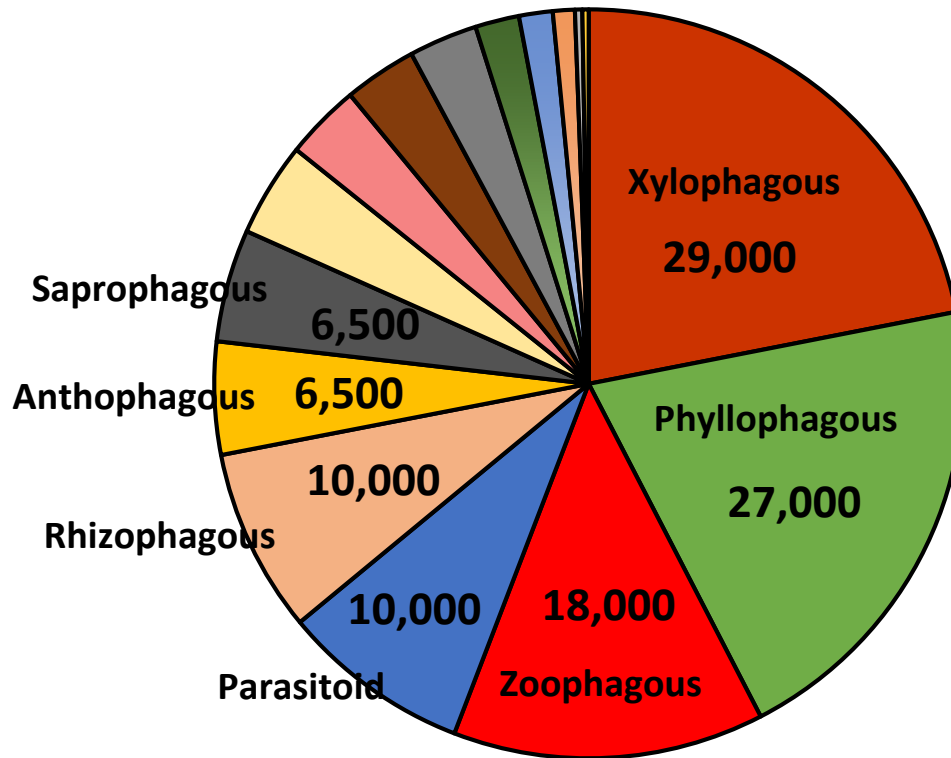
Mycophagous

Saprophagous

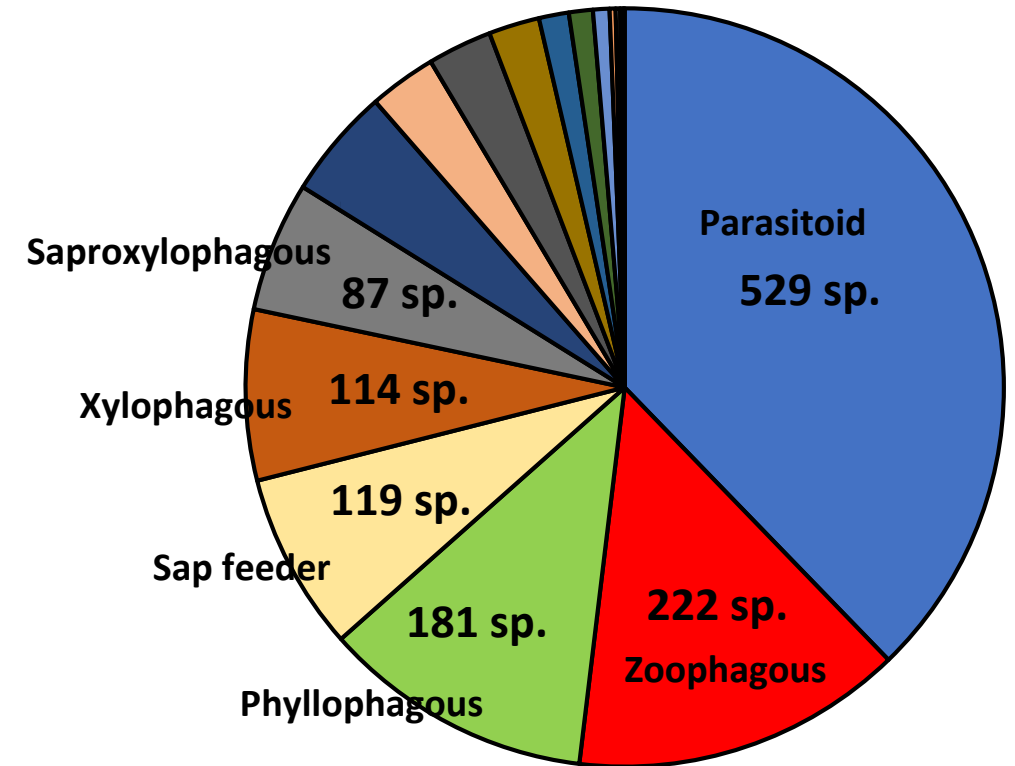
Community overview

**Abundance of larval trophic guilds
(total : 132,000 ind.)**

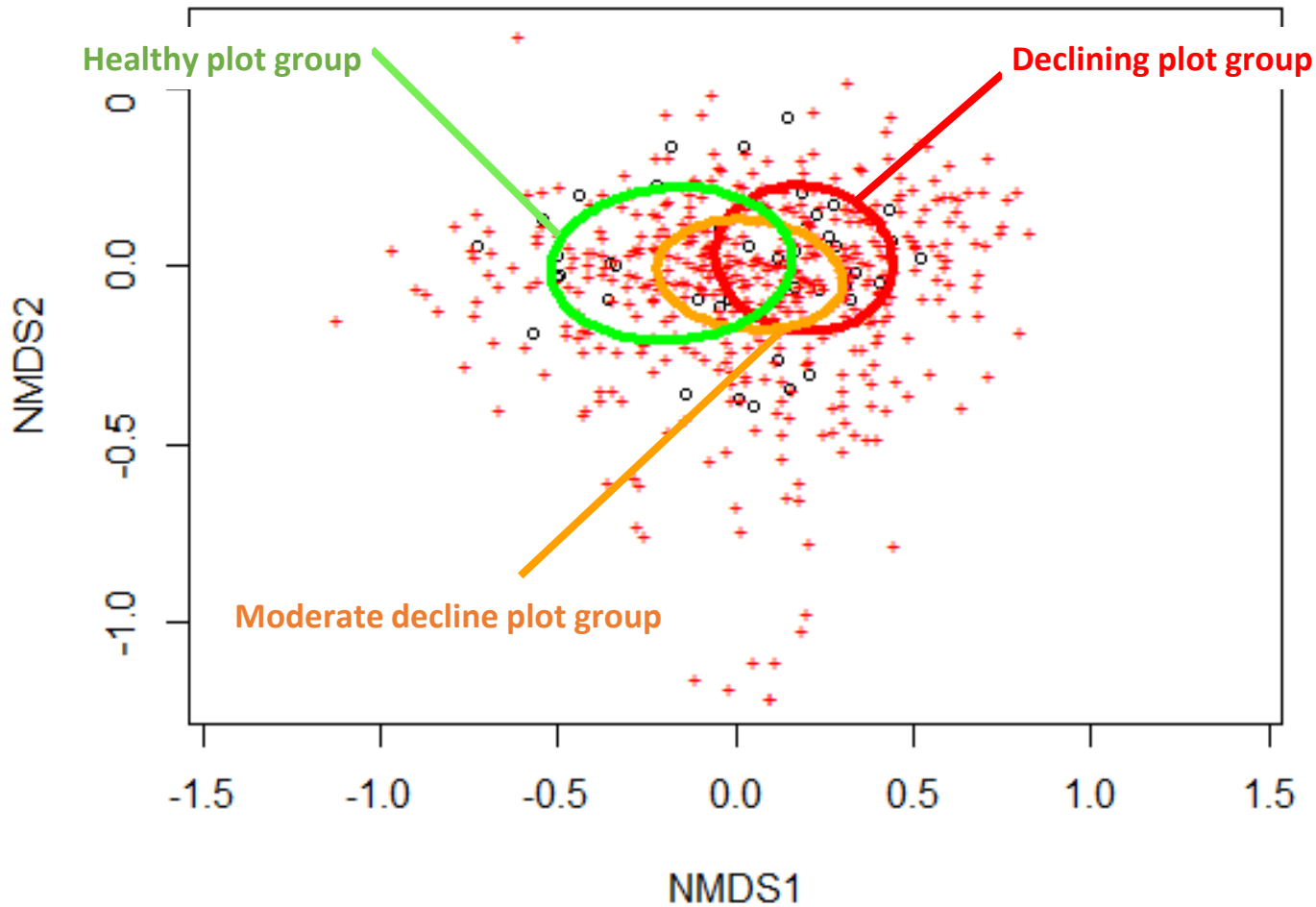
- Xylophagous
- Phyllophagous
- Zoophagous
- Parasitoid
- Rhizophagous
- Anthophagous
- Saprophagous
- Sap feeder
- Zoophyllophagous
- Gall inducer
- Mycophagous
- Saproxylophagous
- Social Polyphagous
- Pollinivorous
- Seminiphagous
- Polyphagous



**Species richness of larval trophic guilds
(total : 1,569 sp.)**



Community richness & composition



The level of plot decline **has an effect on species composition of the community**

PERMANOVA (999 permutations ; $R^2 = 0,13$; $pval = 0.001$ ***)

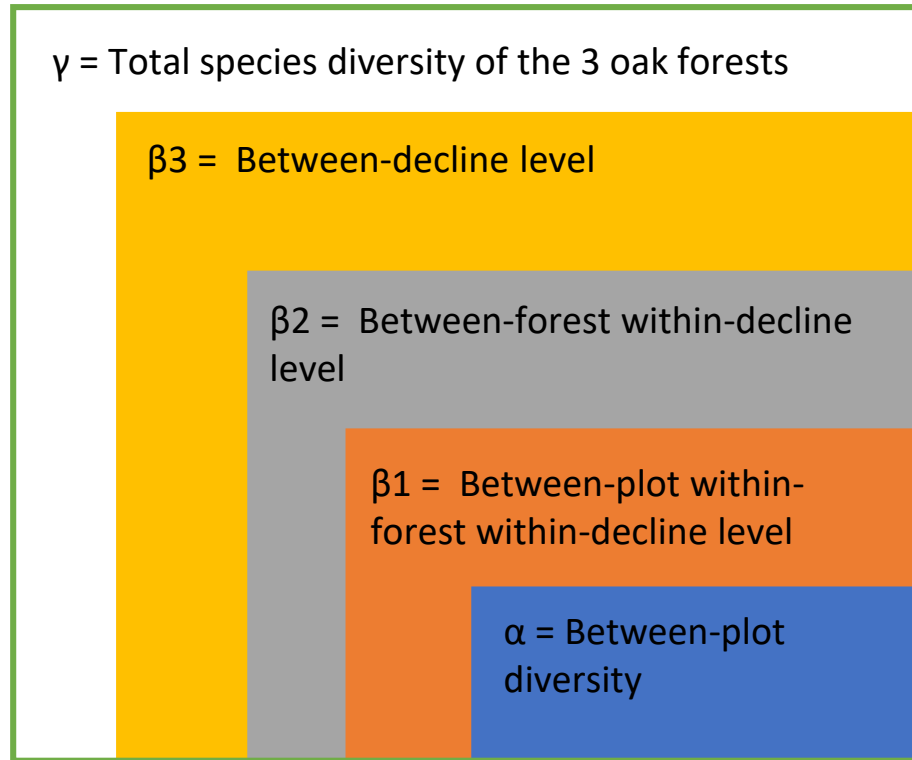
The decline **has no effect on species richness**

GLMER (neg. binom.; best model = null model)

The decline reshapes the community but does not make it neither richer nor poorer.

NMDS ordination (k=3, stress=0.13) of the assemblages of species by site (stand and tree), grouped by levels of plot decline

Community richness & composition

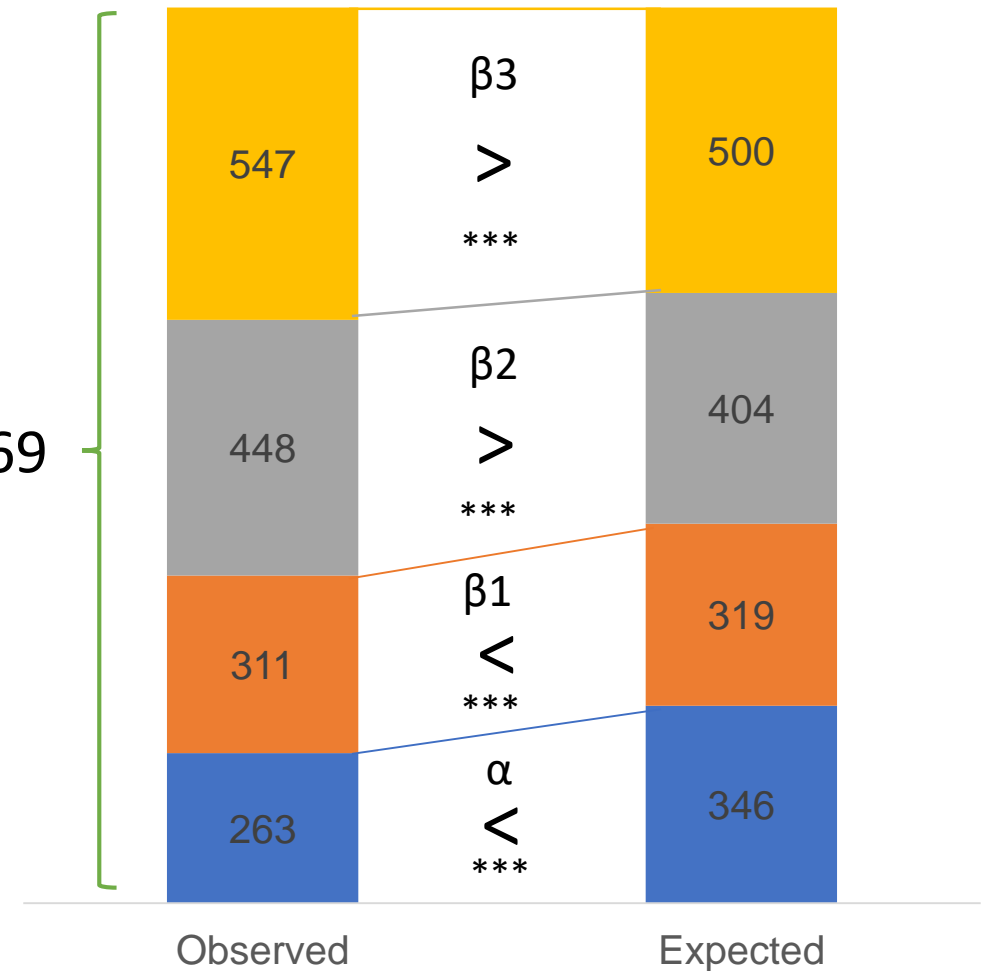


The associations between the spatial scale analysed and each diversity component

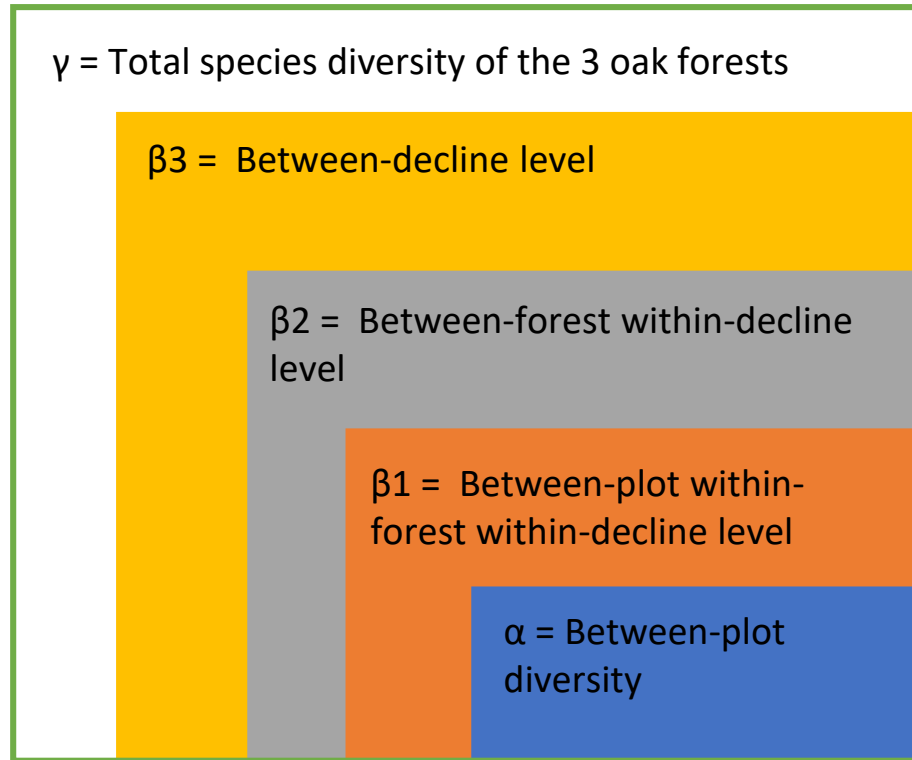
Decline levels: Healthy, Moderate decline and Declining

$\gamma = 1,569$

Additive partitioning of the species diversity components



Community richness & composition

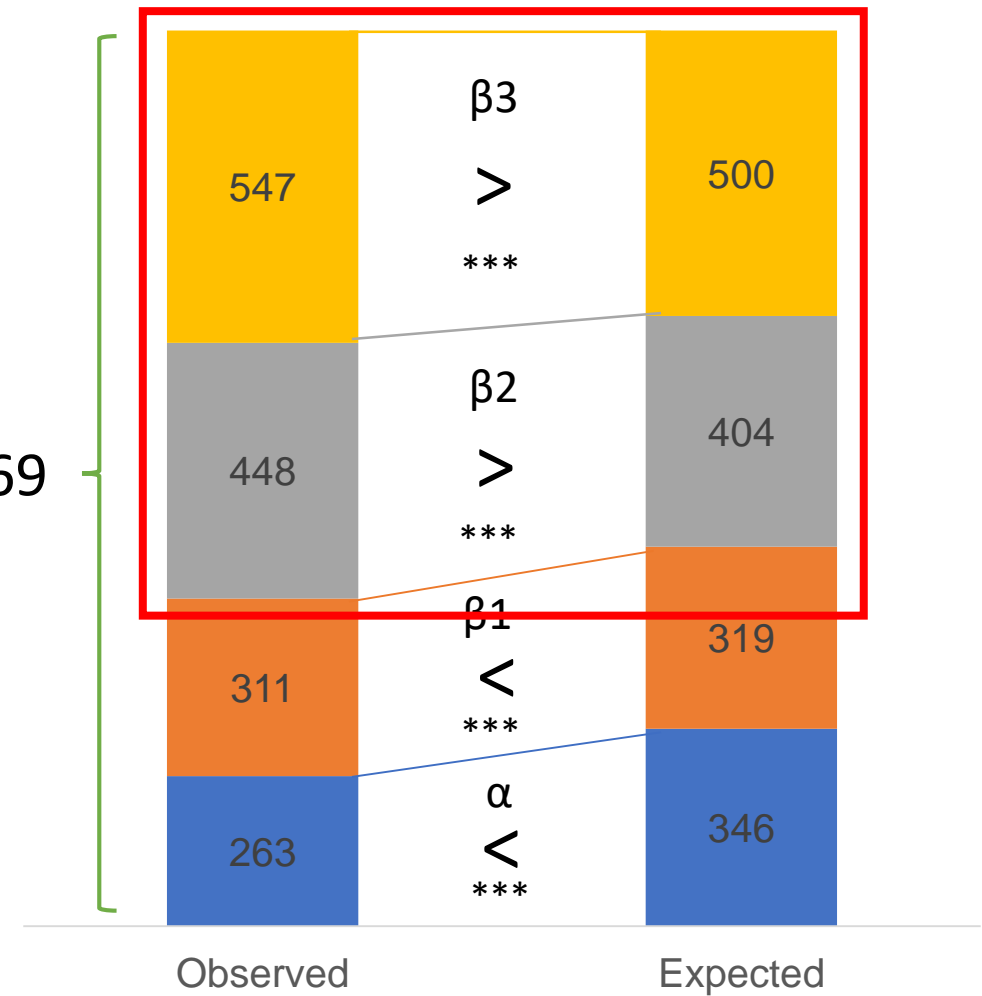


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Additive partitioning of the species diversity components



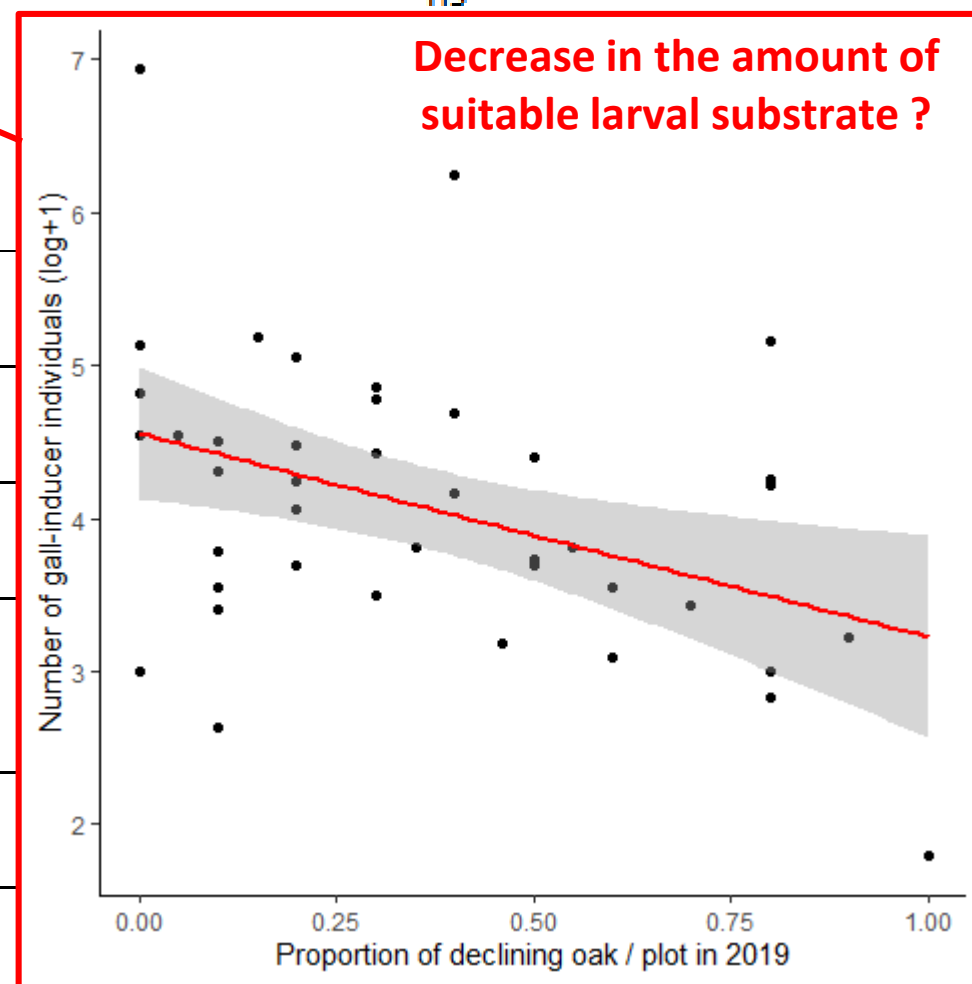
Turnover contributes to change species composition, among levels of plot decline

Larval trophic guilds

	Larval trophic guild	Decline effect on guild abundance	Decline effect on species richness
Plant based diet	Gall-inducer	Negative *	ns
	Rhizophagous	ns	ns
	Seminiphagous	ns	ns
	Phyllophagous	ns	ns
	Sap feeder	ns	ns
Flower dependant	Anthophagous	Positive then negative d1: . ; d2: *	ns
	Pollinivorous	Positive d1: * ; d2: *	ns
Wood based diet	Xylophagous	ns	ns
	Saproxylophagous	ns	ns
Polyphagous	Polyphagous	ns	ns
	Social polyphagous	ns	ns
Prey/host dependent	Parasitoid	ns	ns
	Zoophagous	ns	ns
	Zoophytophagous	ns	ns
Others	Mycophagous	Positive then negative d1: *** ; d2: ***	ns
	Saprophagous	ns	ns
TOTAL		ns	ns

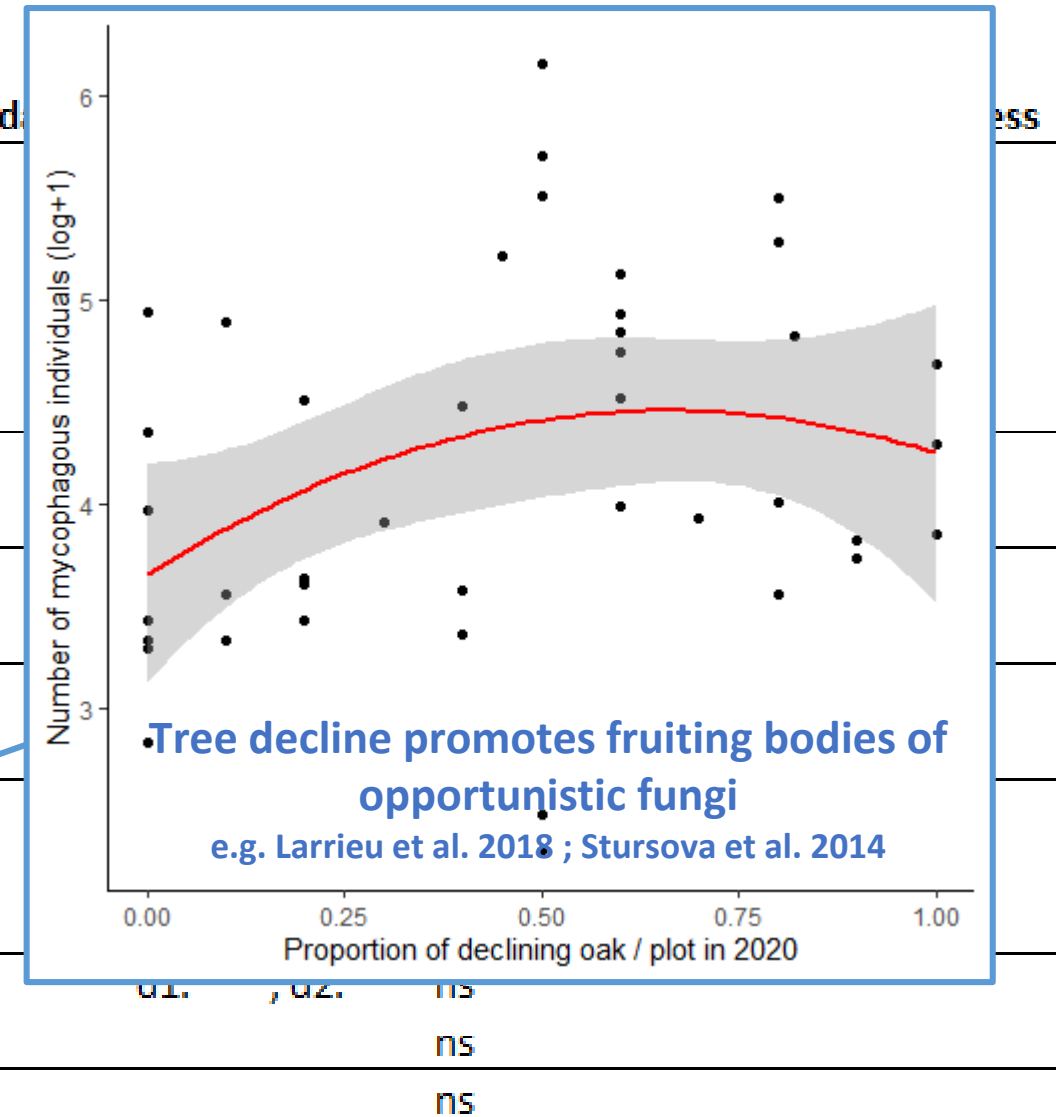
Larval trophic guilds

	Larval trophic guild	Decline effect on guild abundance	Decline effect on species richness
Plant based diet	Gall-inducer	Negative	*
	Rhizophagous	ns	ns
	Seminiphagous	ns	
	Phyllophagous	ns	
	Sap feeder	ns	
Flower dependant	Anthophagous	Positive then negative	
	Pollinivorous	Positive	
Wood based diet	Xylophagous	ns	
	Saproxylophagous	ns	
Polyphagous	Polyphagous	ns	
	Social polyphagous	ns	
Prey/host dependent	Parasitoid	ns	
	Zoophagous	ns	
	Zoophytophagous	ns	
Others	Mycophagous	Positive then negative	
	Saprophagous	ns	
TOTAL		ns	



Larval trophic guilds

	Larval trophic guild	Decline effect on guild abundance
Plant based diet	Gall-inducer	Negative
	Rhizophagous	ns
	Seminiphagous	ns
	Phyllophagous	ns
	Sap feeder	ns
Flower dependant	Anthophagous	Positive then negative
	Pollinivorous	Positive
Wood based diet	Xylophagous	ns
	Saproxylophagous	ns
Polyphagous	Polyphagous	ns
	Social polyphagous	ns
Prey/host dependent	Parasitoid	ns
	Zoopagous	ns
	Zoophytophagous	ns
Others	Mycophagous	Positive then negative
	Saprophagous	ns
TOTAL		ns



Larval trophic guilds

	Larval trophic guild	Decline effect on guild abundance	Decline effect on species richness
Plant based diet	Gall-inducer	Negative *	ns
	Rhizophagous	ns	ns
	Seminiphagous	ns	ns
	Phyllophagous	ns	ns
	Sap feeder	ns	ns
Flower dependant	Anthophagous	Positive then negative	d1: . ; d2: *
	Pollinivorous	Positive	d1: * ; d2: *
Wood based diet	Xylophagous	ns	Contradicts previous results of decline and dieback on saproxylic species e.g. Beudert et al. 2015; Kozak et al. 2021; Cours et al. 2021 Few dendro-microhabitats left in managed forests ?
	Saproxylophagous	ns	
Polyphagous	Polyphagous	ns	
	Social polyphagous	ns	
Prey/host dependent	Parasitoid	ns	
	Zoophagous	ns	ns
	Zoophytophagous	ns	ns
Others	Mycophagous	Positive then negative	d1: *** ; d2: ***
	Saprophagous	ns	ns
TOTAL		ns	ns



Conclusion

Community richness and composition:

- The decline level modifies the community composition but not the species richness.
- Species turnover contributes to community modification.

Larval trophic guilds:

- Few contrasting responses of trophic guild abundance.
- No effect on the species richness by guild.

- Management buffers changes in microhabitats and resources between declining and healthy stands ?
- Integration of both larval AND adult trophic guilds as response variable ?
- Too many species with different ecological traits within each trophic guild ? Use sub-guilds or taxonomic groups instead ?



Philaenus spumarius

© S. Damoiseau

Improvement of conservation strategies:

Decline reshapes the insect community and acts as a driver of diversity.

Promoting a mosaic of healthy and declining patches within a forest would conserve canopy insect diversity.

Thank you for your attention !

Mail : elodie.lesouchu@gmail.com



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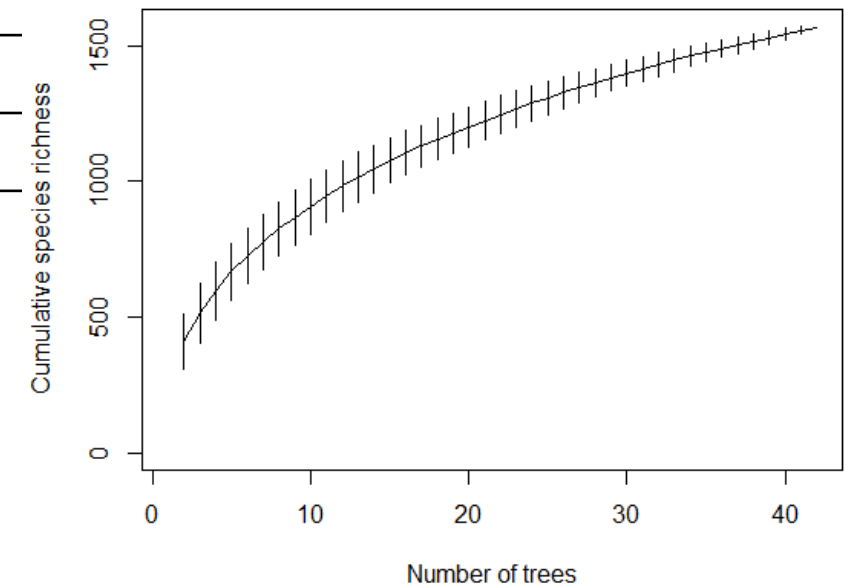
Erwann Marhic, Léa Garreau, Manon Durand, Nathan Jolivard, Lisa Desbrée (students)

Species richness

According to species richness estimators:
between **1,799 and 2,371** sp. expected (67 – 87% of observed sp.)

Completeness of species composition detection estimated using various indices
(Chao, Bootstrap and Jackknife 1 & 2)

Area	Expected					Observed
	Chao	Jackknife 1	Jackknife 2	Bootstrap	Range	
Total	2,150	2,086	2,372	1,799	1,799 – 2,372	1,569 (66 -87%)
Orléans	1,480	1,367	1,593	1,154	1,154 – 1,593	989
Vierzon	1,575	1,456	1,688	1,240	1,240 – 1,688	1,071
Marcenat	1,223	1,170	1,333	1,000	1,000 – 1,333	860



Community composition

	Factors	df	F.Model	R ²	p-value
	Decline	2	3.98	0.13	0.001 ***
Community composition	Forest	2	6.73	0.22	0.001 ***
	Decline*Forest	3	1.83	0.09	0.01 *

Effect of the degree of stand decline and forest on the entire insect community studied.
PERMANOVAS made with 999 permutations. p < 0.05: *; p < 0.01: **; p < 0.001: ***.

Decline effect on the overall composition of species and guild

+ all the guilds except social polyphagous and sap feeder

Forest effect on the overall composition of species and guild

+ all the guilds except social polyphagous and zoophagous