Influence of crop management and landscape diversity on Meligethes aeneus and its biological control

Adrien Rusch, Muriel Valantin-Morison, Jean-Pierre Sarthou, Jean Roger-Estrade

Influence of crop management and landscape context on pollen beetle attacks and its biological control

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Context

- Increased proportions of OilSeed Rape (OSR) in Europe
- Resistance to pesticides
- ↗ insect pest pressure
- Pollen beetle: one of the major OSR pest
- Important yield losses
- A will to reduce agrochemical inputs in France and in EU


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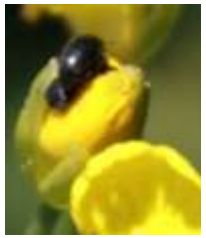
A need to develop alternative pest management strategies

Pollen beetle life cycle

emergence

T >12 C

Long distance dispersal



Alimentation

Winter

Alimentation

Harvest

Spring

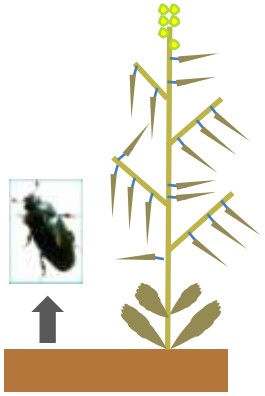
Reproduction

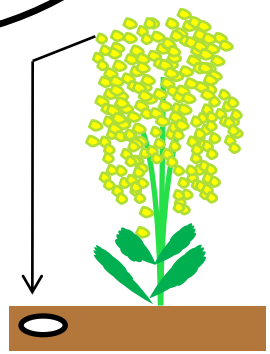
Summer

New generation

Larval development

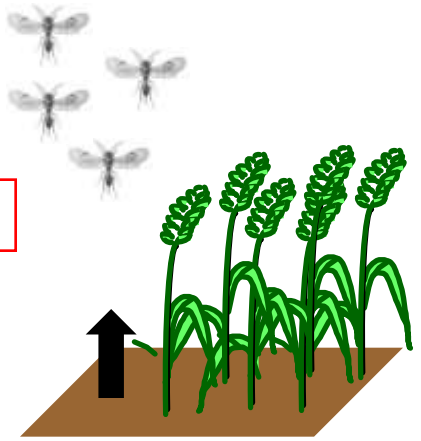
Pupation





Univoltine parasitoids life cycle

Cocoon



Year N +1

Emergence

emergence

T >12 C

Long distance dispersal

Alimentation

Winter

Alimentation

Spring

Hibernation in the soil of the OSR field

Reproduction

Summer

New generation

Larval development

Pupation

Oviposition in PB larvae

Year N

Parasitoid development within the larvae

Crop management and landscape effects

Semi-natural habitats (SNH)

Spatial distribution of SNH

emergence

emergence

T >12 C

Long distance dispersal

Plant species
Cultivar
Sowing date
plant density
Nitrogen

Alimentation

Winter

Alimentation

Soil tillage

Hibernation in the soil of the OSR field

Spring

Reproduction

Summer

New generation

Larval development

Pupation

Oviposition in PB larvae

(*Nilsson and Andreasson, 1987; Cook et al., 2006; Valantin-Morison et al., 2007; Ulber and Klukowski, 2010; Thies & Tscharntke, 2003)*

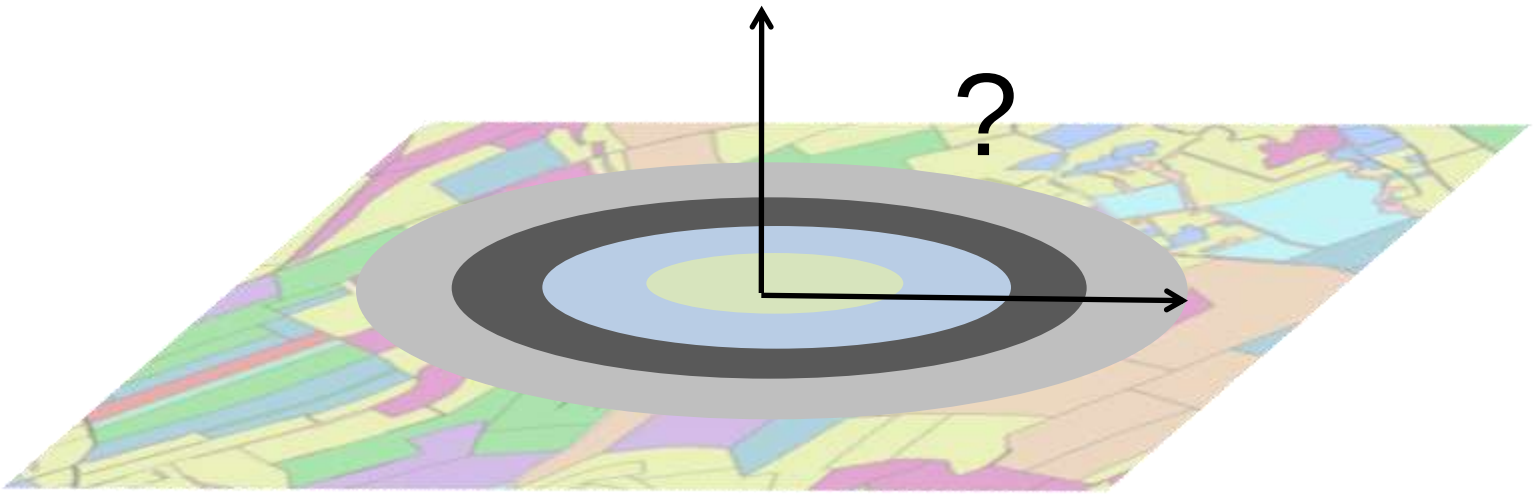
Objectives

• What about the effect of crop management at the local and the landscape scale ?

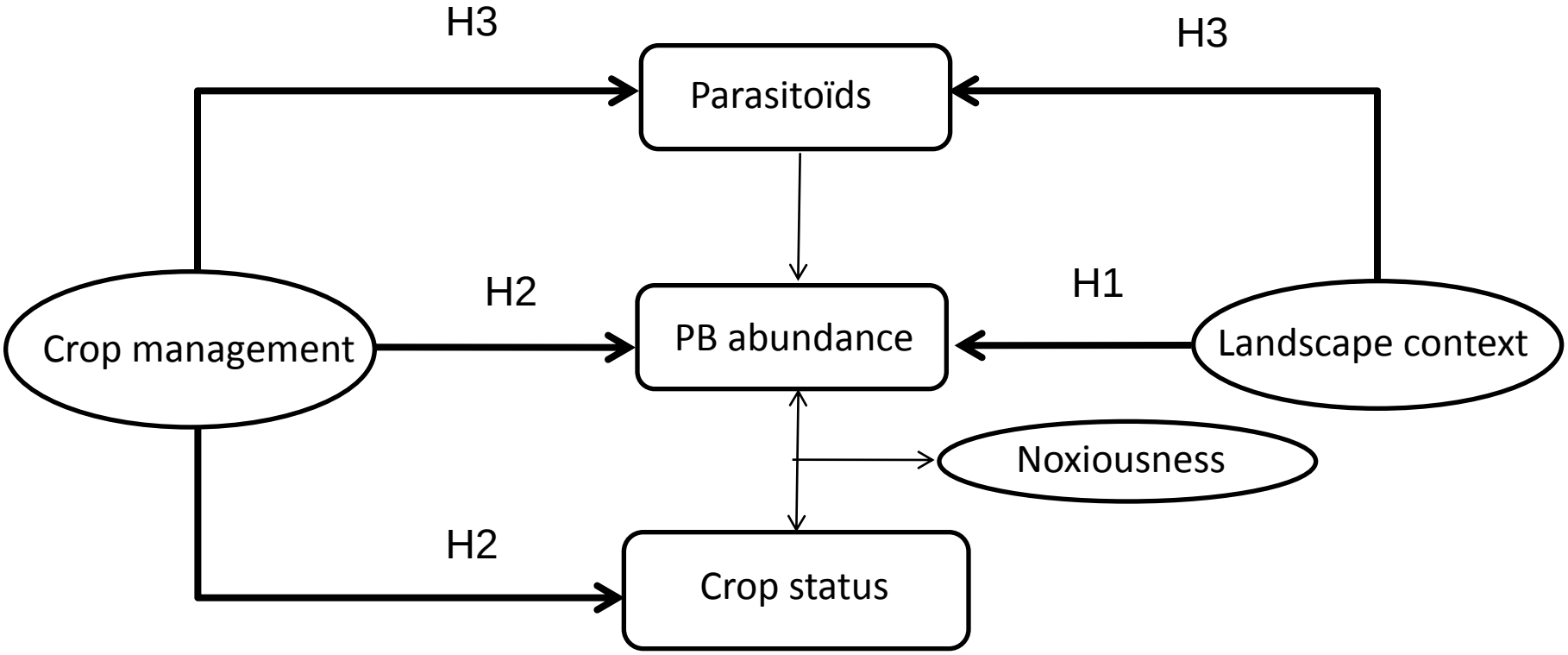
• Identify and rank relevant variables for PB abundance, damage and natural regulation according to their relative importance when considering both:

- Crop management variables at the field scale
- Crop management at the landscape scale
- Landscape complexity

• Identify the more important scale of the given predictors



Hypothesis



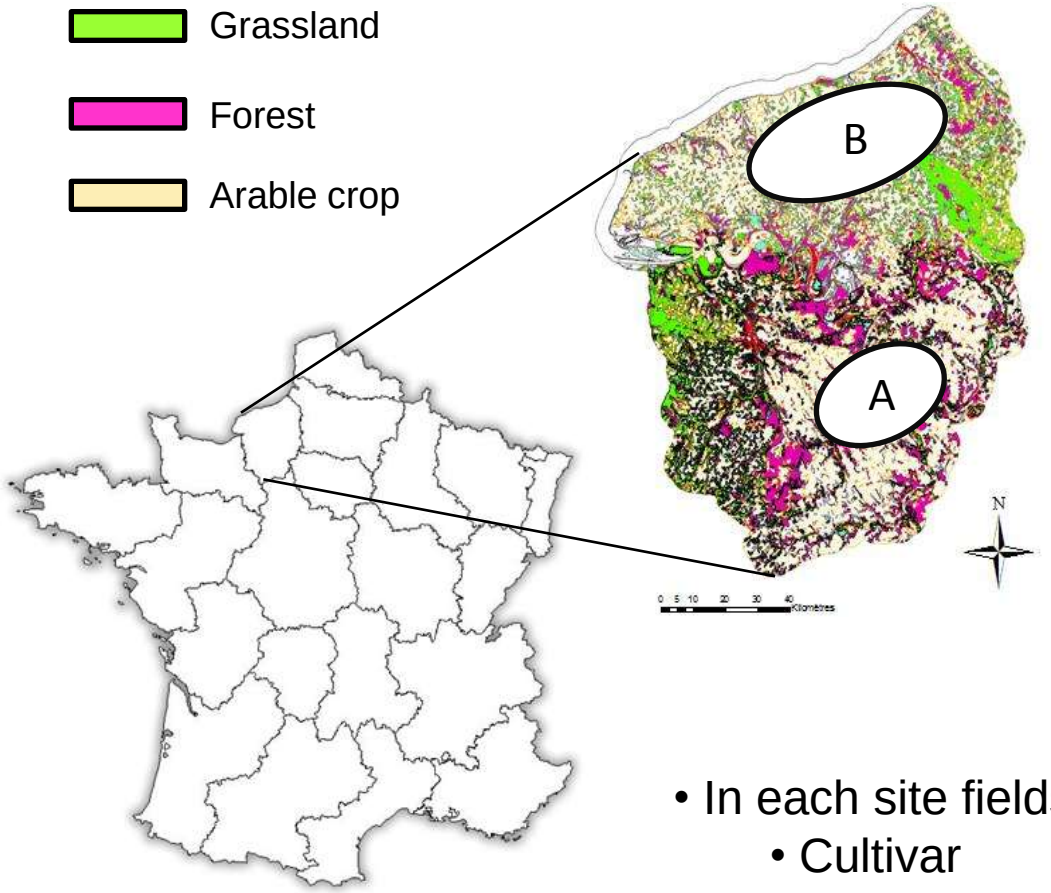
H1: Negative effect of SNH on the PB abundance and parasitism rate considering both crop management and landscape variables

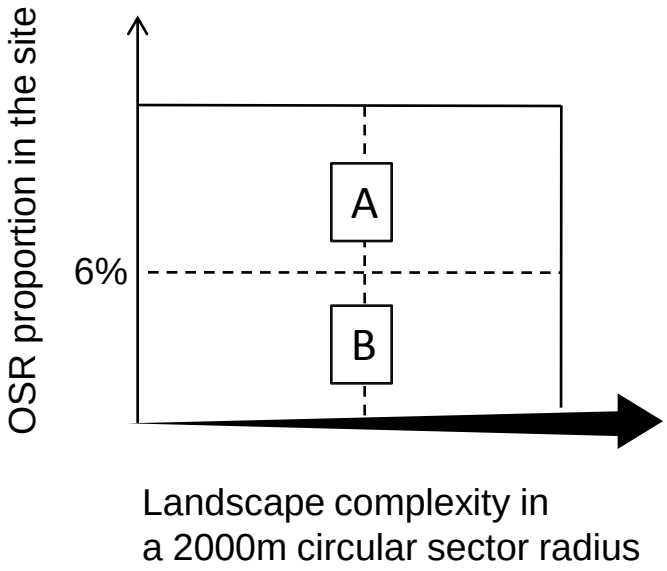
H2: Effect of crop management on the PB abundance and damages

H2': Landscape effects are more important than crop management on PB attacks

Material & Methods

- 42 OSR fields in two sites during two years:





- In each site fields were selected according to:
  - Cultivar
  - Landscape complexity
  - Distance between fields > 4 km

Material & Methods

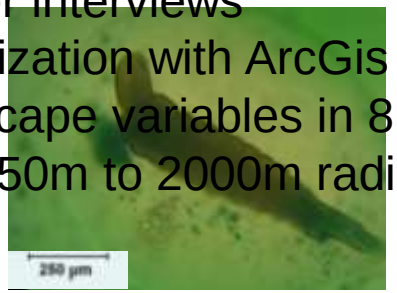
• Pollen beetle: counted weekly on 50 plants between GS 3,1 and GS 4.0.

• Pollen beetle damage: Podless stalks on 60 plants at GS 6,3

• Crop management measures and questionnaires to farmers: Plant density, Nitrogen Nutrition Index, sowing date, Post harvest soil tillage of previous year OSR fields in the 2000m radius circular sector…

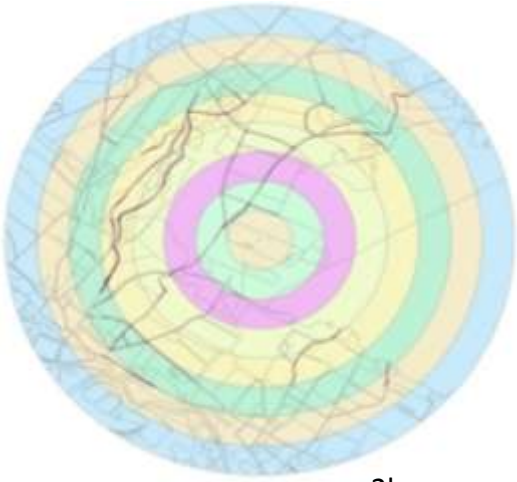
• Parasitism rates: dissecting 150 pollen beetle larvae at L2 stage and identifying parasitoid species based on parasitoid eggs (Osborne, 1960).

• Landscape measures:
  • Field survey / land use cartography
  • Farmer interviews
  • Digitalization with ArcGis
  • Landscape variables in 8 different buffers from 250m to 2000m radius



Phradis spp.

Tersiloc



Material & Methods

Statistical analyses:

- Linear mixed-effect models (year and site as random effects)
- MultiModel Inference approach:
  All possible linear combinations between *K* predictors: 2^K different combinations
- For a given *Y* to explain we performed MMI on 8 different data sets including:

  Local variable + landscape variables computed at one buffer size
- For each data set, models were ranked according to their Akaike weights W_i:

$$w_i = \frac{e^{(-0.5(AIC_i - AIC_{\min}))}}{\sum_{i=1}^{n} e^{(-0.5(AIC_i - AIC_{\min}))}}$$

AICi: model i AIC
AICmin: lower AIC among the 2^K models

- W_i is the probability that model *i* would be selected as the best fitting model if the data were collected under identical circumstances (Whittingham et al. 2007)

Material & Methods

Statistical analyses:

• For each data set (i.e. containing local predictors + landscape variables at a given scale):

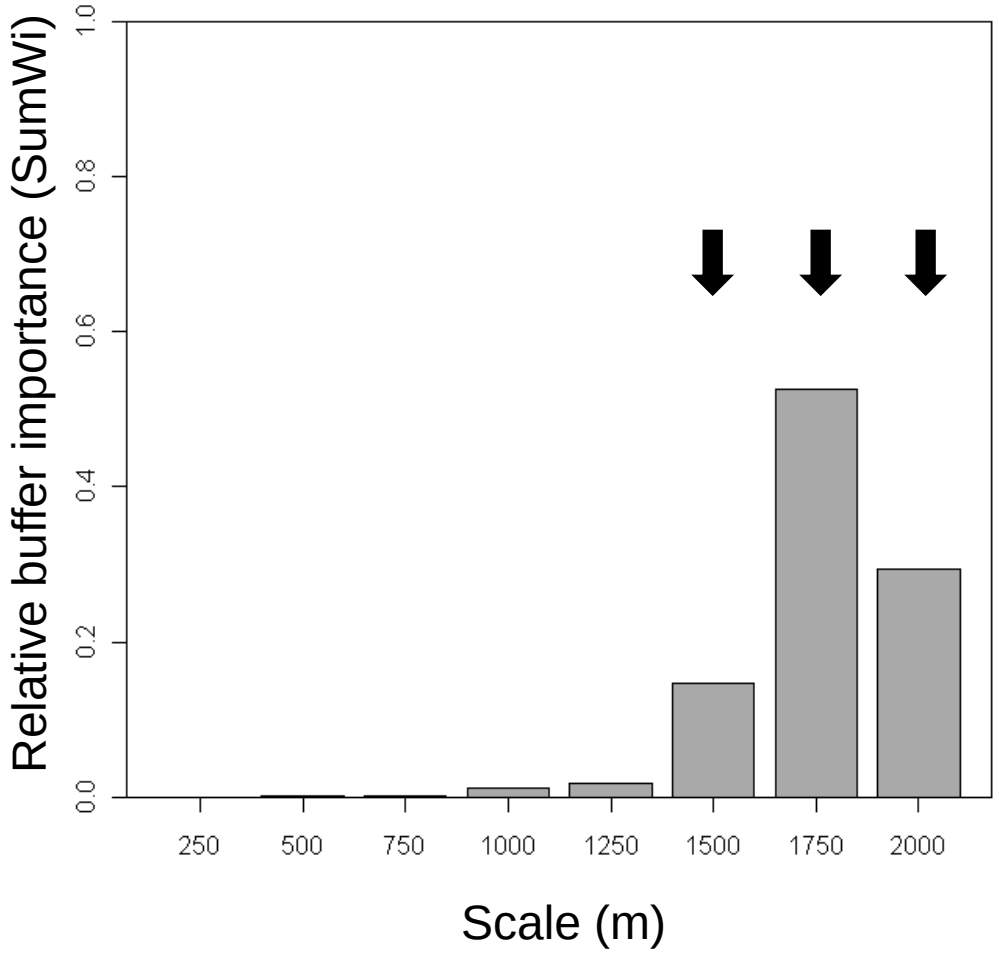
- by summing w_i among models were a given predictor appears, we are able to compute the relative importance value of this predictor

• Considering the 8 datasets together:

- Recalculate the W_i (considering the AICmin among all data sets)
- Summing W_i among models were landscape predictors at a given buffer appear makes it possible to assess the relative importance of that scale.

Results

Pollen beetle abundance: importance of each scale



- Σ Wi for models containing landscape variables computed at scales from 250m to 1250m ≈ 0

- Σ Wi for models containing landscape variables computed at scales from 1500m à 2000m > 0.95

⇒Large scales = more important ones

Results

Pollen beetle abundance: importance of variables at the 1750m scale

scale	1750m	
variable	**Parameter sign**	**Relative variable importance**
Sowing date	-	0.20
NNI	-	0.19
Plant density	+	0.37
Posr	+	0.44
Pforest	+	1.00
Pgrassland	+	1.00

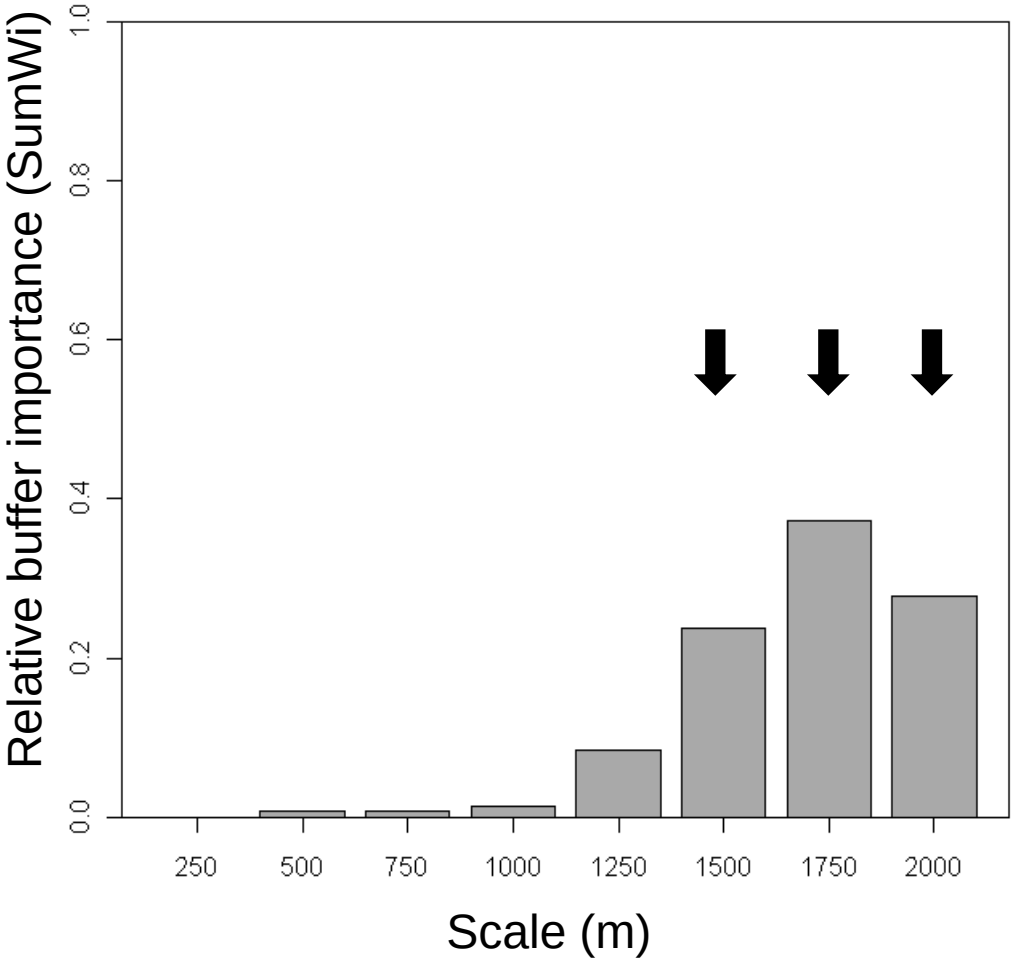
⇒ Importance of semi-natural habitats at large scale

⇒ Positive correlation between proportions of SNH and pollen beetle abundance

⇒ No effect of crop management at the local scale

Main results

Pollen beetle damage: Importance of each scale



- Σ Wi for models containing landscape variables computed at scales from 250m to 1250m ≈ 0

- Σ Wi for models containing landscape variables computed at scales from 1500m à 2000m > 0.95

⇒Large scales = more important ones

Main results

Pollen beetle damage: Importance of variables at each scale

scale	1750m	
variable	**Parameter sign**	**Relative variable importance**
Sowing date	-	0.21
NNI	-	0.64
Plant density	+	0.20
Posr	+	0.22
Pforest	+	1.00
Pgrassland	+	0.33

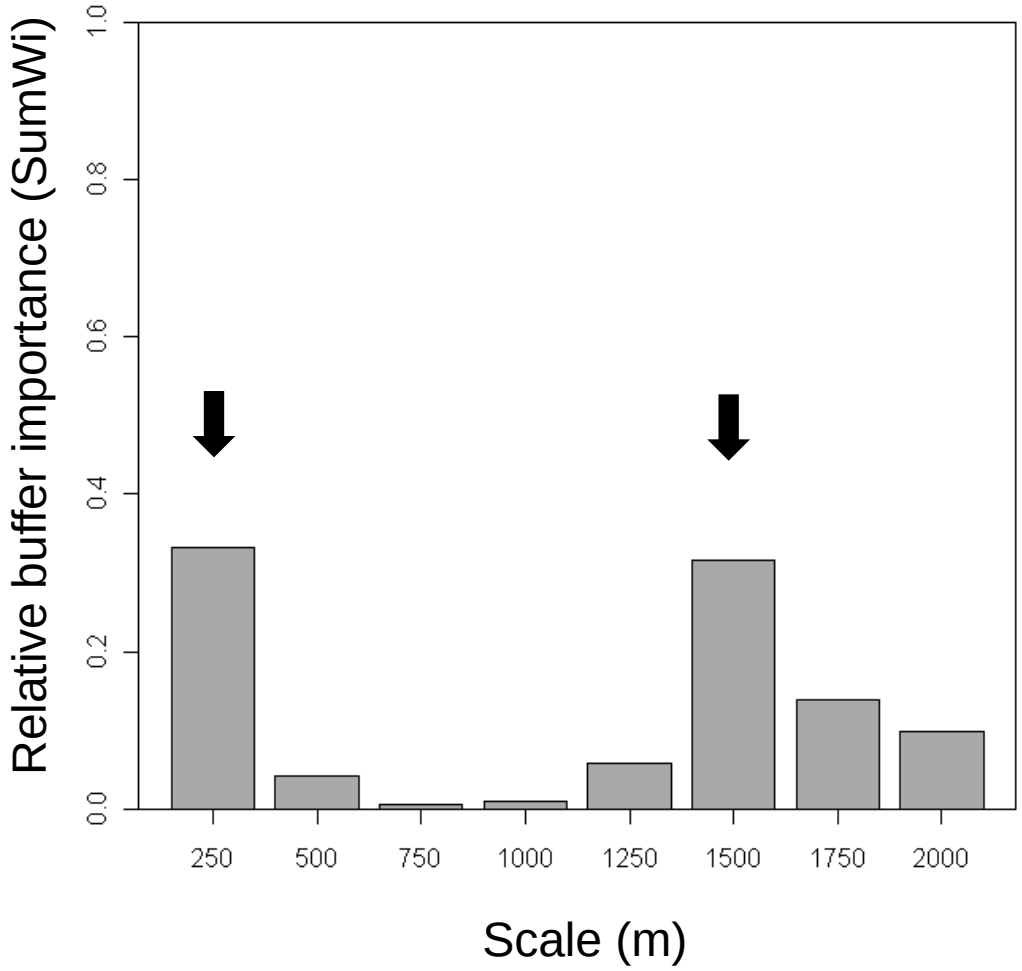
⇒ Importance of the proportion of forest at large scale

⇒ Positive correlation between proportions of forest and pollen beetle abundance

⇒ Negative correlation between NNI and pollen beetle damage

Main results

Parasitism rates: importance of each scale



- Two scales seems to be more important than the others: the 250m and the 1500m radius.

- Landscape variables computed from 500m and 1250m radius are not important

$\Rightarrow$ Both fine and large scale seems to be important.

Main results

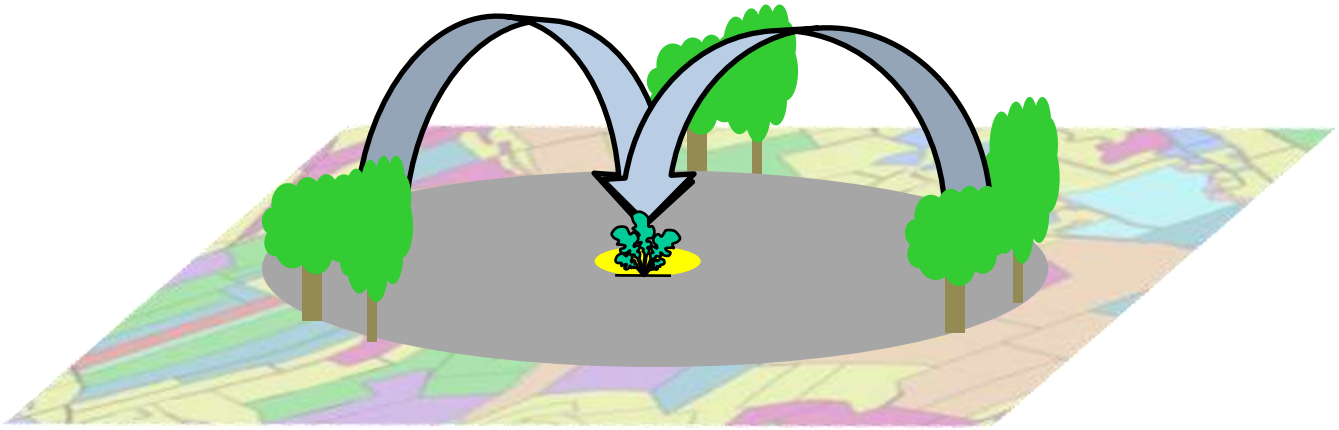
Importance of local and landscape variables for parasitism rates :

scale	250m		…	1500m	
variable	**parameter sign**	**Relative variable importance**	…	**parameter sign**	**Relative variable importance**
Field area	+	0.18		-	0.24
Host abundance	-	0.18		-	0.22
Prop CT OSR(n-1)	+	0.17		-	0.62
Prop forest	+	1.00	…	+	0.73
Prop Grassland	+	0.97		+	1.00
Proximity OSR(n-1)	+	0.74		+	0.38

⇒ Importance of semi-natural habitats at both fine and large scale
⇒ Positive correlation between proportions of SNH and parasitism rates
⇒ Important positive effect of the proximity to OSR(n-1) at fine scale
⇒ Negative effect of the proportion of OSR(n-1) under conventionnal profound tillage

Conclusions

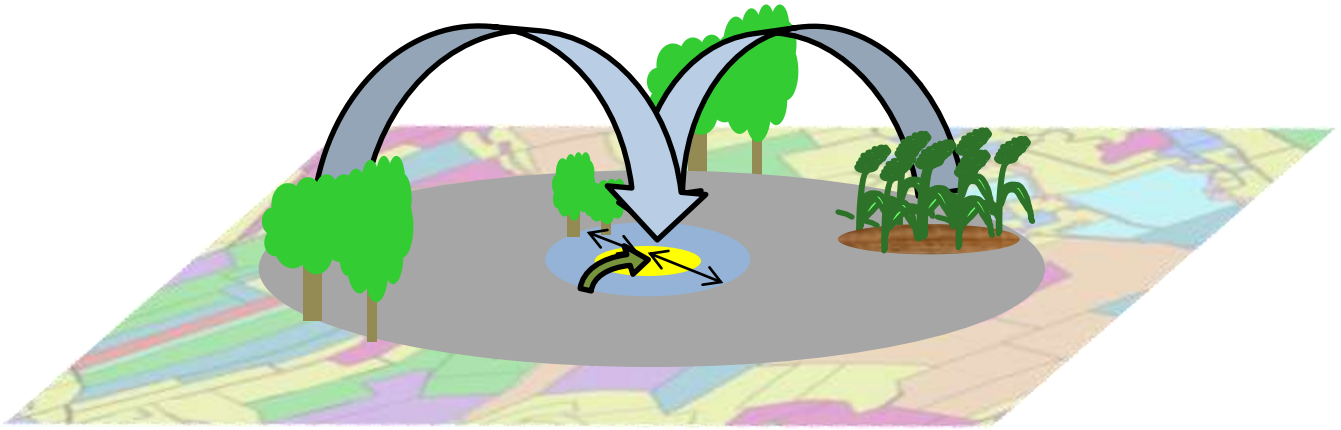
PB abundance and damage are mainly determined by SNH at large scales



- Large scales are more important : 1500m to 2000m:
  - pollen beetle dispersal range
- Positive effect of SNH at large scale
  - SNH are used as overwintering sites (Müller 1941; Rusch et al. *subm.*)
- No effect of crop management at the local scale on PB abundance:
  - Host plant quality does not influence abundance of PB at the field scale
- Negative correlation between NNI and PB damage:
  - Importance of crop nitrogen status to compensate PB damage

Conclusions

Biological control of PB: a multi-scale process



- Positive effect of SNH at fine and large scales
  - Alternative hosts, floral ressources ?
  - Small scale: trade-off between host-foraging and food-foraging
  - Large scale: long distance dispersal

- Positive effect of proximity to OSR(n-1)
  - Reduced mortality of parasitoids with proximity to source patches
  - Long distance flights: energetic reserve exhaustion and predation

- Negative effect of conventional soil tillage on OSR(n-1) at large scale
  - high parasitoid mortality: desiccation, exposure to predation, climatic cond.

Conclusions

- High PB infestation where high parasitism rates :
  - What part of pest population is escaping biological control ?
  - Alternative host-plant for PB ?
  - Dispersal range of PB just before overwintering: migrating toward complex landscapes and filling the PB pool in landscapes where PB have been controlled locally ?

- Positive effects of SNH on parasitoid populations:
  - Floral ressources effects on parasitoid:
    - OSR Vs non-cultivated floral ressources ?
  - Alternative host for parasitoids ? Other *Meligethes* spp. ?
  - Overwintering sites for parasitoids ?
  - What about polyvoltine species ?

Many thanks to:
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Y. Ballanger

Thank you !

M. Gosme

Main results

PB abundance

H1

⇒ Confirm positive effect of SNH at large scale

SNH = Overwintering sites, particularly forest (Muller, 1941; Rusch et al. unpubl.)

H2

⇒ No effect of crop management at the local scale

PB damage

H1

⇒ Positive effect of forest at large scale

H2 & H2'

⇒ Negative correlation between NNI and PB injuries

⇒ SNH effects more important than NNI effects

NNI = ability of the crop to compensate for PB damage

Parasitism rates

H3

⇒ Negative effect of conventional soil tillage on OSR(n-1) at large scale

high parasitoid mortality: desiccation, exposure to predation…(Nilsson et al. 1987)

H3'

⇒ Positive effects of SNH at fine and large scales

⇒ More important than soil tillage effects

Small scale = trade-off between host and food foraging ?
Large scale = long distance dispersal ?