Does landscape influence weed diversity and distribution through modification of weed fitness?

A. Alignier, S. Petit & D. Bohan
INRA Dijon, UMR 1347 Agroécologie, France
Current address: INRA Toulouse, UMR 1201 Dynafor
audrey.alignier@toulouse.inra.fr
Can we maintain farmland biodiversity?

Weeds, invertebrates and seed-eating birds

Yield

1945 2005

Fuller et al. 1995
Sotherton 1998

Chamberlain et al. 2000
Donald et al. 2001

Butler et al. 2007
Kleijn et al. 2011
Weeds in farmland

Weeds play a dual role in agricultural fields

- Depressing crop yield
- Supporting biodiversity through food webs

We need to optimize these two roles: the yield and biodiversity we want!

Pollinators

Seed eaters

Weeds are usually managed at the field level.
Landscape-scale management practices are gaining increasing traction in national and international policies.

Greater landscape heterogeneity, greater biodiversity
Consequences of landscape changes

- **Community level**
  - Assembly rules
    - (richness, diversity)

- **Population level**
  - Species performance
    - (how a species utilizes resources to maintain and increase population size)

- **Individual level**
  - Fitness
    - (ability to survive and reproduce)

Most of the ‘fitness’ literature deals with forest and grassland habitats.
Our hypotheses

Landscape changes

Increase of landscape heterogeneity

Resources, Refugia

Community level
Assembly rules (richness, diversity)

Population level
Species performance (how a species utilizes resources to maintain and increase population size)

or =

Individual level
Fitness (ability for an organism to survive and reproduce)
Our hypotheses

- **Population level**
  - Species performance
    - (how a species utilizes resources to maintain and increase population size)

- **Individual level**
  - Fitness
    - (ability for an organism to survive and reproduce)

- **Community level**
  - Assembly rules
    - (richness, diversity)

- **Landscape changes**
  - Increase of landscape heterogeneity
    - Resources
      - Refugia

- **Extinction debt**
A nationwide study

The Farm Scale Evaluation (FSE) database:

- Beet (n = 56)
- Maize (n = 59)
- Spring Rape (n = 67)
- Winter Rape (n = 65)

257 fields, 4 crops, 2 treatments (GM and conventional)
Surveys between 2000 and 2004
Plant sampling

12 transects per field
Sampling point at several distances
Sampling according to the life cycle
Plant performance variates (n=3) consisted of population metrics, measured for each species in field: Biomass, Count, Seedrain.
Plant fitness variates (n=3) consisted of *per capita* metrics, calculated as mean across a population in a field: *Biomass/Count, Seedrain/Count, Seedbank change*
Landscape variables

Landscape heterogeneity measured as Shannon habitat diversity (H’), at two scales:

- Neighbourhood scale: 
  scale relevant to management by individual farmers 
  local landscape features surrounding each field

- Landscape scale: 
  scale relevant to management by multiple farmers 
  landscape features in 2km diameter buffers centered on each field (LCM2000)

Land Cover Map 2000
Level 2: 26 classes
Statistical analyses

216 species recorded – selection of 83 species present in at least 3 fields

83 plants x 2 scales x 3 variates (performance or fitness)
= 498 GLMMs

At the population level (performance):
Performance variate $\sim H' + \text{crop} + H' : \text{crop}$

At individual level (fitness):
Performance variate $\sim \text{count} + H' + \text{crop} + H' : \text{crop}$
Seedbank $t+1 \sim \text{seedbank}_t + H' + \text{crop} + H' : \text{crop}$
Results

**PERFORMANCE**

Population level

43.5% of analyses provided significant GLMMs coefficients for habitat diversity ($H'$)

**FITNESS**

Individual level

39.5% of analyses provided significant GLMMs coefficients for $H'$

Biomass

Neighbour. Landscape

Count

Seedrain

Biomass $\sim$ Count

Neighbour. Landscape

Seedbank $t_1$ $\sim$ SB$_t$

Seedrain $\sim$ Count
Results

**PERFORMANCE population level**

43.5% of analyses provided significant GLMMs coefficients for habitat diversity ($H'$)

**FITNESS individual level**

39.5% of analyses provided significant GLMMs coefficients for $H'$

**Box plots**

- Biomass
- Count
- Seedrain
- Biomass $\sim$ Count
- Seedbank $t+1$ $\sim$ SB$_t$
- Seedrain $\sim$ Count
Results

For **14 distinct species** we found evidence for **extinction debt**; with a positive/neutral effect of $H'$ on performance variates and a negative effect of $H'$ on fitness variates.

<table>
<thead>
<tr>
<th></th>
<th>fitness $H'&lt;0$</th>
<th>fitness $H'=0$</th>
<th>fitness $H'&gt;0$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>neigh. landscape</td>
<td>neigh. landscape</td>
<td>neigh. landscape</td>
</tr>
<tr>
<td><strong>Biomass</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>perf.$H'&lt;0$</td>
<td>16 21</td>
<td>3 6</td>
<td>0 3</td>
</tr>
<tr>
<td>perf.$H'=0$</td>
<td>1 3</td>
<td>27 27</td>
<td>4 1</td>
</tr>
<tr>
<td>perf.$H'&gt;0$</td>
<td>4 5</td>
<td>2 1</td>
<td>21 13</td>
</tr>
<tr>
<td><strong>Seedrain</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>perf.$H'&lt;0$</td>
<td>12 12</td>
<td>3 0</td>
<td>2 1</td>
</tr>
<tr>
<td>perf.$H'=0$</td>
<td>0 1</td>
<td>49 49</td>
<td>3 1</td>
</tr>
<tr>
<td>perf.$H'&gt;0$</td>
<td>1 4</td>
<td>1 2</td>
<td>12 12</td>
</tr>
</tbody>
</table>

Patterns appeared not to be linked to dispersal type or seedbank longevity or rarity.
To conclude

- Strong support for the hypothesis that landscape diversity and, by implication, landscape management affects the fitness of a significant number of common plants in farmland at national scale.

... variates we used were proxies but high replication!
To conclude

• **Strong support** for the hypothesis that **landscape diversity** and, by implication, **landscape management** affects the **fitness** of a significant number of common plants in farmland at national scale.

  ... *variates we used were proxies but high replication!*

• Habitat diversity surrounding farm fields tends to support plant fitness whereas effect of habitat diversity at the landscape scale tends to be negative.

  ... *patterns not yet explained. A combination of mechanisms?*
To conclude

- **Strong support** for the hypothesis that **landscape diversity** and, by implication, **landscape management** affects the **fitness** of a significant number of common plants in farmland at national scale.

  ... *variates we used were proxies but high replication!* 

- Habitat diversity surrounding farm fields tends to support plant fitness whereas effect of habitat diversity at the landscape scale tends to be negative.

  ... *patterns not yet explained. A combination of mechanisms?*

- 14 plant species showed evidence for **extinction debt** with habitat diversity.

Large scale management of the farmland landscape might need to be carefully considered to avoid impact on plant fitness and extinction debt.
Thanks for attention

Contact: audrey.alignier@toulouse.inra.fr
Data sampling
Sampling design

![Diagram of sampling design]

- Transects into crop
- Seedbank and seed trap samples
- Field edge
- Crop
- Buffer between GMHT and conventional crop
PCA on $H'$ coefficients of GLMMs
PCA on H’ coefficients of GLMMs

Species were classed according to their dispersal type.
PCA on $H'$ coefficients of GLMMs

Species were classed according to their seedbank longevity (Grime, 2001)