Spatial heterogeneity in landscape structure influences dispersal and genetic structure: empirical evidence from a grasshopper in an agricultural landscape



Bertrand Gauffre, Sophie Mallez, Marie-Pierre Chapuis, Raphael Leblois, Isabelle Litrico, Sabrina Delaunay, Isabelle Badenhausser

Landscape connectivity

- The degree to which the landscape facilitates or impedes movement (Taylor et al. 1993)
  - **Structural connectivity**: the spatial structure of a landscape
  - **Functional connectivity**: the response of individuals to landscape features

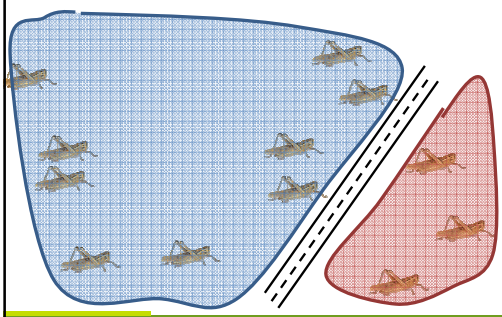
→ Important to assess for conservation and management of biodiversity in fragmented landscapes

Landscape genetics

A framework to study connectivity (Manel et al. 2003)

Landscape structure and environmental features → Genetic diversity, differentiation and contemporary gene flow

- Individual-based sampling / analyses



- Discriminate between the effect of:
  - Geographic distance

    Isolation-by-distance (Rousset 2000)
  - Landscape boundaries

    Isolation-by-barrier

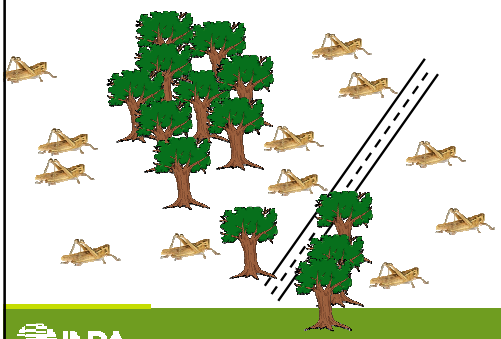
    Clustering methods (Geneland/Structure/DAPC)

Landscape genetics

A framework to study connectivity (Manel et al. 2003)

Landscape structure and environmental features → Genetic diversity, differentiation and contemporary gene flow

- Individual-based sampling / analyses



- Discriminate between the effect of:
  - Geographic distance

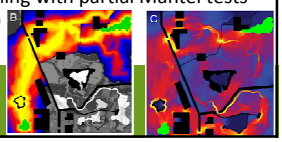
    Isolation-by-distance (Rousset 2000)
  - Landscape boundaries

    Isolation-by-barrier

    Clustering methods (Geneland/Structure/DAPC)
  - Landscape resistance

    Isolation-by-resistance (Mc Rae 2006)

    e.g. Causal modelling with partial Mantel tests (Cushman 2006)



INRA SCIENCE & IMPACT BES-SFE Meeting – Lille 2014

Landscape genetics

A framework to study connectivity (Manel et al. 2003)

Landscape structure and environmental features → Genetic diversity, differentiation and contemporary gene flow

Computer simulations (Epperson et al. 2010)

IBDsim (Leblois et al. 2009)

CDpop (Landguth et al. 2010)

- Compare statistical methods and investigate ability / power to detect landscape genetics relationships: sample size/ markers… (Landguth et al. 2012)
- Applications to real systems
  - Determine contemporary vs historical isolating events (+ lag time)
  - Understanding causal relationships between landscape resistance and dispersal (Landguth et al. 2010)

e between the effect of:

ic distance

listance (Rousset 2000)

e boundaries

rrier

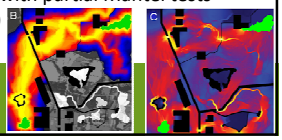
thods (Geneland/Structure/DAPC)

e resistance

esistance (Mc Rae 2006)

ng with partial Mantel tests

006)



Context of the study

Pezotettix giornae

- Small-sized unwinged grasshopper (reduced dispersal capacities).
- A single generation each year
- subservient to grassland habitats for reproduction (Hill & al., 1995).

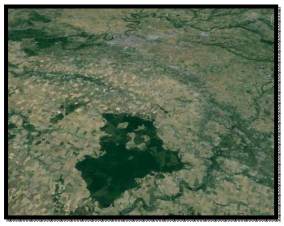
- How landscape heterogeneity affects *P. giornae* gene flow?
- How this species subsist in farmlands in the context of agricultural intensification?

- Loss of grassland habitats and their **connectivity** (Benton 2003)
- Intensification of agricultural practices (eg, artificial/temporary grasslands)

Aim of the study

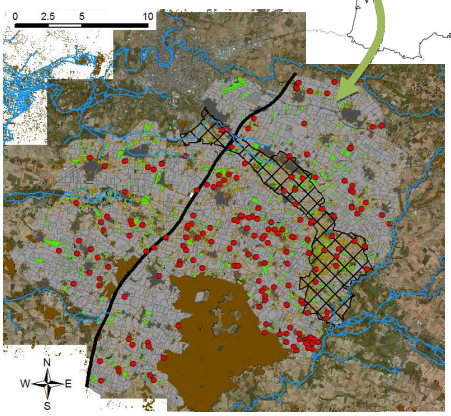
1) Assess the influence of landscape structure and grasslands characteristics on *P. giornae* dispersal and gene flow

2) Assess the scale of spatial and genetic structure of *P. giornae* to gain insight on its dispersal patterns in farmlands



Material

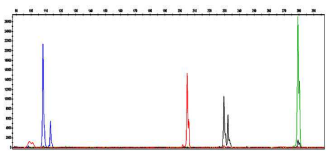
Zone atelier « *Plaine et Val de Sèvre* » (LTER)



Genetic sampling

- Individual based sampling:
  -> 377 individuals from 190 grasslands

- 11 microsatellites loci



Results
Microsatellites characteristics

Locus	A	He	Ho	F_{IS} (sign)
Pezo_3	3	0.152	0.085	0.439 ***
Pezo_8	2	0.417	0.592	-0.419 ***
Pezo_9	3	0.241	0.111	0.538 ***
Pezo_13	2	0.473	0.366	0.227 ***
Pezo_19	2	0.223	0.207	0.07 ns
Pezo_24	3	0.264	0.043	0.839 ***
Pezo_27	2	0.307	0.271	0.116 **
Pezo_29	6	0.304	0.311	-0.024 ns
Pezo_31	3	0.482	0.264	0.453 ***
Pezo_32	3	0.494	0.501	-0.016 ns
Pezo_37	2	0.497	0.449	0.096 *

Low levels of genetic diversity
(from 2 to 6 alleles per locus)

Overall heterozygosity deficit
(Fis = 0.169)

➡ Presence of null alleles (Dakin & Avise 2004 ; Chapuis *et al.* 2005)
✔ At 6 loci

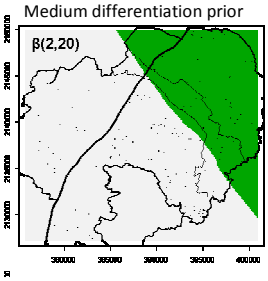
➡ Spatial genetic structure

Results
Spatial genetic structure

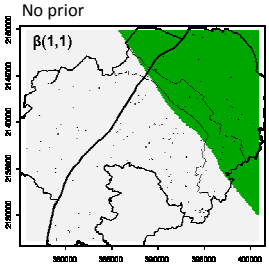
Bayesian genetic clustering (Geneland, Guillot *et al.* 2005)

- Correlated allele frequencies model + presence of null alleles

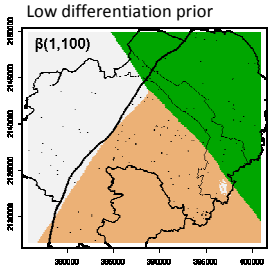
Medium differentiation prior



No prior



Low differentiation prior



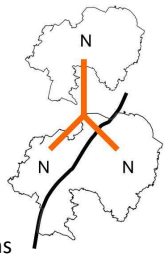
► 2 genetic clusters separated by the **linear hedged farmland**
► > 90% individuals unambiguously assigned to their cluster

► A third cluster not strongly supported
► No individuals unambiguously assigned to the 2 Western clusters

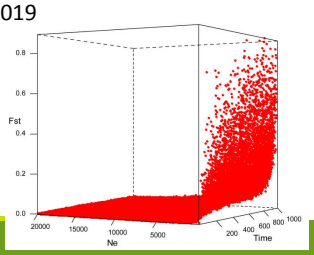
Results

Spatial genetic structure

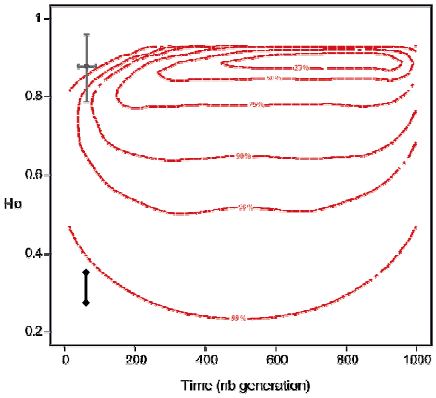
(Gauffre et al. 2008)



- 40 – 90 generations
- Ho = 0.88
- Fst = 0.0019



Combination Ho/Nb Generation for which Fst > 1%

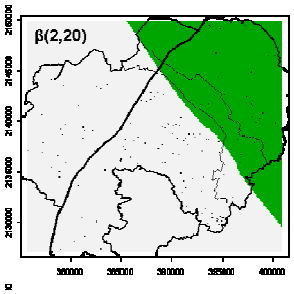


- 30 generations
- Ho = 0.3
- Fst = 0.007**

Results

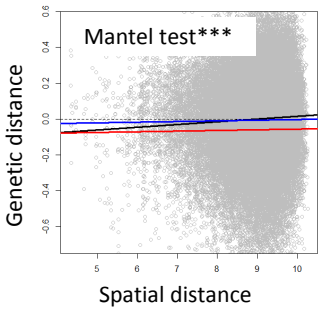
Spatial genetic structure

Bayesian genetic clustering (Geneland, Guillot *et al.* 2005)



► Fst = 4.5 %
► Individuals from the linear hedged farmland mainly assigned to the Eastern cluster (70 %)

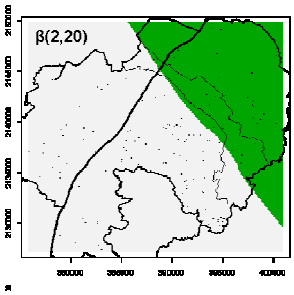
Isolation-by-distance (IBD)



► Genetic differentiation increases with distance
► IBD can generate erroneous inference of genetic clusters (Guillot & Santos 2008)

Results

Landscape characteristics

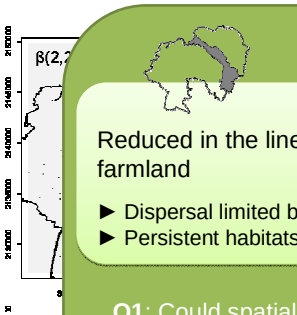


	Western side	Hedged farmland	Eastern side
Grassland	~ 10 %	~ 25 %	~ 10 %
Grassland <2 years	43 %	33 %	52 %
Permanent Grassland	32 %	45 %	23 %
Distance among 10 closest grassland (m)	340	240	445
Hedgerow index	~ 3	~ 10	~ 2

► The linear hedged farmland contains more favorable and persistent habitat and hedgerows
► *P. giornae* density did not vary significantly among zones

Results

Landscape characteristics



Hypothesis: gene flow is…

Reduced in the linear hedged farmland

► Dispersal limited by hedgerows
► Persistent habitats

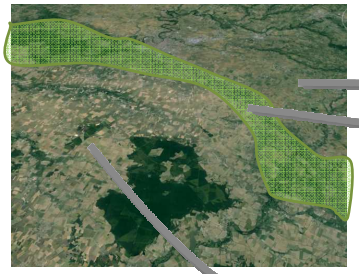
Enhanced in its Western and Eastern sides

► No physical barriers
► Disturbed habitats

Q1: Could spatial heterogeneity in dispersal lead to inference of 2 genetic clusters ?
Q2: Why only two clusters?
Q3: Why individuals from the hedged farmland were assigned to the eastern cluster?

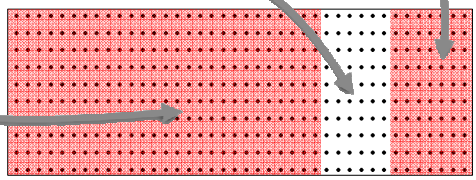
Computer simulations

Results
Computer simulations

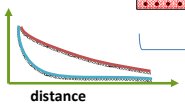


- **Q1**: Could spatial heterogeneity in dispersal lead to inference of 2 genetic clusters ?

Simulation of a single IBD population (IBDsim, Leblois & al. 2006)



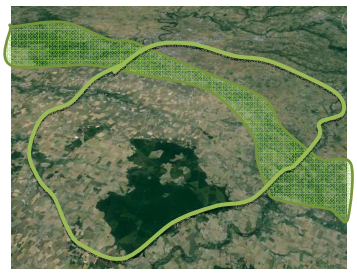
Constant density



e **= dispersal rate**

g **= parameter of the geometric law**

Results
Computer simulations

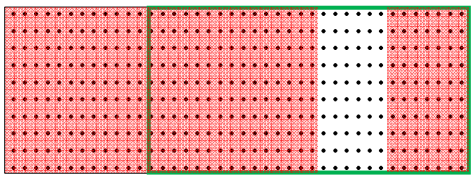


- **Q1**: Could spatial heterogeneity in dispersal lead to inference of 2 genetic clusters ?

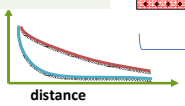
Simulation of a single IBD population (IBDsim, Leblois & al. 2006)

Scenario 1 : moderate contrast
Scenario 2 : strong contrast

Scenario	High disp. zone	Low disp. zone
Moderate contrast	*e* = 0.6 *g* = 0.75	*e* = 0.4 *g* = 0.67
Strong contrast	*e* = 0.8 *g* = 0.75	*e* = 0.2 *g* = 0.5



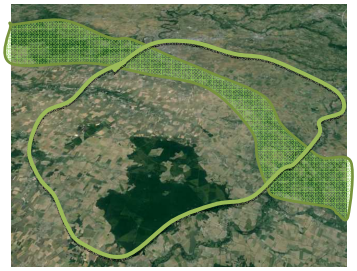
Constant density



e **= dispersal rate**

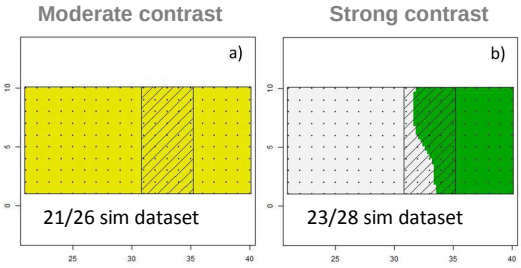
g **= parameter of the geometric law**

Results
Computer simulations



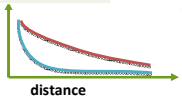
- **Q1**: Could spatial heterogeneity in dispersal lead to inference of 2 genetic clusters ?

Scenario	High disp. zone	Low disp. zone
Moderate contrast	*e* = 0.6 *g* = 0.75	*e* = 0.4 *g* = 0.67
Strong contrast	*e* = 0.8 *g* = 0.75	*e* = 0.2 *g* = 0.5



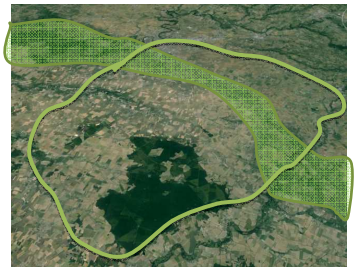
***e* = dispersal rate**

***g* = parameter of the geometric law**

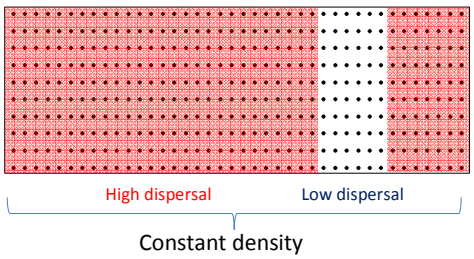


► 2 clusters only with strong contrast (IBD can't lead to the erroneous detection of 2 clusters)

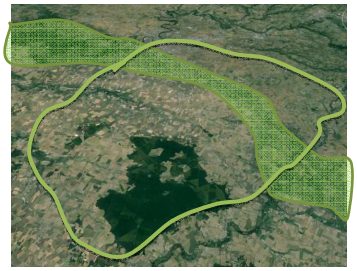
Results
Computer simulations



- **Q1**: Could spatial heterogeneity in dispersal lead to inference of 2 genetic clusters ?
- **Q2**: Why only 2 clusters ?

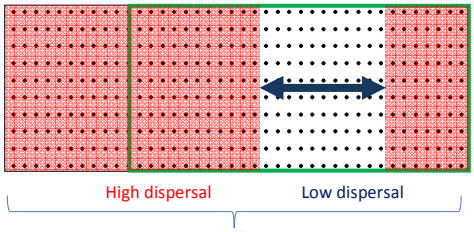


Results
Computer simulations



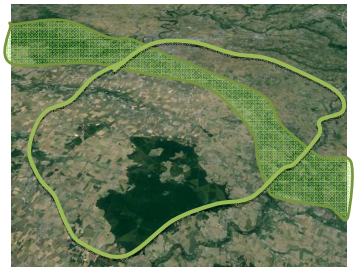
- **Q1**: Could spatial heterogeneity in dispersal lead to inference of 2 genetic clusters ?
- **Q2**: Why only 2 clusters ?

Scenario 3 : strong contrast + wider low dispersal zone



Constant density

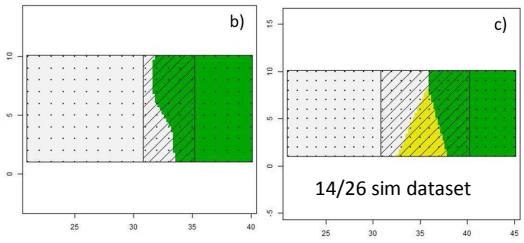
Results
Computer simulations



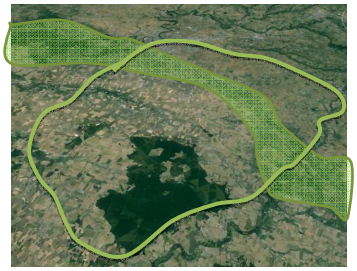
- **Q1**: Could spatial heterogeneity in dispersal lead to inference of 2 genetic clusters ?
- **Q2**: Why only 2 clusters ?

IBD slope: 4 times larger than in real dataset / others scenario

3 clusters !

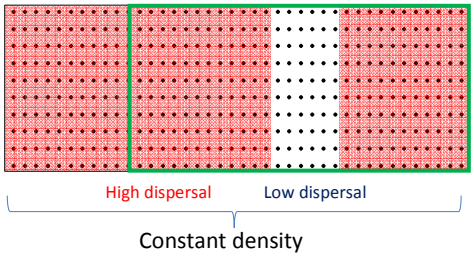


Results
Computer simulations

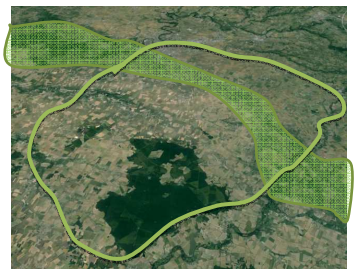


- **Q1**: Could spatial heterogeneity in dispersal lead to inference of 2 genetic clusters ?
- **Q2**: Why only 2 clusters ?
- **Q3**: Why individuals from the hedged farmland are assigned to the eastern cluster?

Scenario 4 : strong contrast + central low dispersal zone

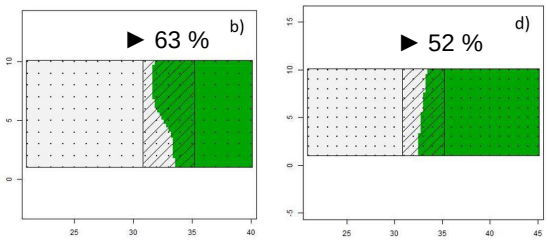


Results
Computer simulations



- **Q1**: Could spatial heterogeneity in dispersal lead to inference of 2 genetic clusters ?
- **Q2**: Why only 2 clusters ?
- **Q3**: Why individuals from the hedged farmland are assigned to the eastern cluster?

Scenario 4 : strong contrast + central low dispersal zone



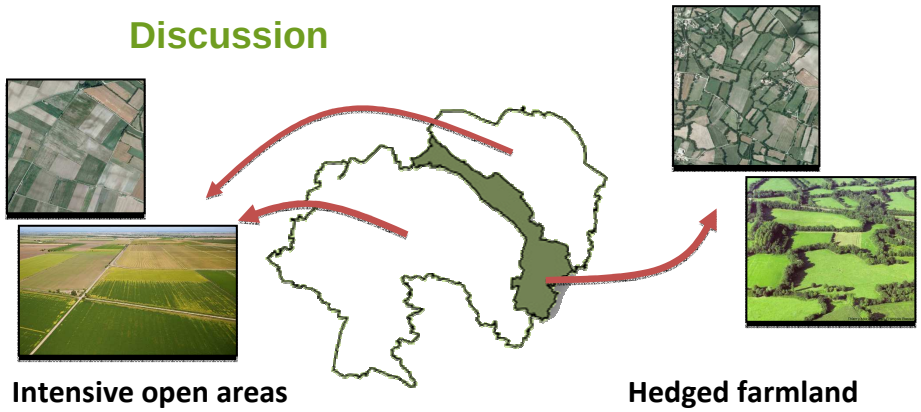
Discussion

Hedged farmland

► Dispersal slowed down

⇒Reduced dispersal rates and distance
. Hedgerows (physical barrier)
. Grasslands: Circe principle ? (Landers et al. 2008)

Discussion



Intensive open areas

► Dispersal rate and distance enhanced

⇒Small scale intense dispersal
Promoted by habitat instability
(Travis et al. 1999, Denno et al. 2001)

Hedged farmland

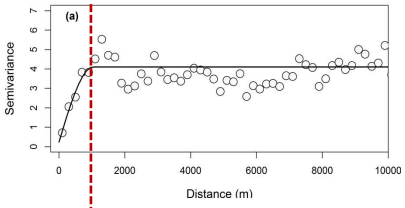
► Dispersal slowed down

⇒Reduced dispersal rates and distance
. Hedgerows (physical barrier)
. Grasslands: Circe principle ? (Landers et al. 2008)

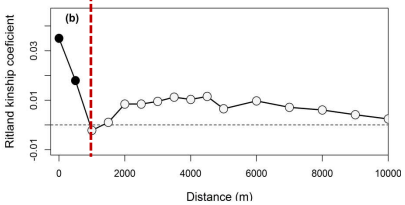
Results

Scale of spatial and genetic structure

Spatial autocorrelation of abundances: up to 1 km



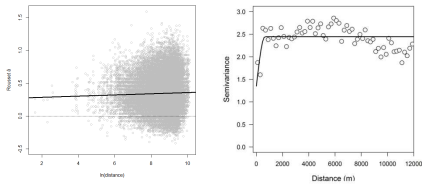
Spatial genetic autocorrelation based on relatedness: up to 1 km



► Both results suggest intense small scale dispersal

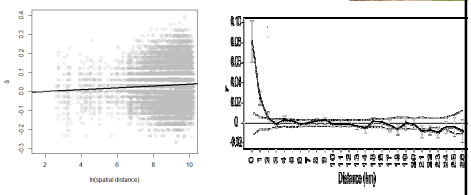
Discussion

Poecilus cupreus



- Homogénéité génétique à grande échelle + IBD
- Autocorrélation spatiale des abondances à faible distance
- Dispersion biaisée vers les males

Microtus arvalis



- Homogénéité à grande échelle + IBD
- Autocorrélation génétique à faible distance
- Dispersion biaisée vers les males
- Faible distance / forts taux

► « Syndrome Agroécosystème »
Forçage paysager ? Perturbations => dispersion

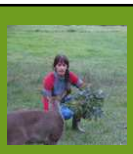
Marrec & al. In prep

Gauffre et al. 2008/2009

Conclusion

- Importance of computer simulations in landscape genetics
  - Analysis of empirical data -> hypotheses about pattern-process relationships governing population genetic substructure
  - Simulations -> evaluate the conditions under which inferred process correctly re-create the observed genetic pattern (Landguth *et al.* 2010)
- importance of addressing landscape genetics processes in terms of isolation by differential resistance

Thank you !



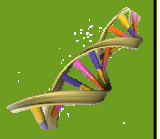
Nadine Guillon

Marilyn Roncoroni

Centre d'Études Biologiques de Chizé

Isabelle Badenhausser

Charles Poncet (Gentyane)



Isabelle Litrico

Sophie Mallez

CBGP

Raphael Leblois
Marie-Pierre Chapuis
Sylvain Piry