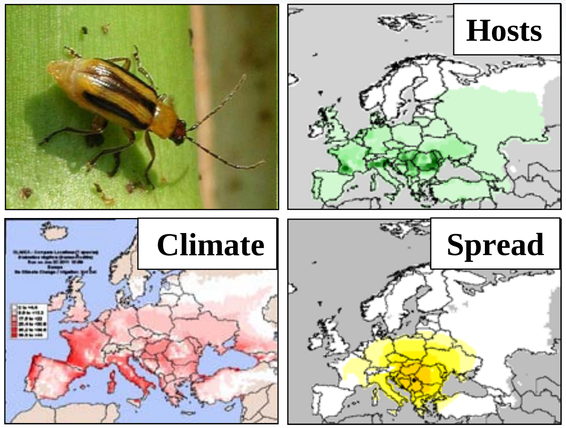
Christelle Robinet, Hella Kehlenbeck, Wopke van Der Werf

A suite of simple models to support quantitative assessment of spread and impact in pest risk analysis – concepts and applications



Christelle ROBINET[1], Hella KEHLENBECK[2] and Wopke VAN DER WERF[3]

1 INRA, Forest Zoology Unit, Orleans, FRANCE
2 JKI, Institute for National and International Plant Health, Kleinmachnow, GERMANY
3 WU, Centre for Crop Systems Analysis, Wageningen, NETHERLANDS

Fort Collins (USA), August 16-18th, 2011

International Pest Risk Mapping Workshop V

INRA WAGENINGEN UNIVERSITY WAGENINGEN UR JKI

1- Introduction

Purpose and concept

To develop a **generic** spread module within an integrated modelling framework linked to the EPPO PRA scheme
→ to be applicable to many different pests

That will enable risk assessors:

- to map the potential geographical expansion of invasive pests over time (t)
- to produce dynamic quantitative assessments of impacts
- to justify their responses to the spread questions **in the EPPO PRA scheme**

What is novel about the generic spread module?

Until now:

- only few attempts (e.g., Carrasco and Pitt)
- still complicated for non-modellers to use

Here: simple models provided but

- **designed or adapted for non-modellers (pest risk assessors)**
- **tested on:**
  - **- insects** (*Diabrotica virgifera*, *Anoplophora chinensis* and *A. glabripennis*)
  - **- nematodes** (*Bursaphelenchus xylophylus*, *Meloidogyne enterolobii*)
  - **- plant** (*Eichhornia crassipes*)
  - **- pathogen** (*Gibberella circinata*)

PRATIQUE

A set of five models (scenarios)

Consideration of space / Output variable	Temporal process models	Spatio-temporal process models
Presence/absence of the pest	Model 2	Model 3 Model 4
Pest density	Model 1	Model 5

These models were coded in R, a free software available at : http://www.r-project.org/

Prerequisites for the models

- **Climatic suitability (CLIMEX outputs)**
- **Host, habitat** or **soil** distribution data, as appropriate
- An elevation limit if appropriate

} **Area of potential establish-ment**

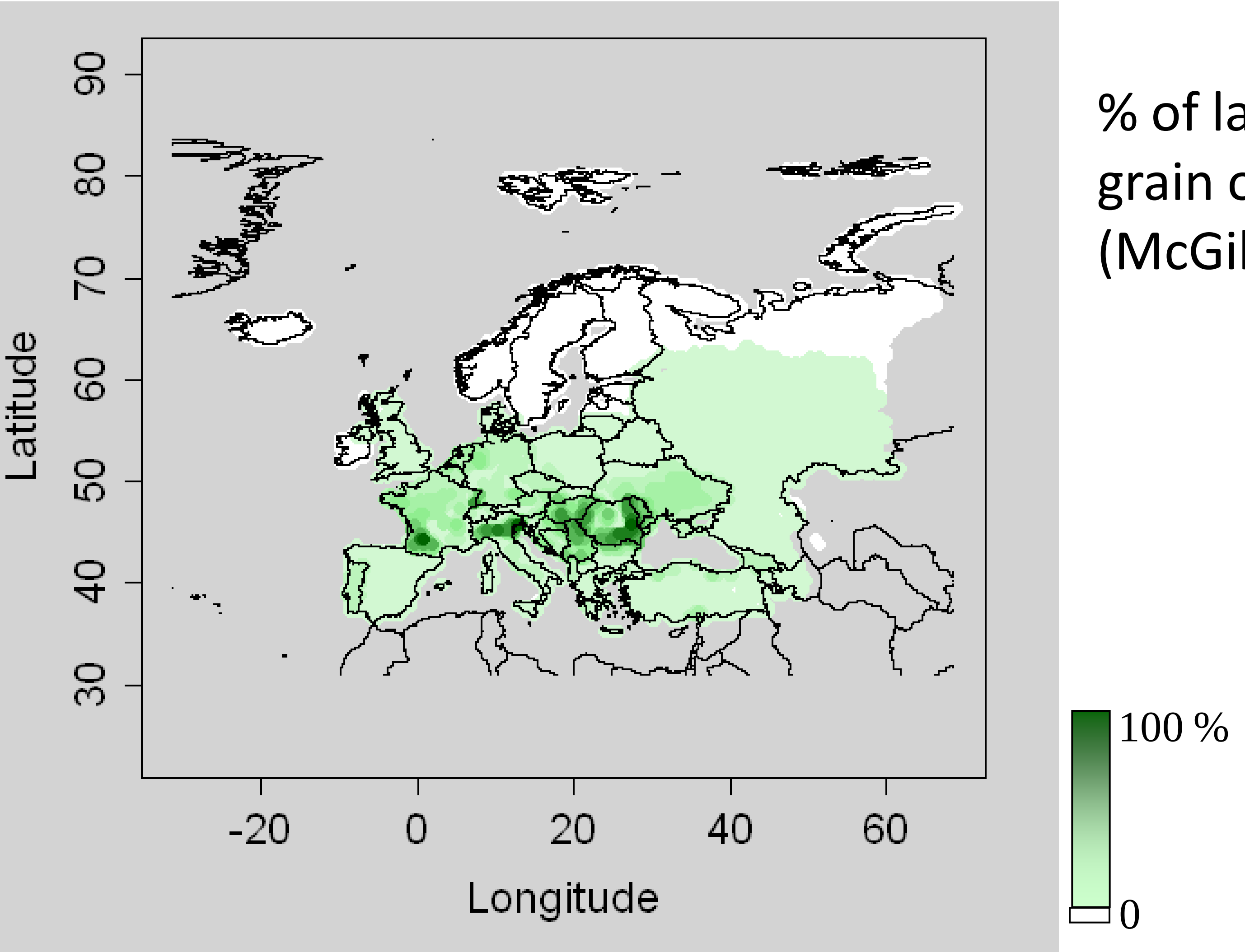
- + basic data on population dispersal and development

2- The western corn rootworm, *Diabrotica virgifera*

An example showing the application of the spread module

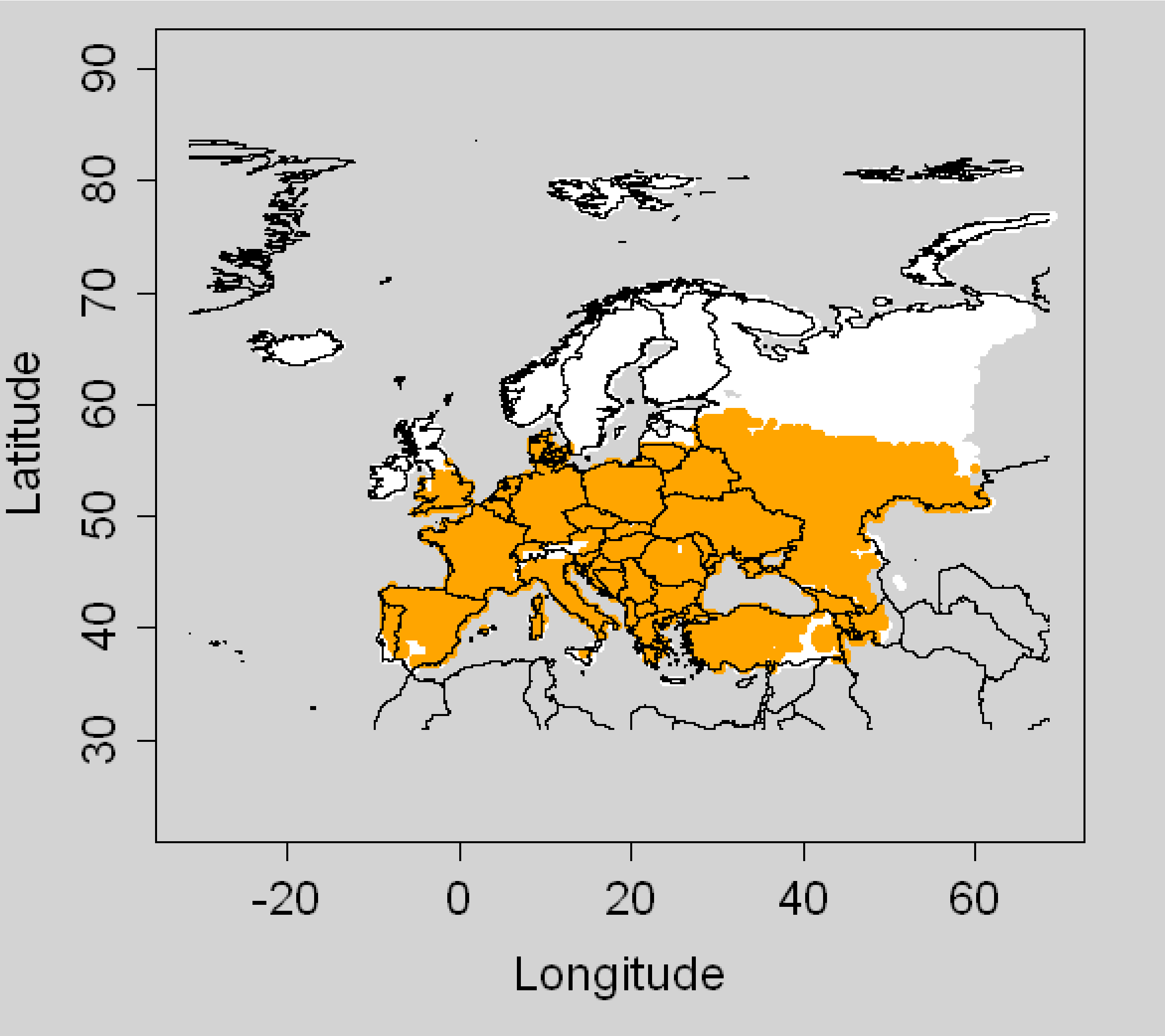
2- The western corn rootworm, *Diabrotica virgifera*

Host distribution
for *Diabrotica virgifera*



% of land covered by grain or forage maize (McGill University)

Area of potential establishment for *Diabrotica virgifera*



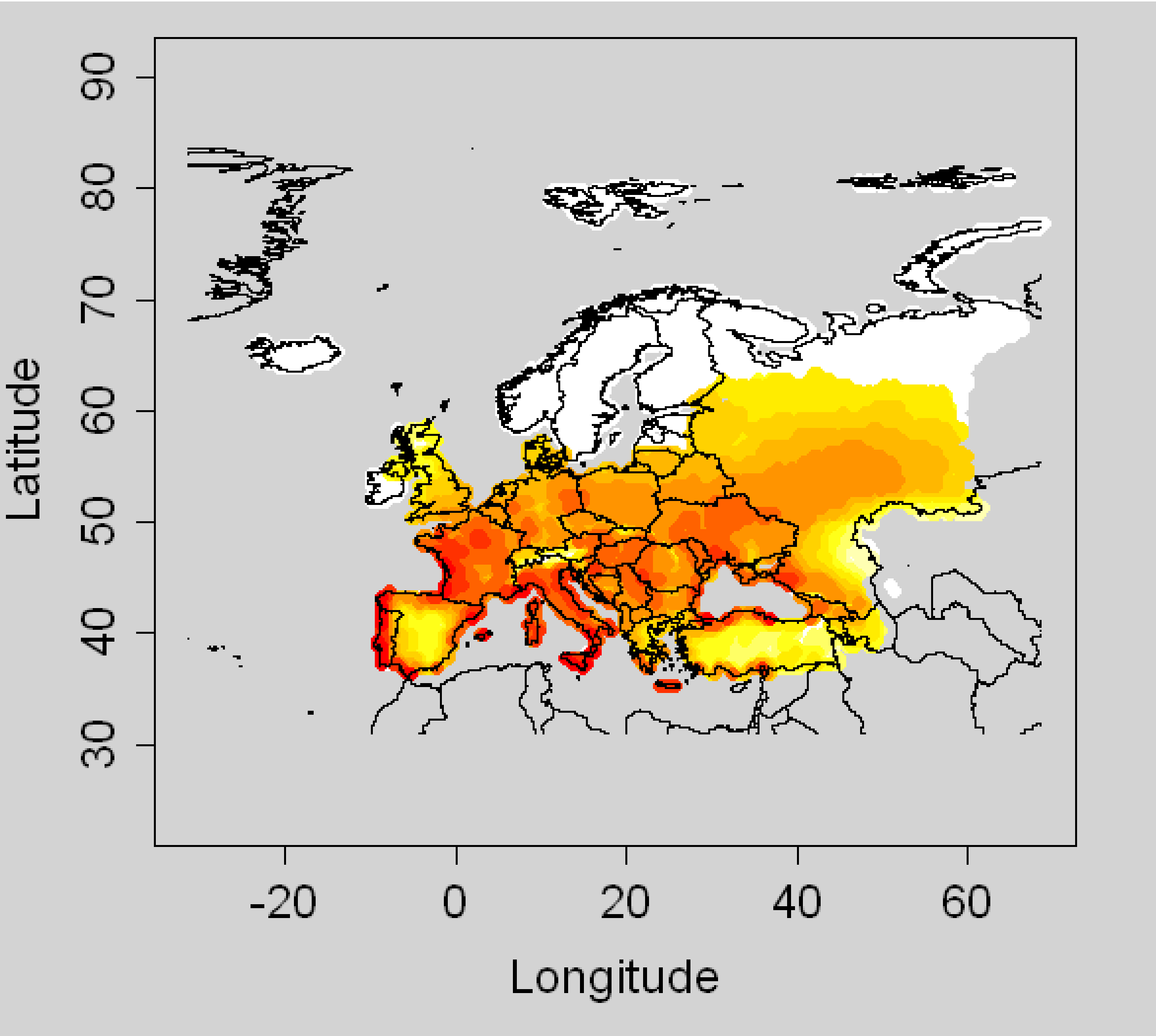
Area where :

1) **Host is present**
   (Grain+forage maize,
   McGill University)

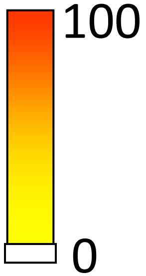
2) **Ecoclimatic Index>0**
   (CLIMEX model,
   P. Reynaud and D. Kriticos)

2- The western corn rootworm, *Diabrotica virgifera*

Growth potential for *Diabrotica virgifera*



1) **Growth Index** (CLIMEX model, P. Reynaud and D. Kriticos)
2) **GI re-scaled** to have values from 0 to 100



2- The western corn rootworm, *Diabrotica virgifera*

1st type of model: Temporal process models

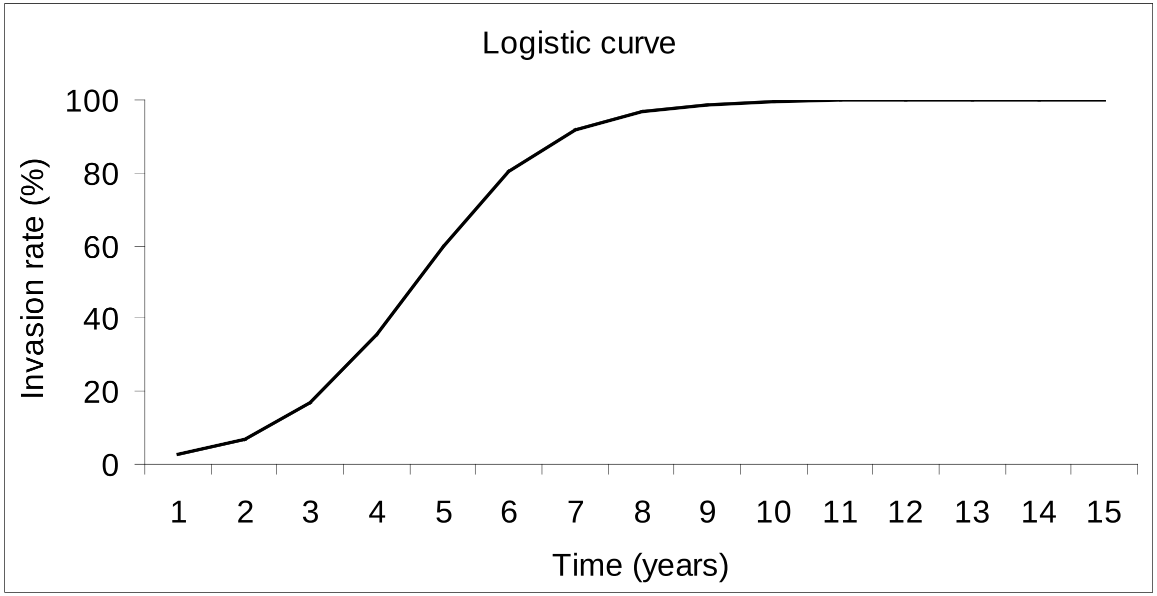
Consideration of space / Output variable	Temporal process models	Spatio-temporal process models
Presence/absence of the pest	Model 2	Model 3 Model 4
Pest density	Model 1	Model 5

Temporal process models

Model 1. Population dynamics model (SLG)

Description

- An initial population abundance is introduced in **each** cell within the area of potential establishment
- Within each cell, the increase of the population is calculated with the simple logistic growth function



Model 1. Population dynamics model (SLG)

Parameters needed:

- **N_0**
  Population abundance (%) for all suitable cells at time t = 0 (year of entry) expressed as a percentage of the maximum abundance (**carrying capacity K**)

- **λ_{max}**
  Maximum year to year multiplication factor that a population could achieve under optimal conditions in the PRA area

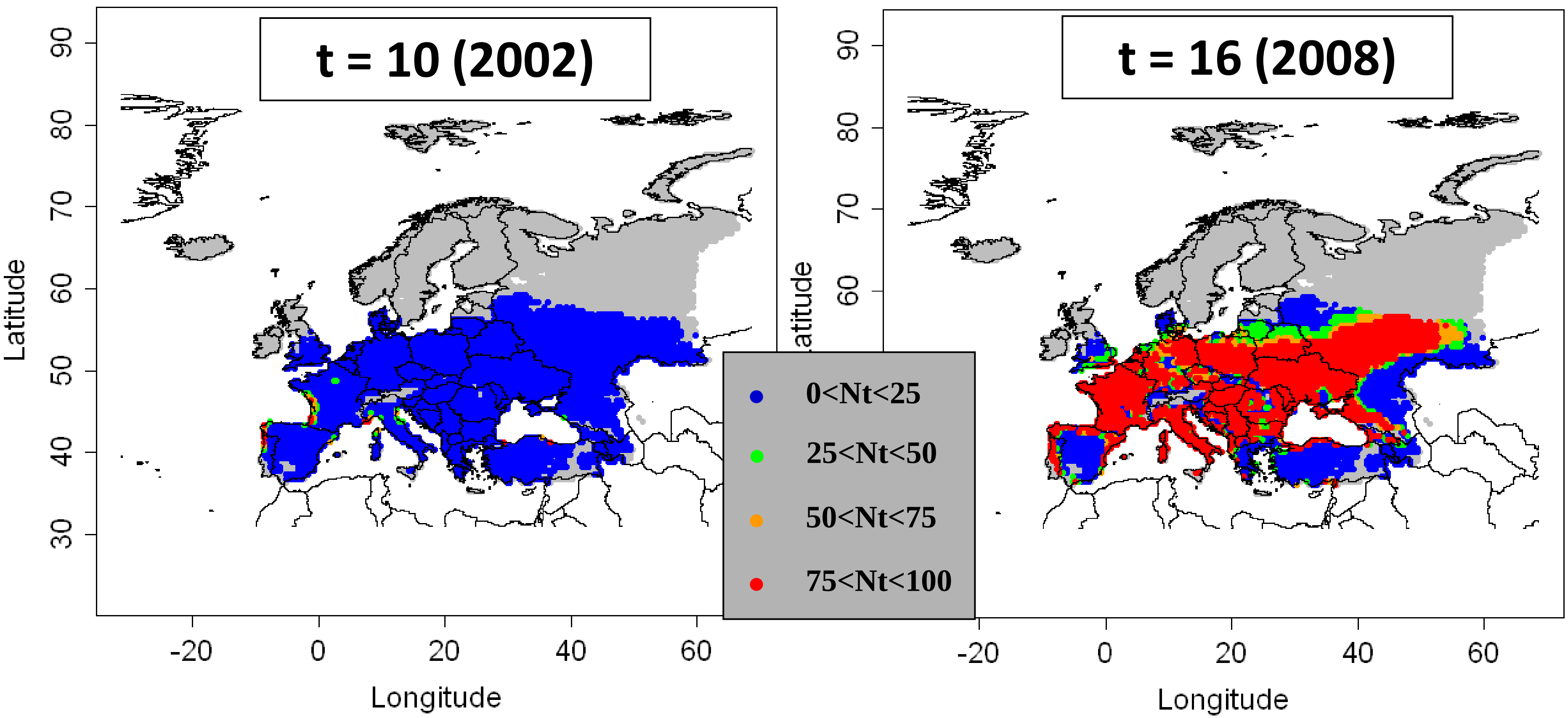
- **Time t :** number of years after entry for simulations

t = 0 in 1992 for *D. virgifera*

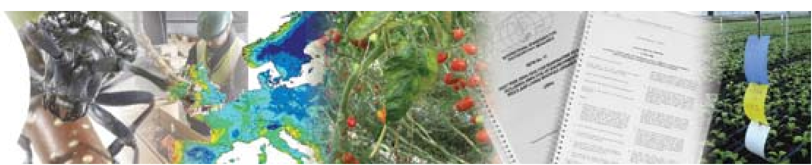
Temporal process models

Model 1. Population dynamics model (SLG)

Nt : population density at time t (% of the carrying capacity)



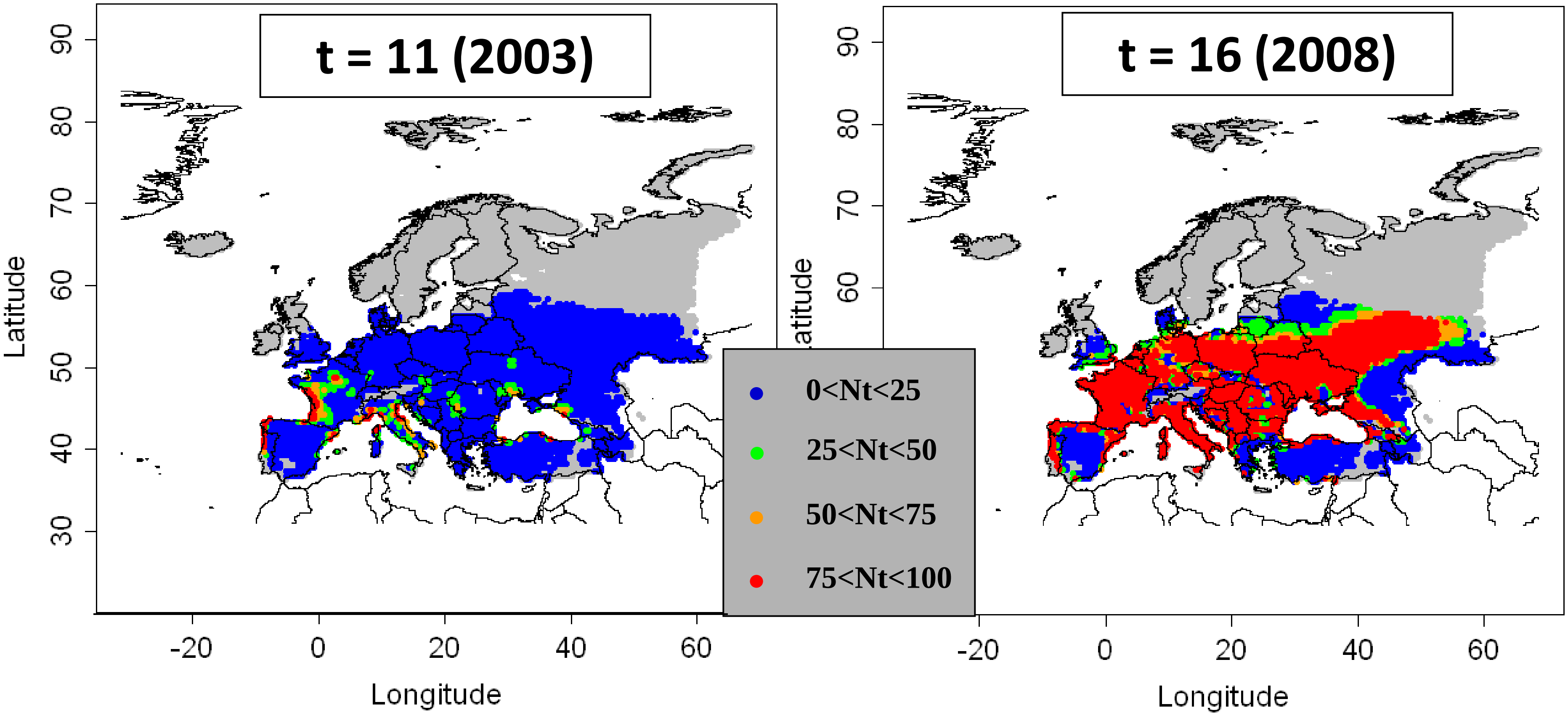
PRATIQUE



Temporal process models

Model 1. Population dynamics model (SLG)

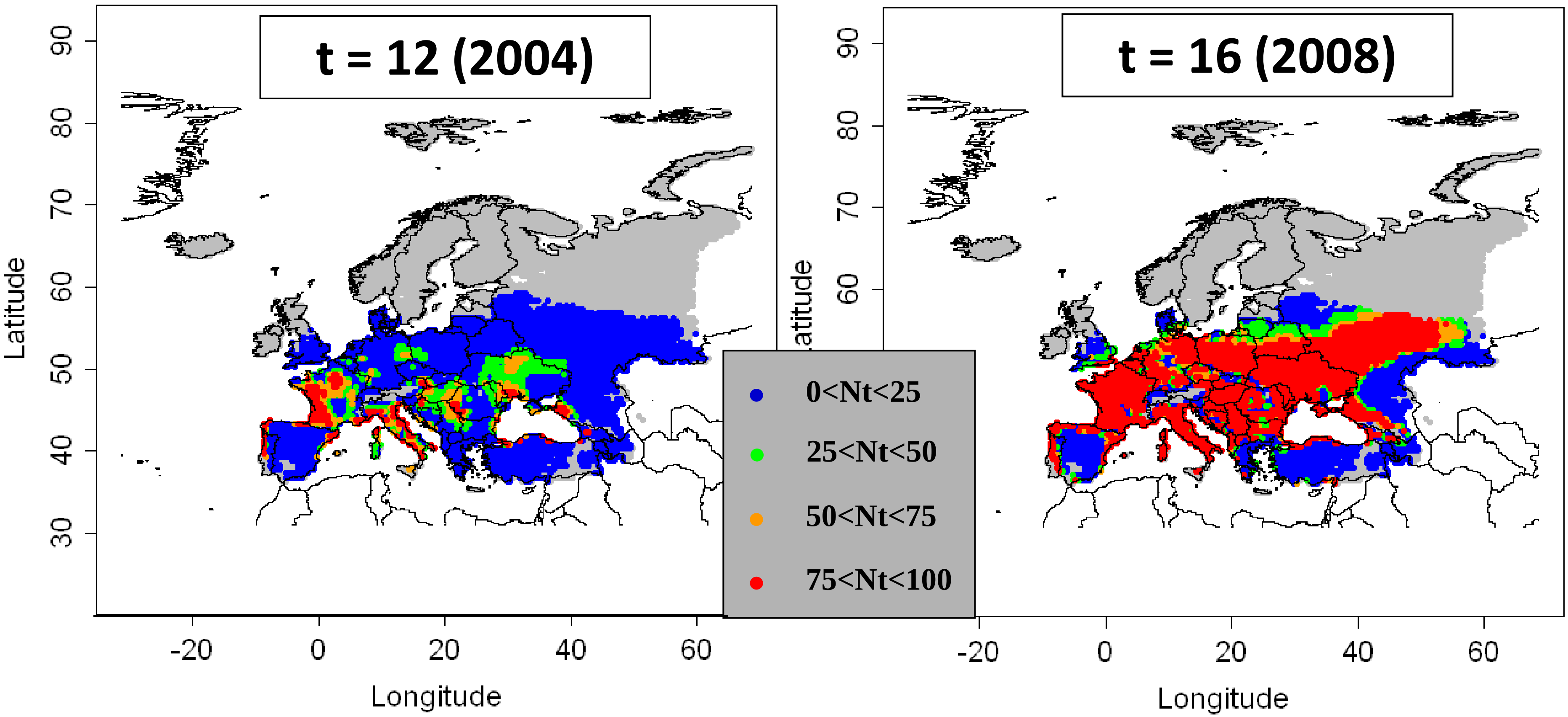
Nt : population density at time t (% of the carrying capacity)

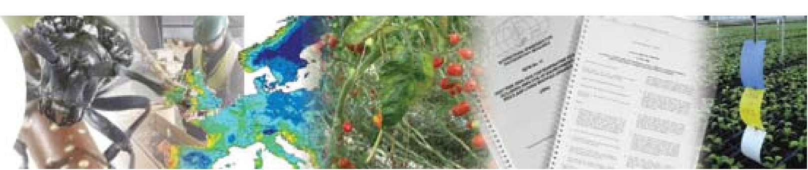


Temporal process models

Model 1. Population dynamics model (SLG)

Nt : population density at time t (% of the carrying capacity)

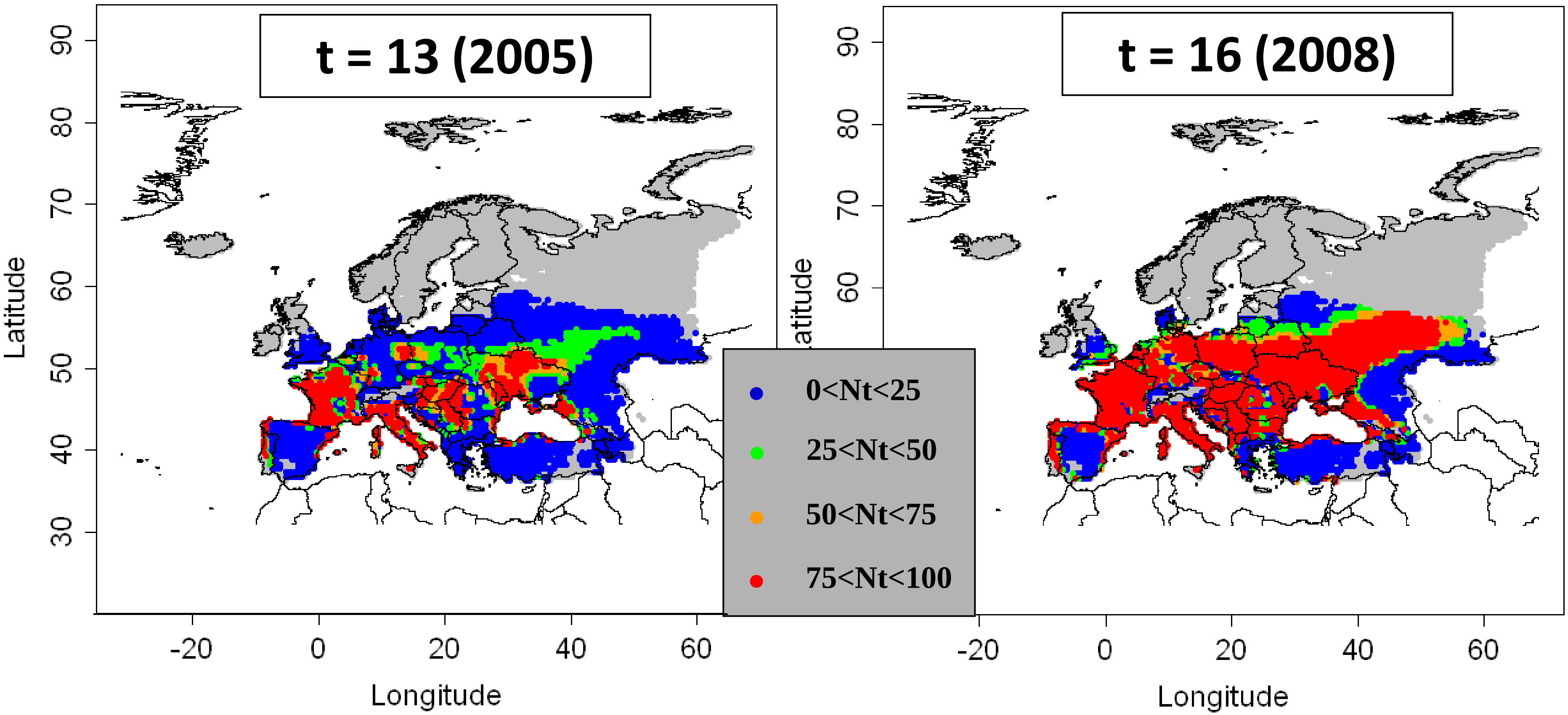




Temporal process models

Model 1. Population dynamics model (SLG)

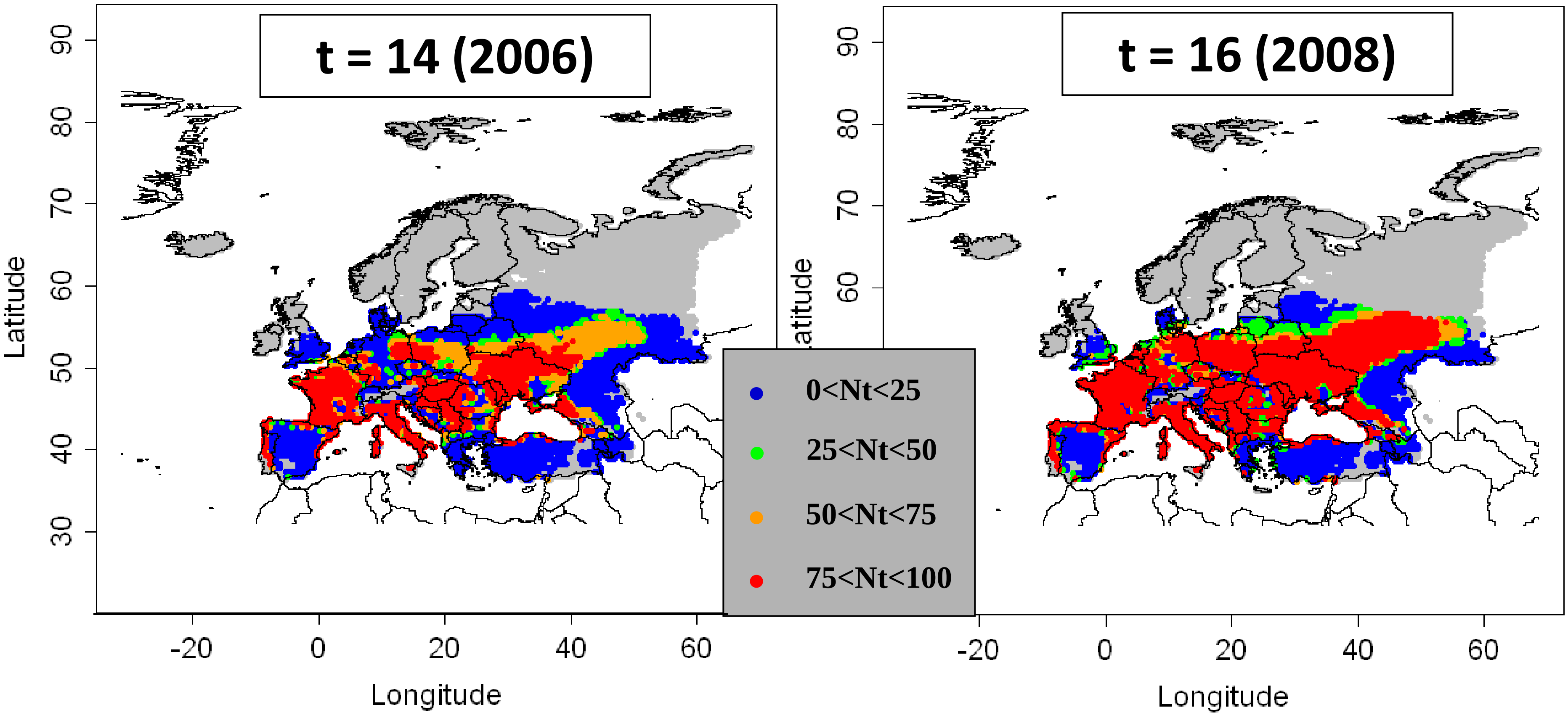
Nt : population density at time t (% of the carrying capacity)



Temporal process models

Model 1. Population dynamics model (SLG)

Nt : population density at time t (% of the carrying capacity)

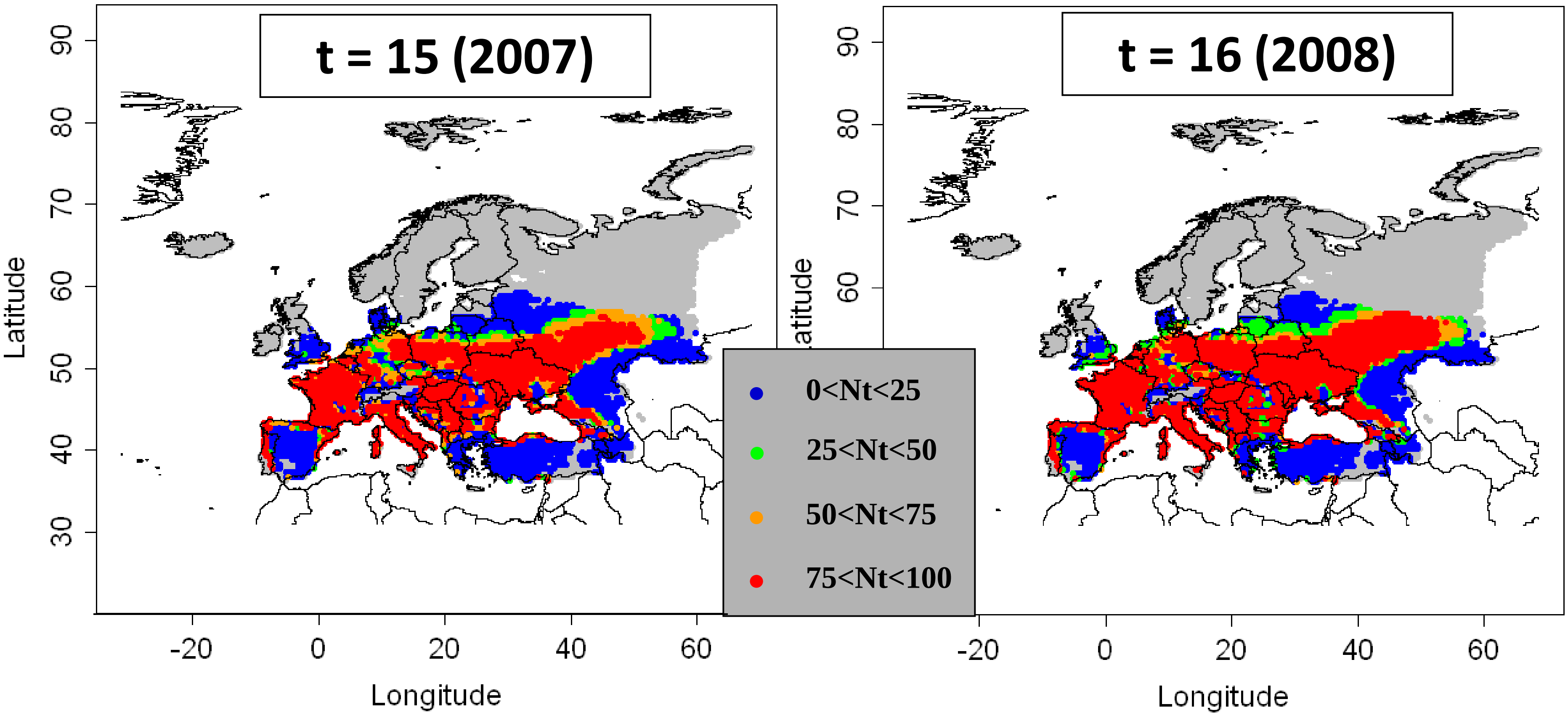


PRATIQUE

Temporal process models

Model 1. Population dynamics model (SLG)

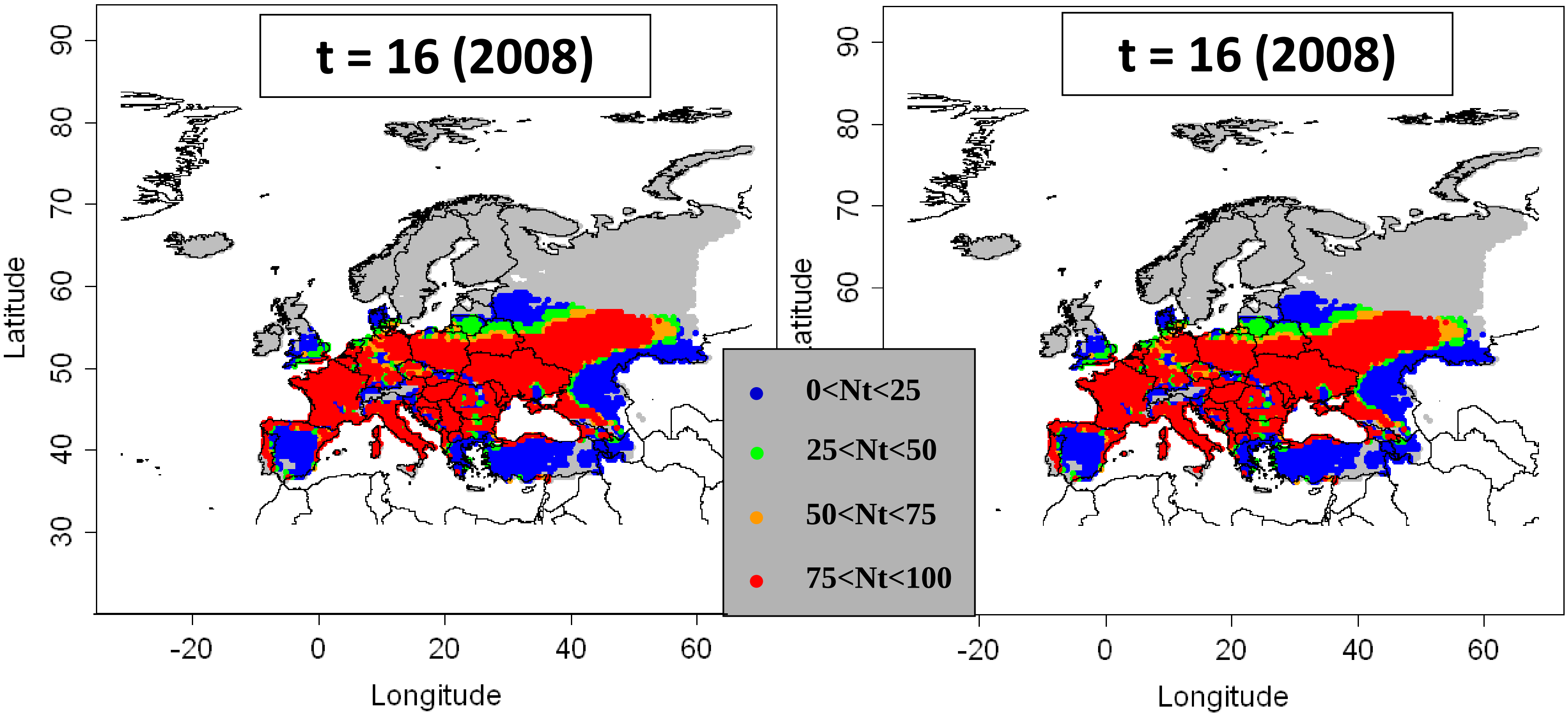
Nt : population density at time t (% of the carrying capacity)

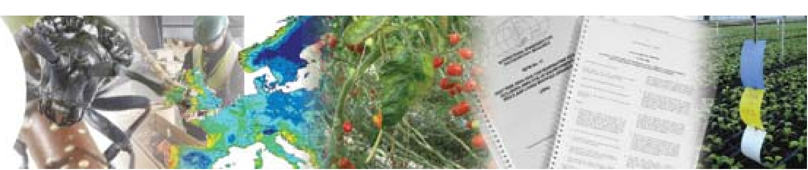


Temporal process models

Model 1. Population dynamics model (SLG)

Nt : population density at time t (% of the carrying capacity)





Model 1. Population dynamics model (SLG)

Results

- Provides information on **population abundance** within the cells (assuming the species has spread throughout the area of potential establishment)
- Useful for **identifying areas where high pest densities are to be expected** and to decide where surveillance and phytosanitary measures should be applied in priority.

Model 2. Temporal spread over cells integrated with impact

Description

- Calculates the potential impact
- A logistic function is used to calculate the percentage of the cells invaded at time t.
- The location of these invaded cells is chosen according to 3 scenarios:
  - **Worst case scenario**: highest economic value cells invaded first
  - **Best case scenario**: lowest economic value cells invaded first
  - **Random scenario**: invaded cells chosen independently of their value

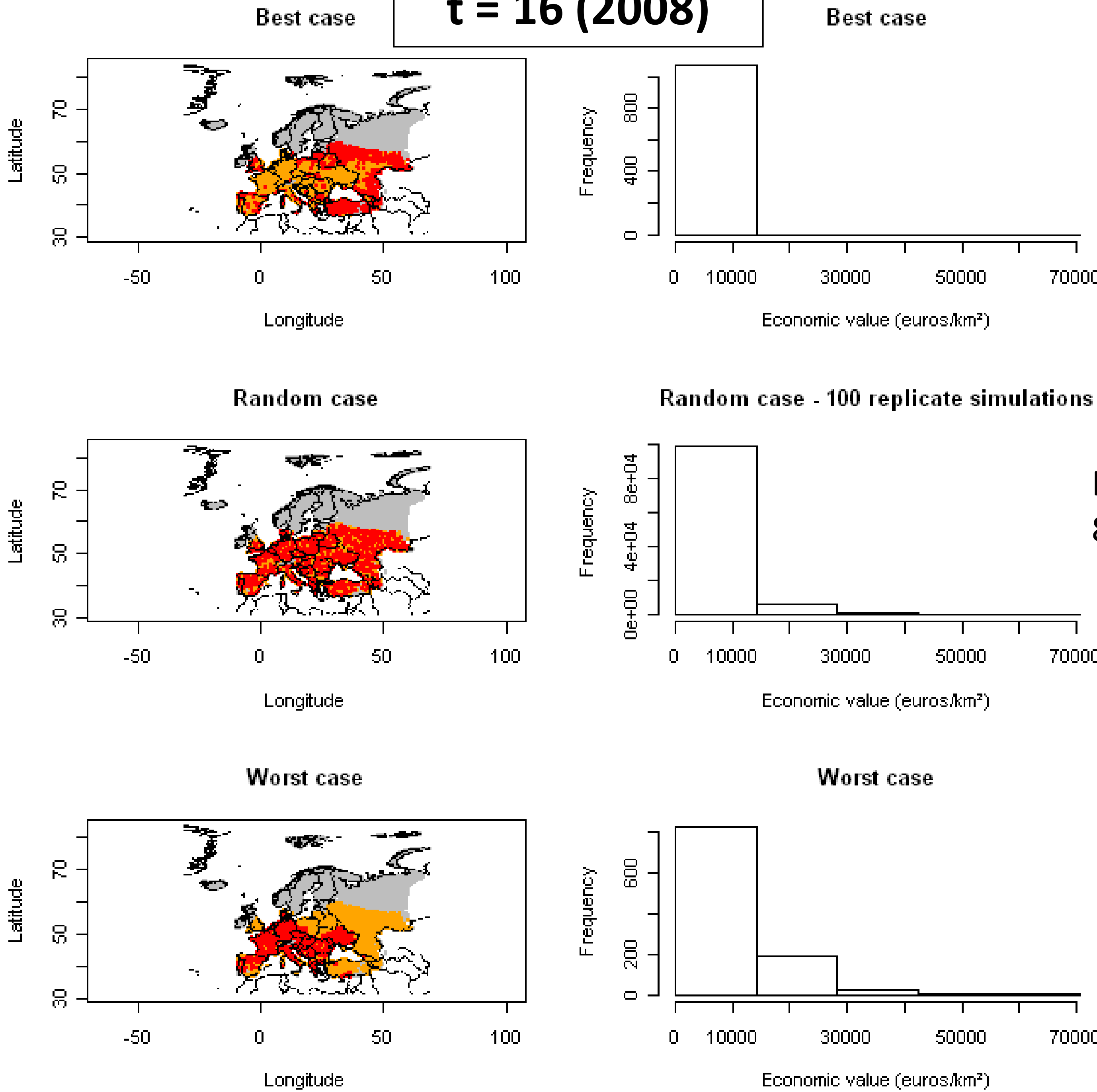
Temporal process models

Model 2. Temporal spread over cells integrated with impact

Parameters needed:

- **N_0**
  Initial percentage of the cells within the area of potential establishment which are invaded at time t=0
- **r**
  Relative rate of spatial increase
- **Spatial Data on the economic value of the host plants (euros/km²)**

t = 16 (2008)



Best case scenario:
9.5 10^8 euros

Random scenario:
8.4 10^9 - 1.05 10^{10} euros

Worst case scenario:
2.4 10^{10} euros

N_0=0.0301, r=0.46

Model 2. Temporal spread over cells integrated with impact

Results

- **Presence or absence** of the pest in a cell
- Calculates the accumulated economic values (€) for the different scenarios (best case, worst case, random case)
- Incorporates potential impact

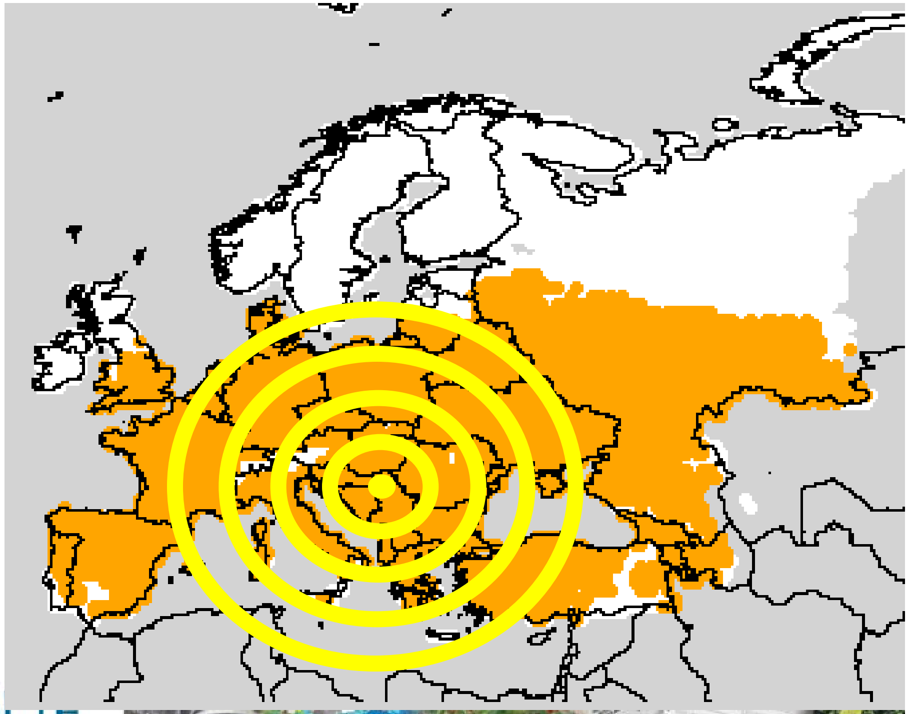
2nd type of model: Spatio-temporal process models

Output variable \ Consideration of space	Temporal process models	Spatio-temporal process models
Presence/absence of the pest	Model 2	Model 3 Model 4
Pest density	Model 1	Model 5

Model 3. Radial Range Expansion Model

Description

- The spread is determined by the radial expansion rate (RR) from an entry point

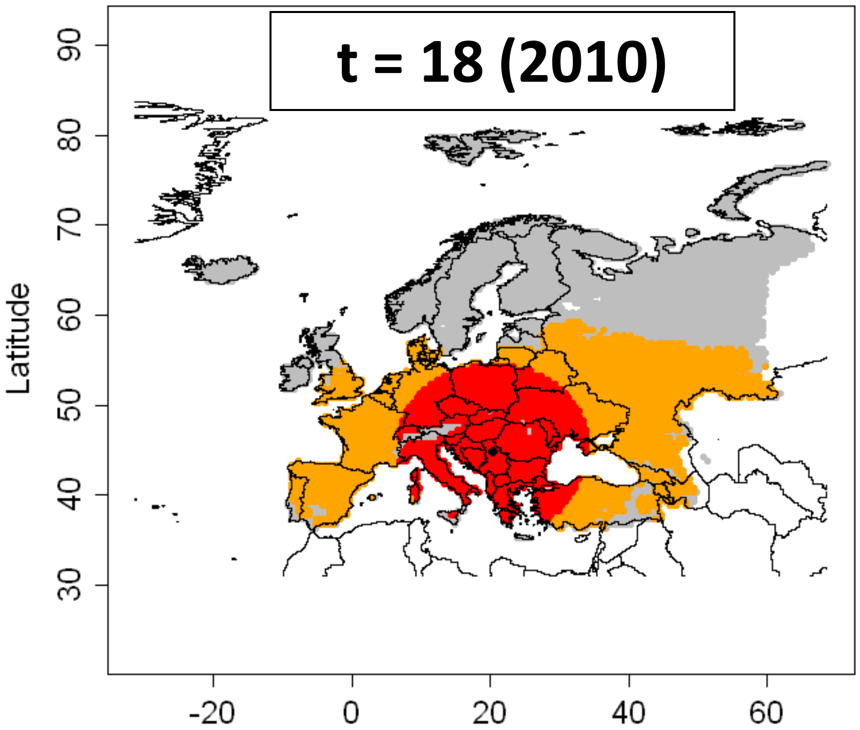


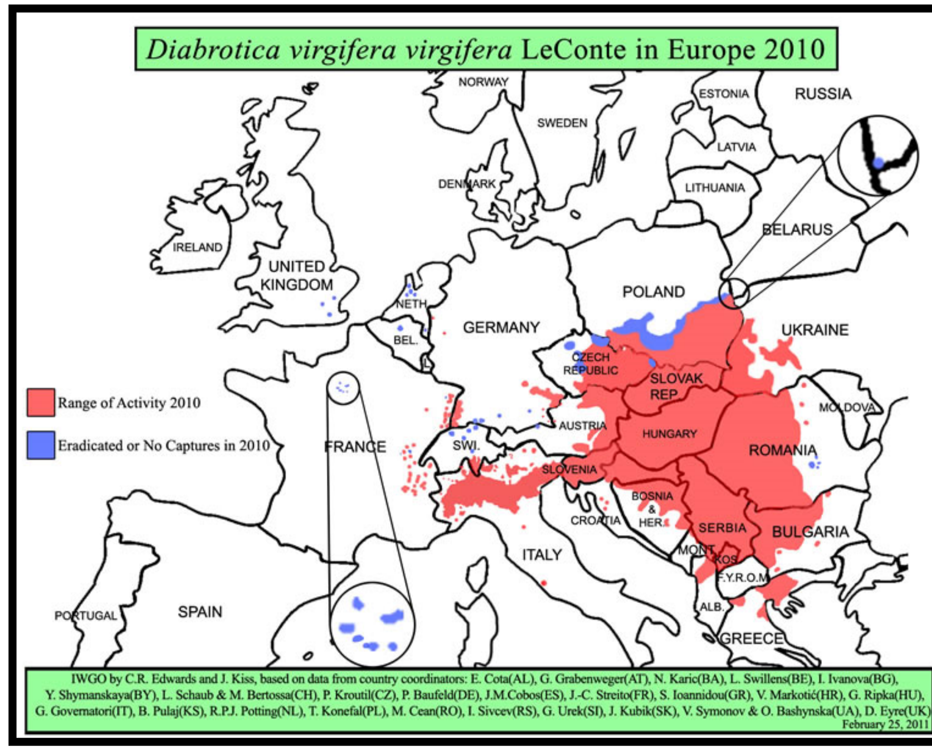
Parameters needed:

- **RR** (km/year)
- **Entry point(s)**

Spatial process models

Model 3. Radial Range Expansion Model





RR = 60 km/year

Point of entry: Belgrade (Serbia) (in 1992)

Model 3. Radial Range Expansion Model

Results

- **Presence or absence** of the pest in a cell
- Very simple and easy to apply
- Makes range expansion visible on a map

→ reasonable results for several tested insect species

Model 4. Hybrid of logistic growth and radial rate exp. model

Description

- The number of invaded cells is given by the logistic function of model 2 (temporal spread integrated with impacts) but model 4 is independent of economic data

- Invaded cells are randomly chosen within the area given by model 3 (radial range expansion model)

Model 4. Hybrid of logistic growth and radial rate exp. model

Parameters needed:

- **Radial expansion rate per year** (RR in km/year)
- **Entry point(s)**

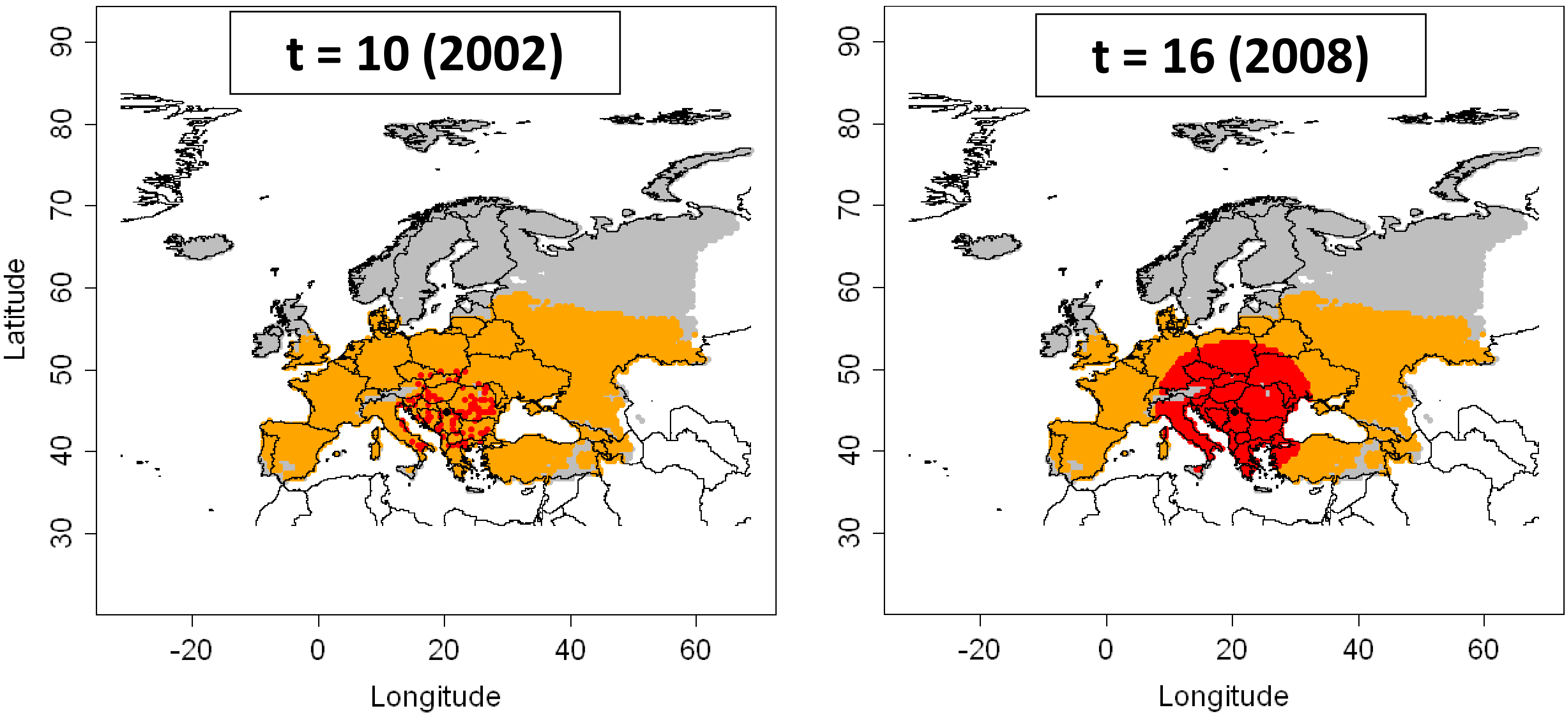
} Same as model 3

- **Initial population N_0**
- **Relative rate of spatial increase r**

} Same as model 2

Spatial process models

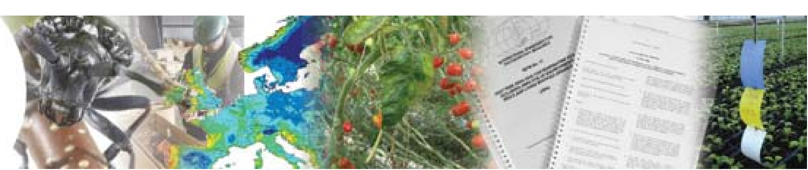
Model 4. Hybrid of logistic growth and radial rate exp. model



Model 4. Hybrid of logistic growth and radial rate exp. model

Results

- **Presence or absence** of the pest in a cell
- Simple approach of model 3 combined with a the relative rate of spatial increase of model 2
  => improves model 3



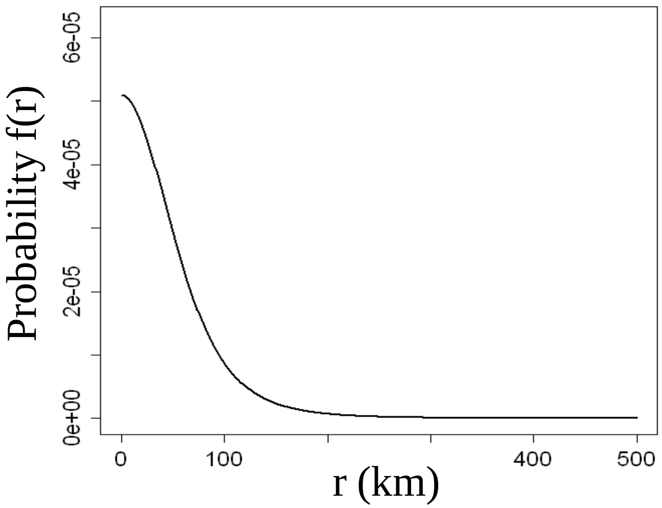
Spatial process models

Model 5. Dispersal kernel model

Description:

- Growth model is logistic model 1
- Dispersal kernel: probability to disperse at distance r:

$$f(r) = \frac{1}{u^2 p\pi} \frac{\Gamma\left(\frac{p+1}{2}\right)}{\Gamma\left(\frac{p-1}{2}\right)} \frac{1}{\left(1 + \frac{1}{p}\frac{r^2}{u^2}\right)^{\frac{p+1}{2}}}$$



u : length scale parameter
p: shape parameter

p=1 Cauchy distribution (thick tail)
=> a large number of individuals disperse at long distance

$p \to +\infty$ normal distribution (thin tail)
=> individuals disperse at short distance

Spatial process models

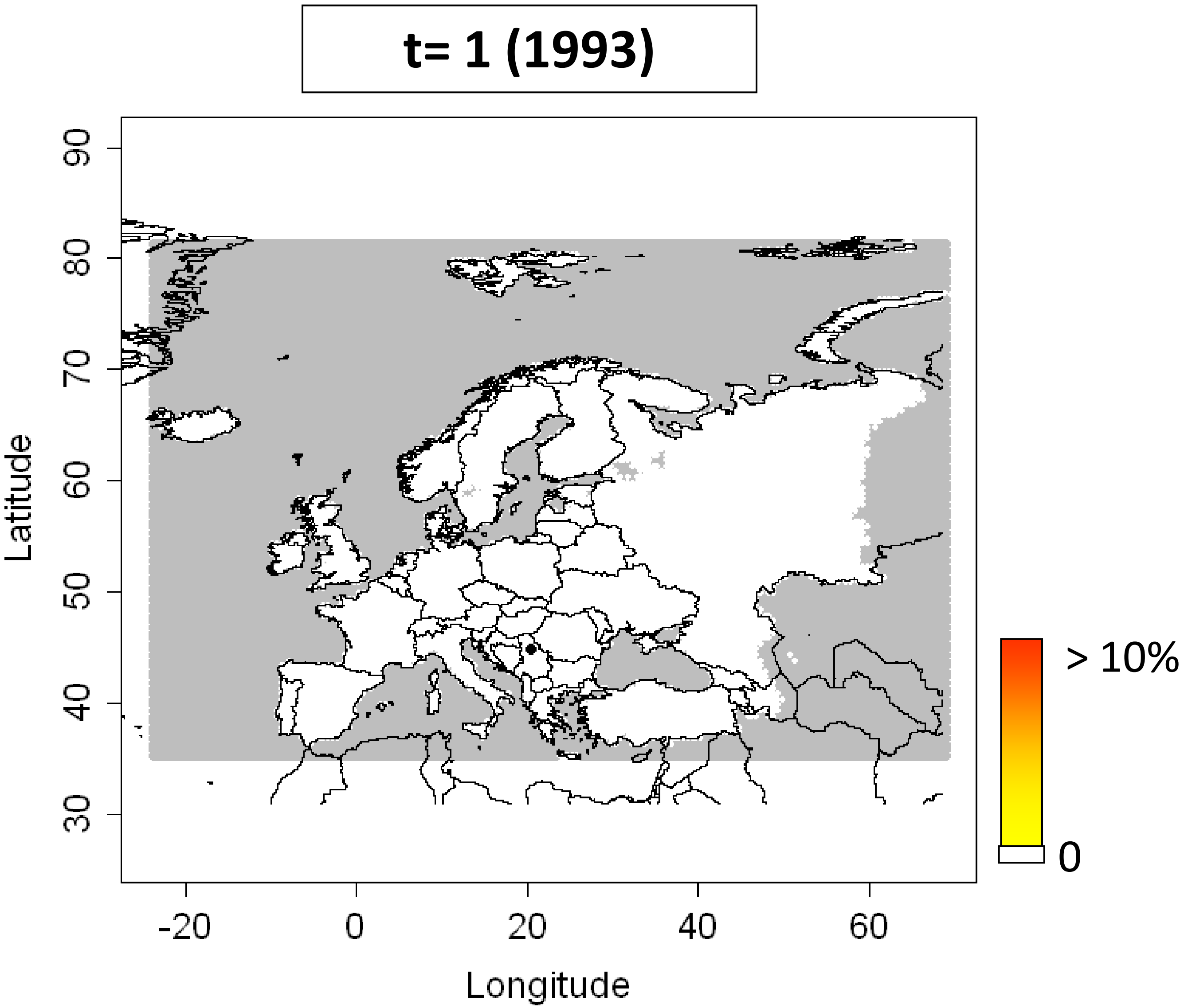
Model 5. Dispersal kernel model

Parameters needed

- Initial population N_0 } same as Model 1
- λ_{max} } same as Model 1
- **u - Scale parameter** (km)
  → as a first estimate, same as model 3: **u = RR = 60 km**
- **p - Shape parameter** (number of degrees of freedom)
  → **p = 5** because we suspect a large number of individuals to disperse far away
- coordinates of the entry point: Belgrade

Spatial process models

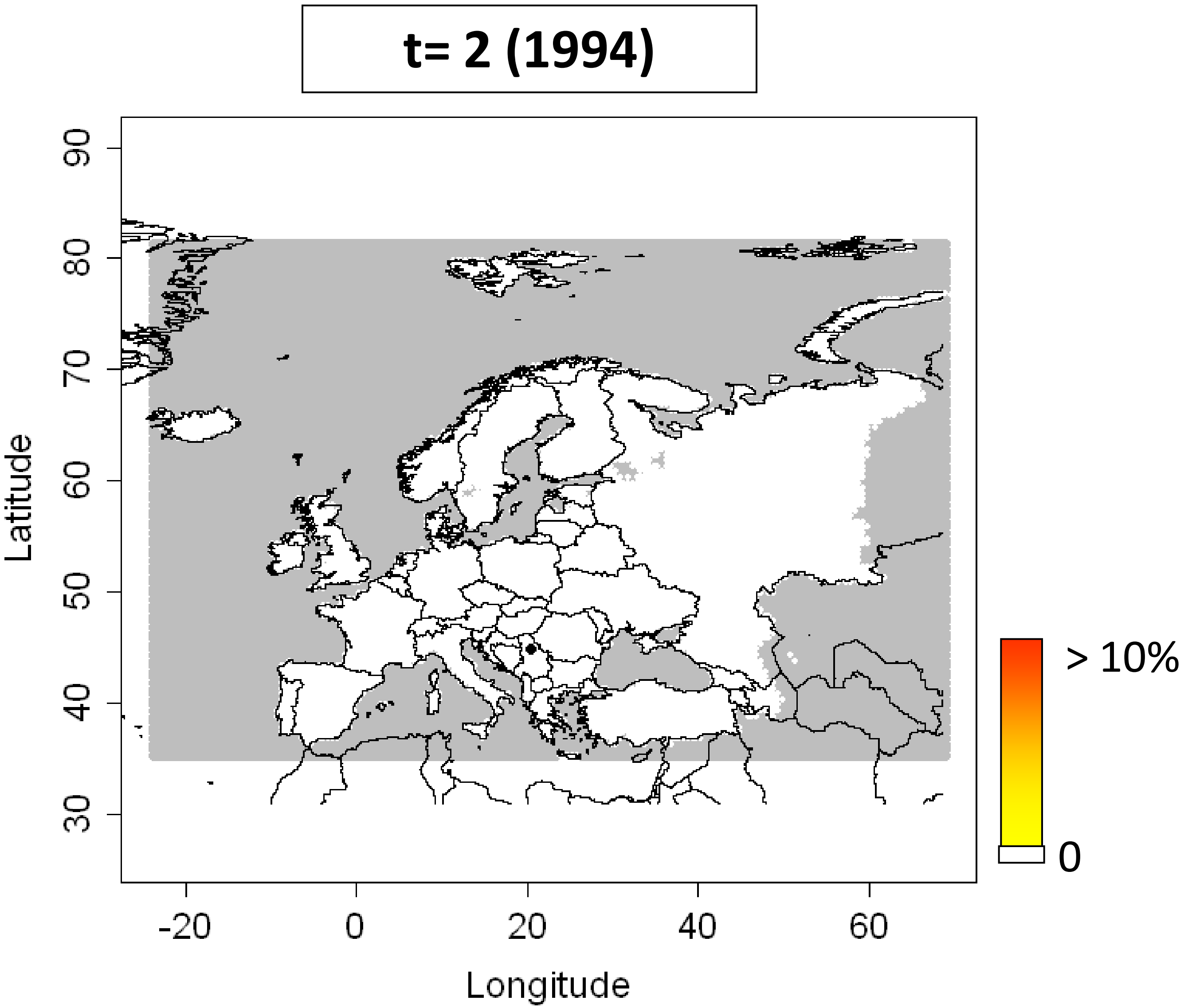
Model 5. Dispersal kernel model



PRATIQUE

Spatial process models

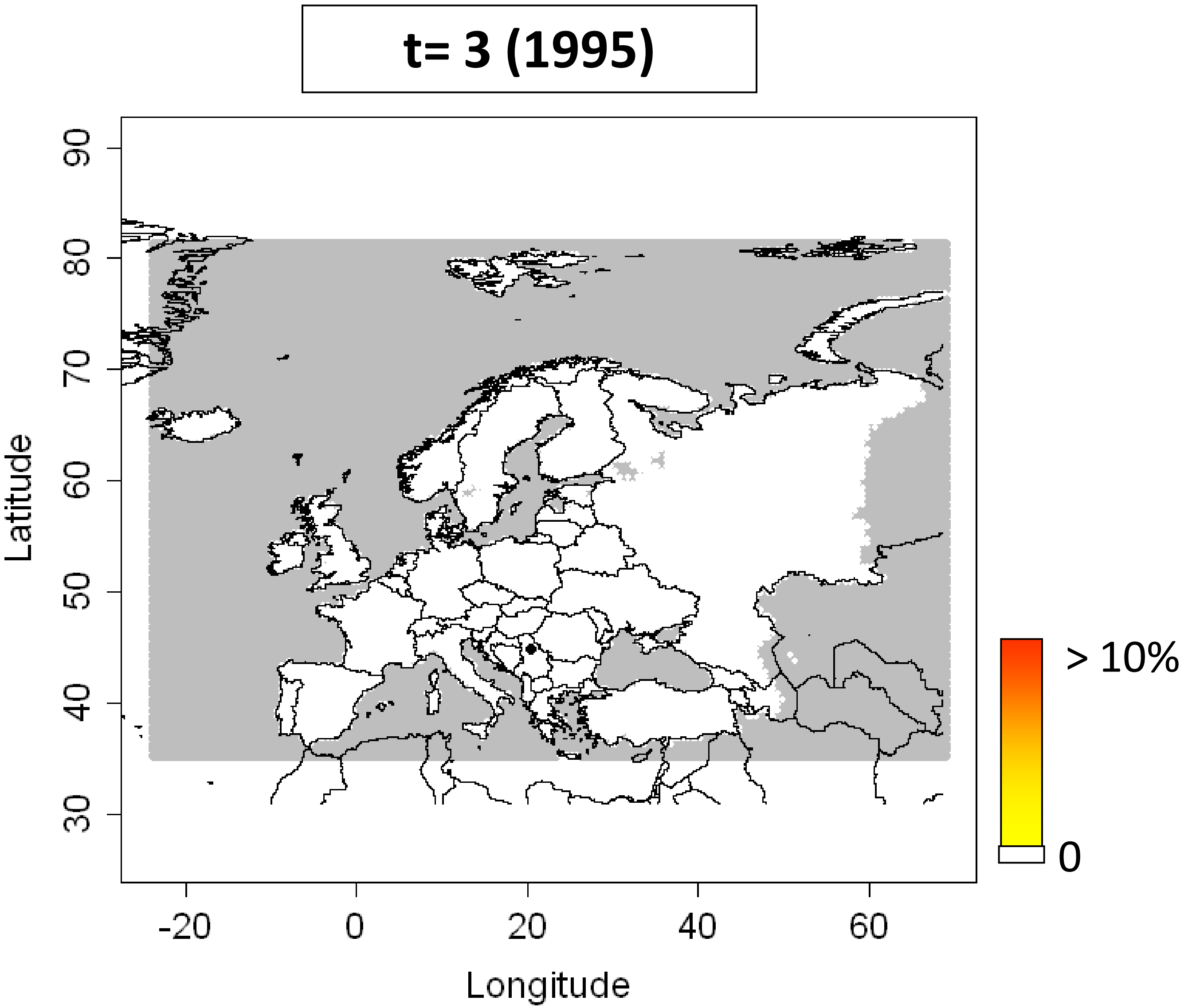
Model 5. Dispersal kernel model



PRATIQUE

Spatial process models

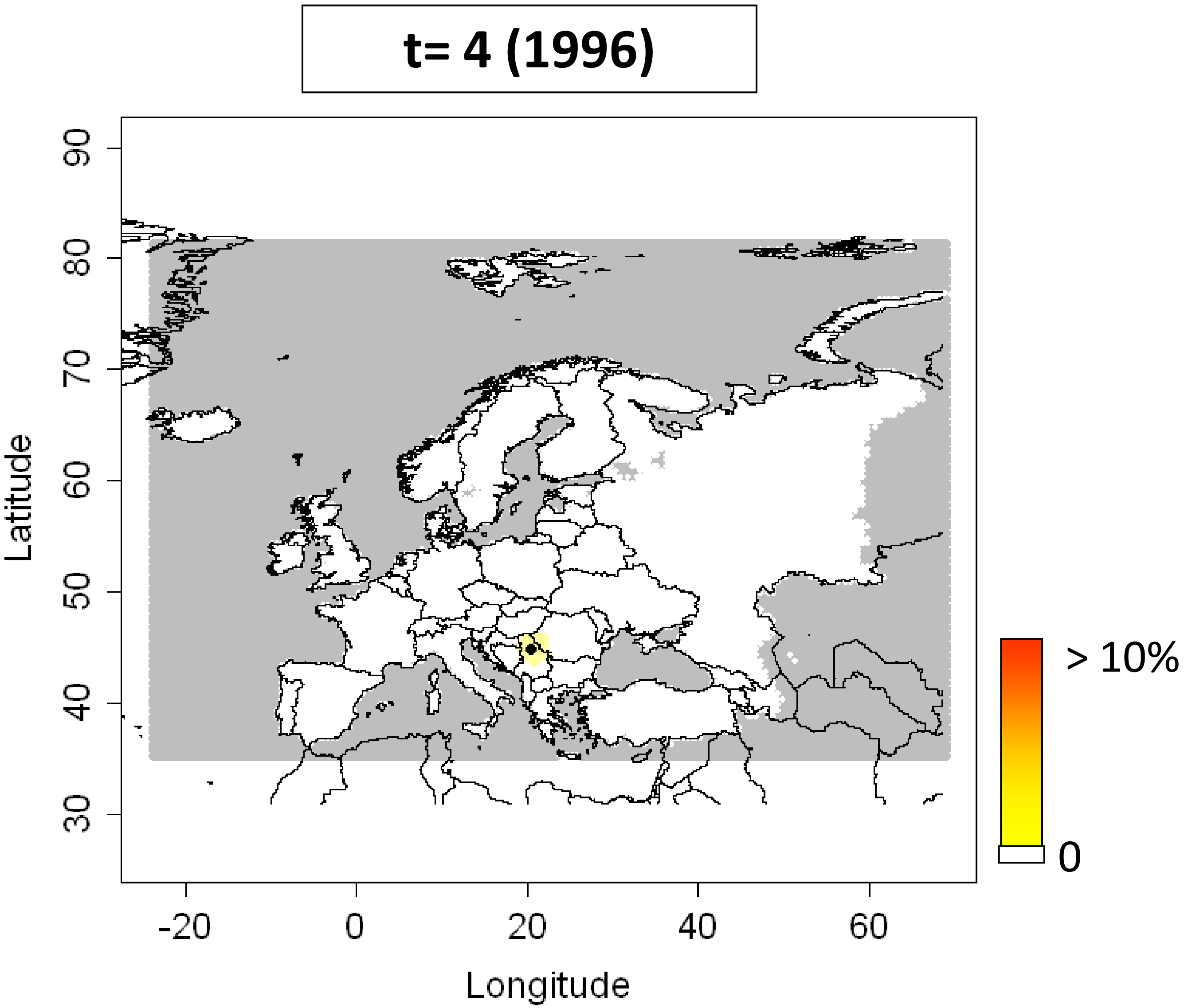
Model 5. Dispersal kernel model



PRATIQUE

Spatial process models

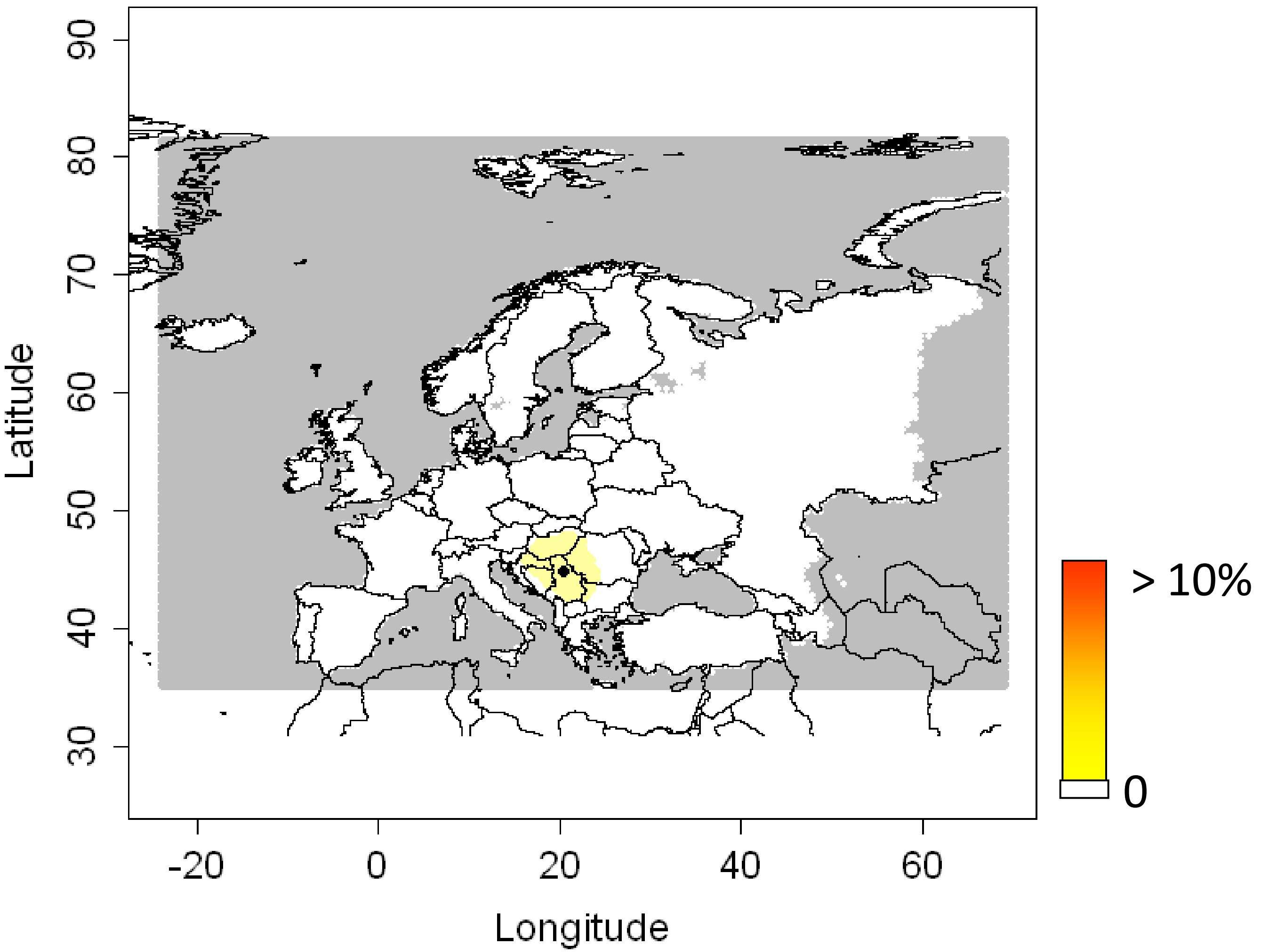
Model 5. Dispersal kernel model



Spatial process models

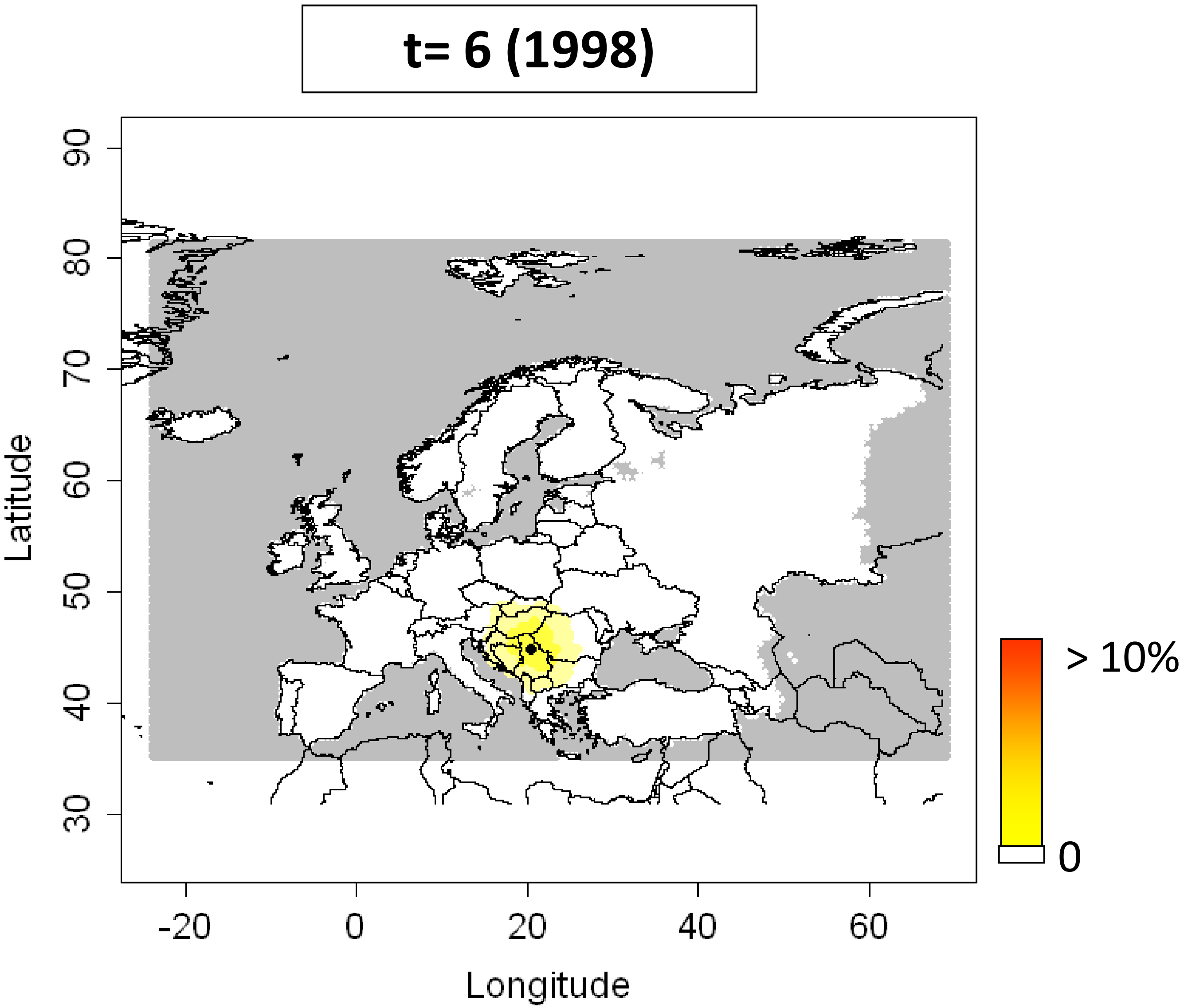
Model 5. Dispersal kernel model

t= 5 (1997)



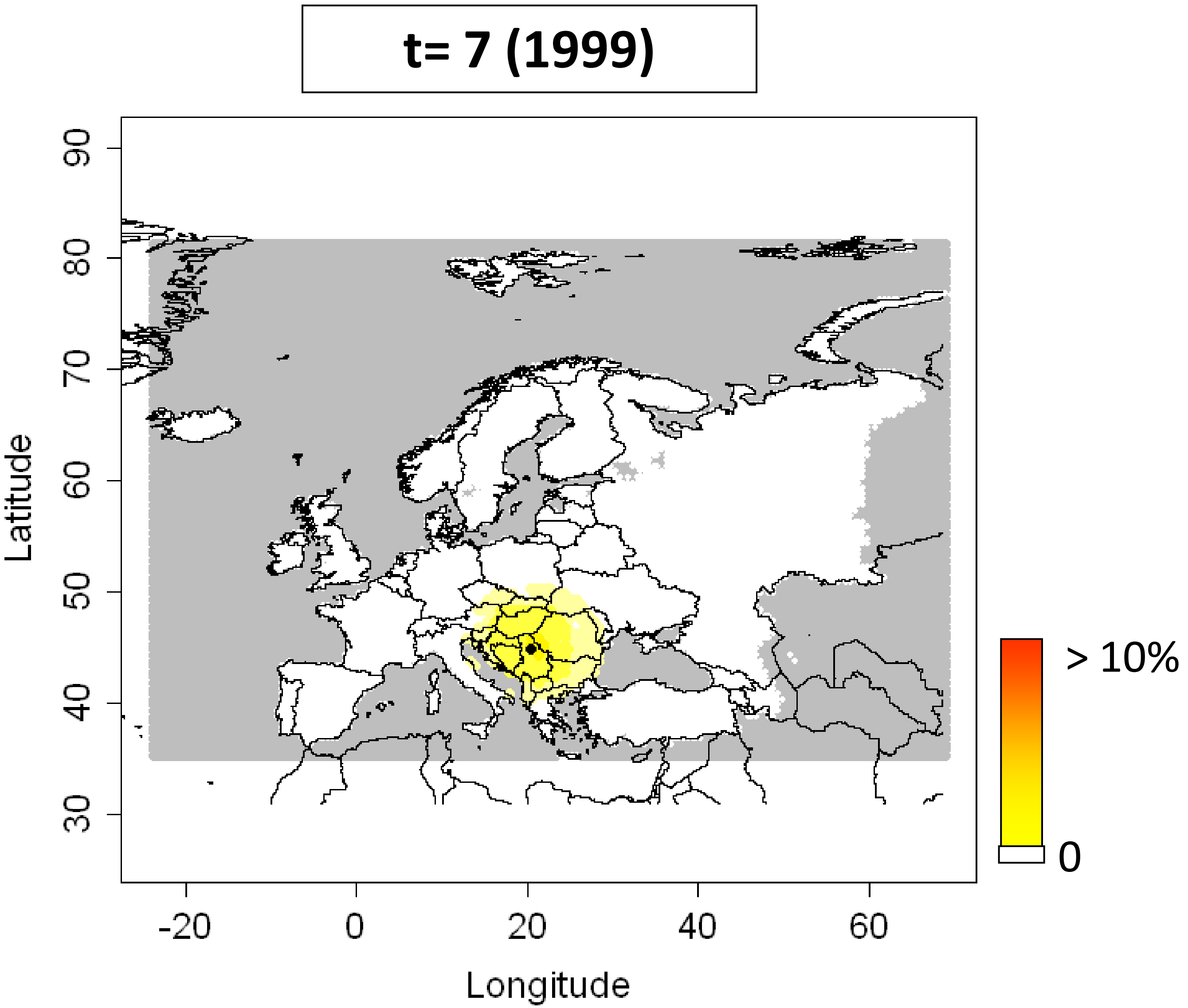
Spatial process models

Model 5. Dispersal kernel model



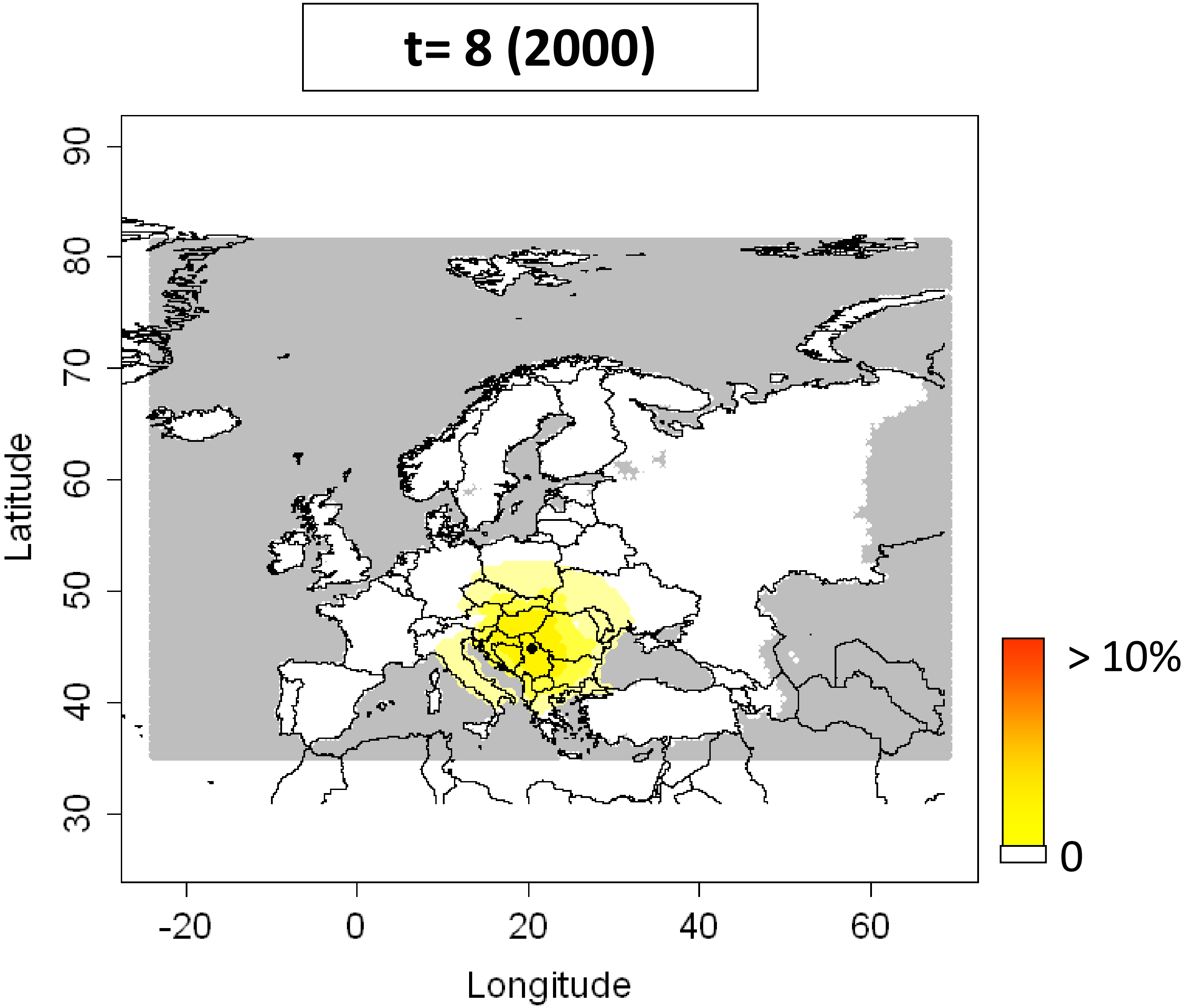
PRATIQUE

Spatial process models
Model 5. Dispersal kernel model



Spatial process models

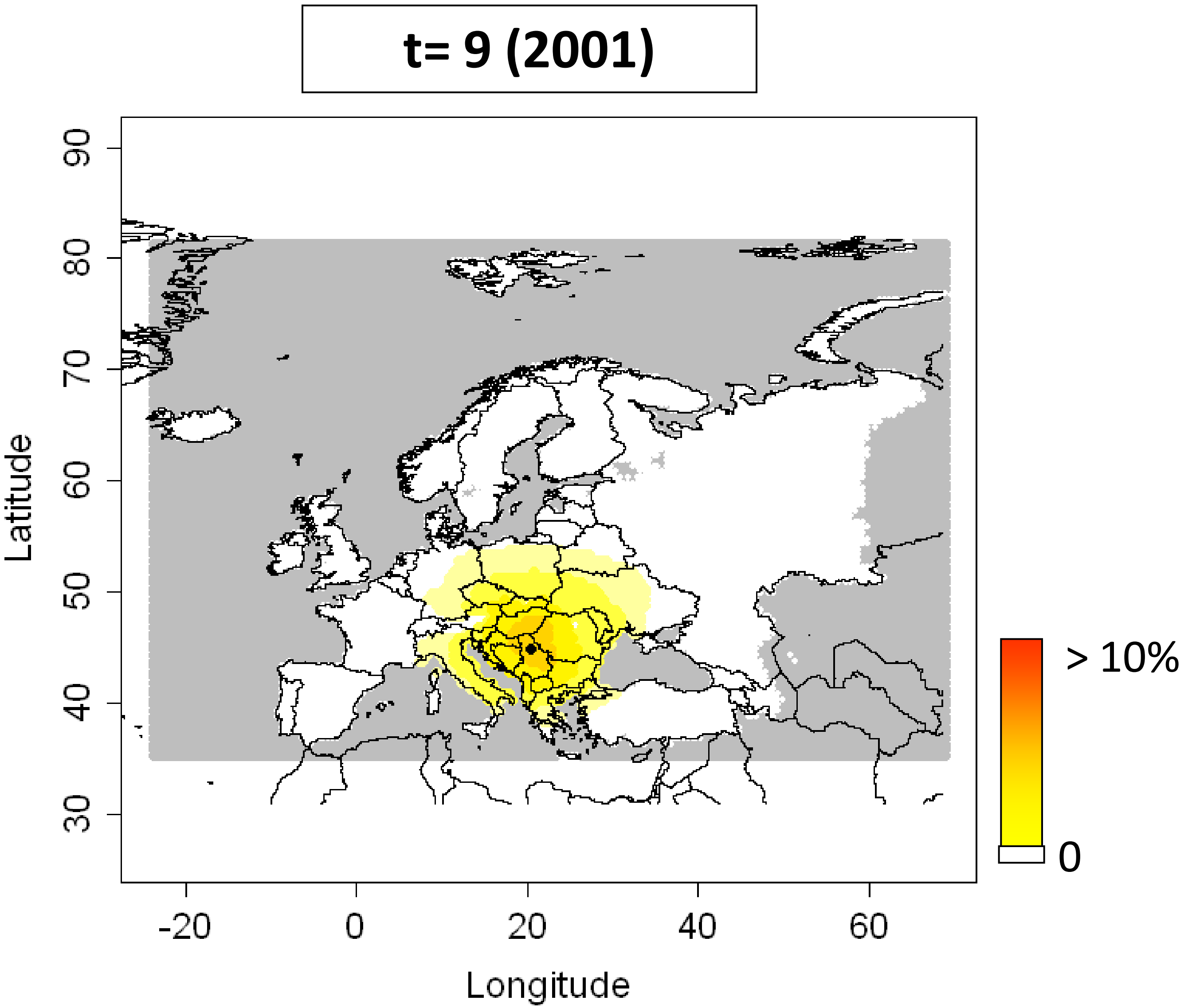
Model 5. Dispersal kernel model



PRATIQUE

Spatial process models

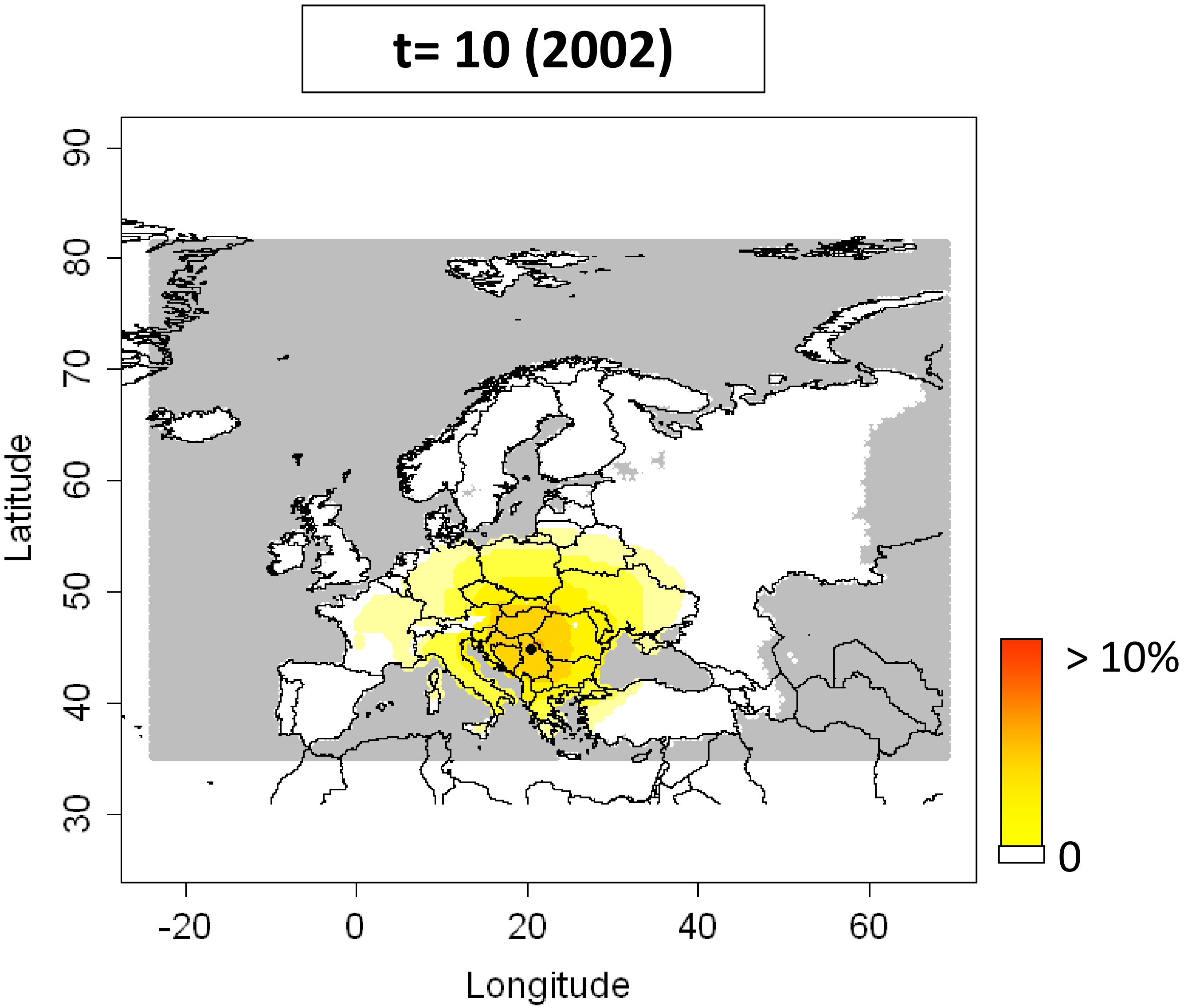
Model 5. Dispersal kernel model



PRATIQUE

Spatial process models

Model 5. Dispersal kernel model

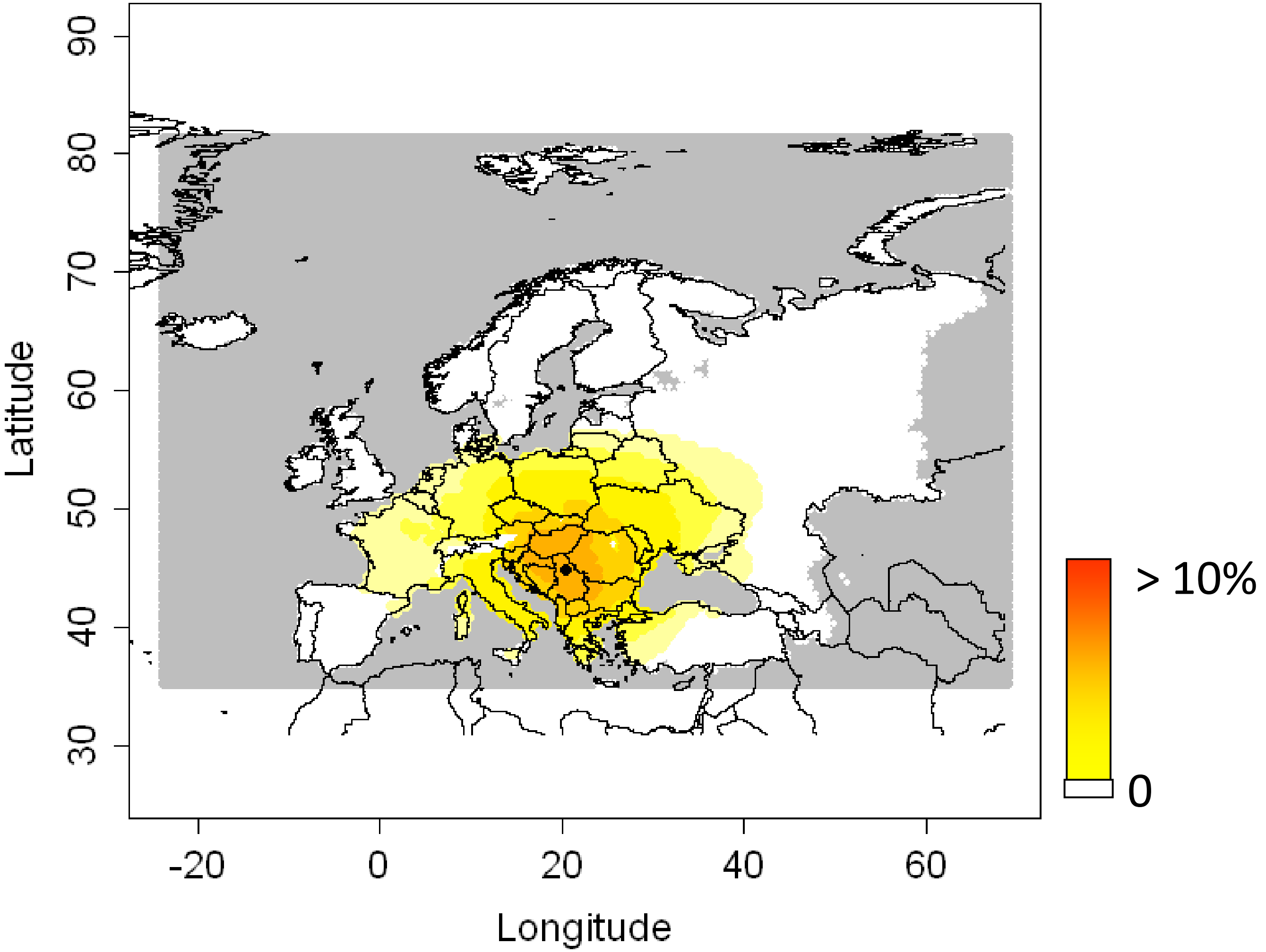


PRATIQUE

Spatial process models

Model 5. Dispersal kernel model

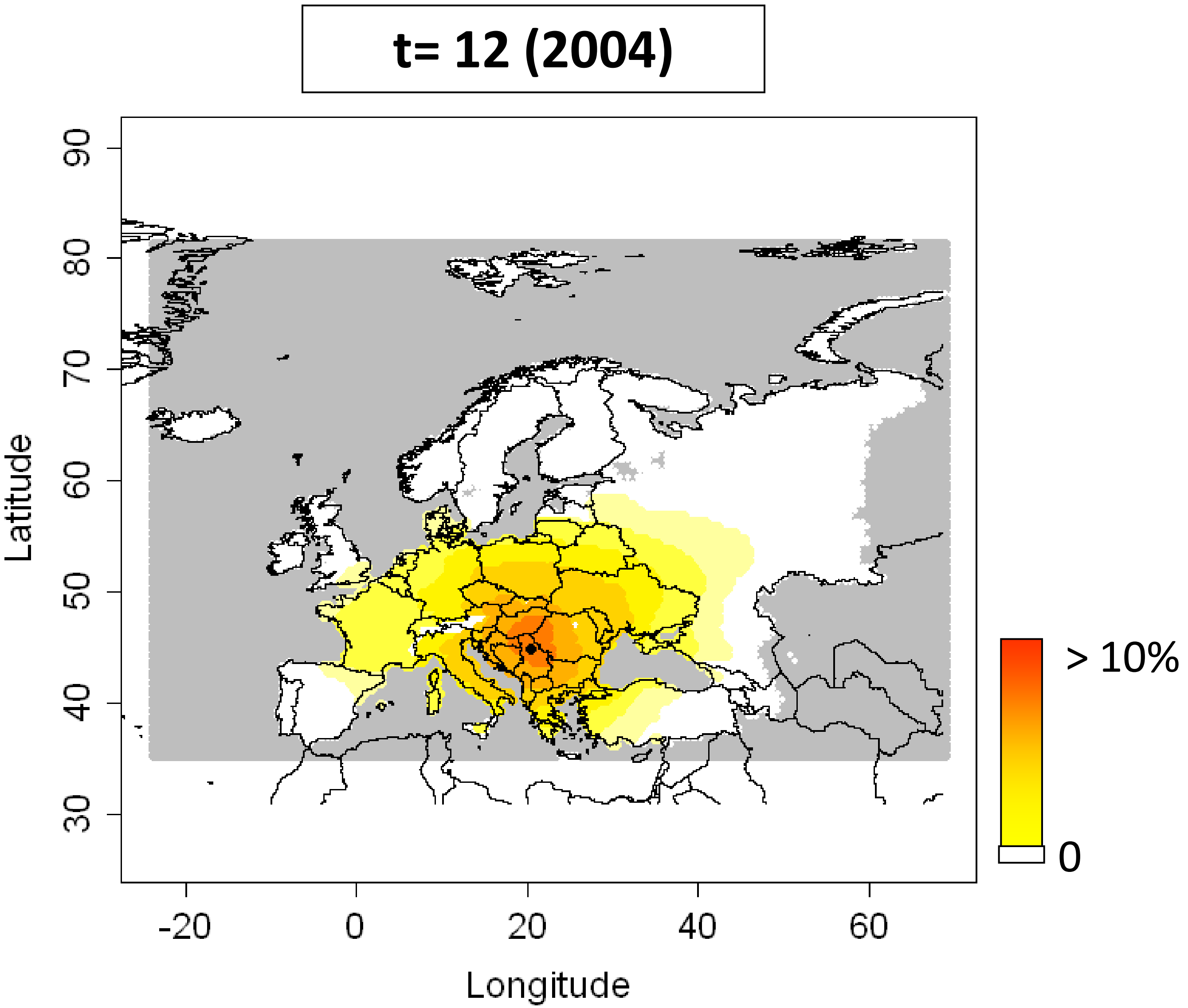
t= 11 (2003)



PRATIQUE

Spatial process models

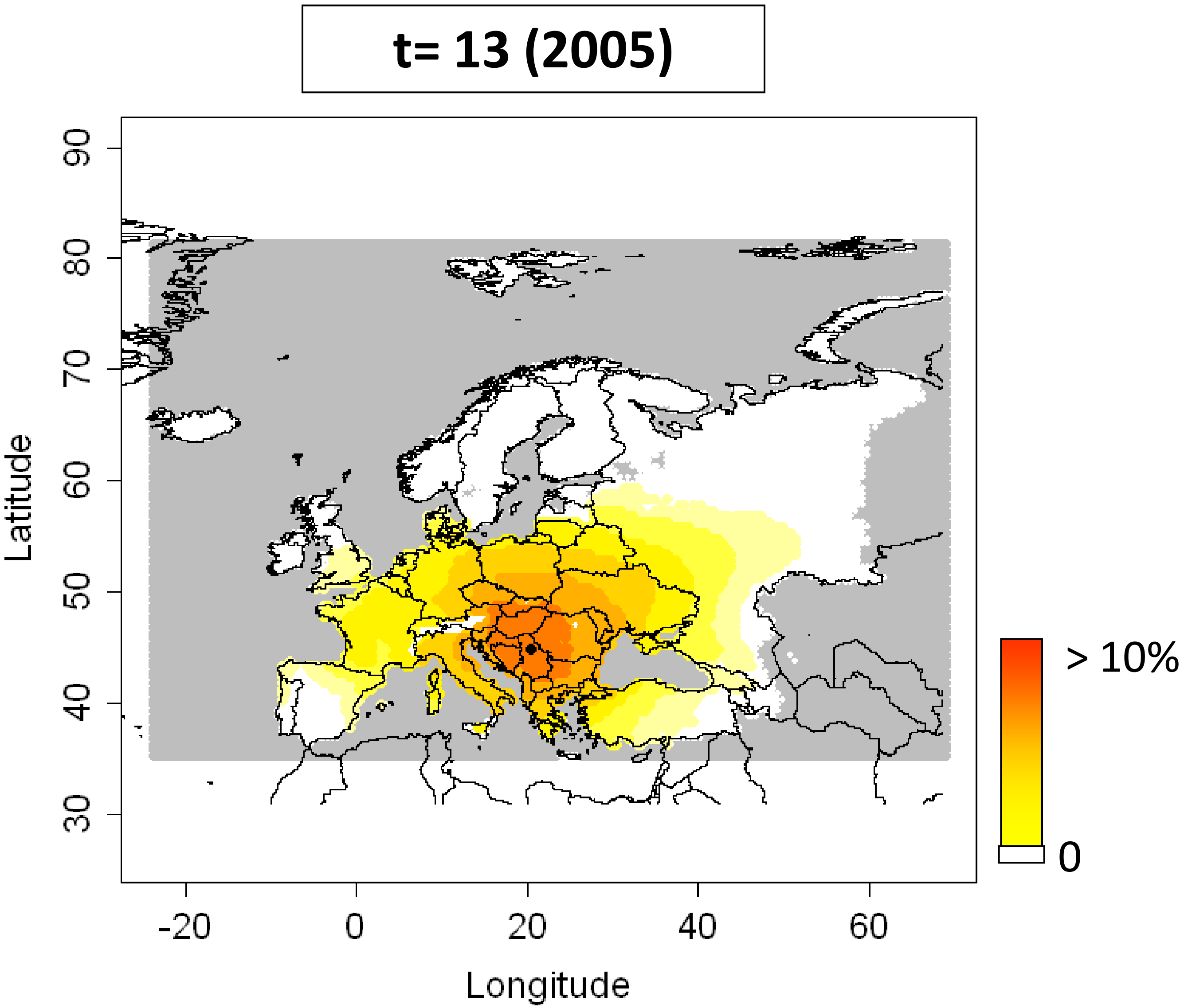
Model 5. Dispersal kernel model



PRATIQUE

Spatial process models

Model 5. Dispersal kernel model

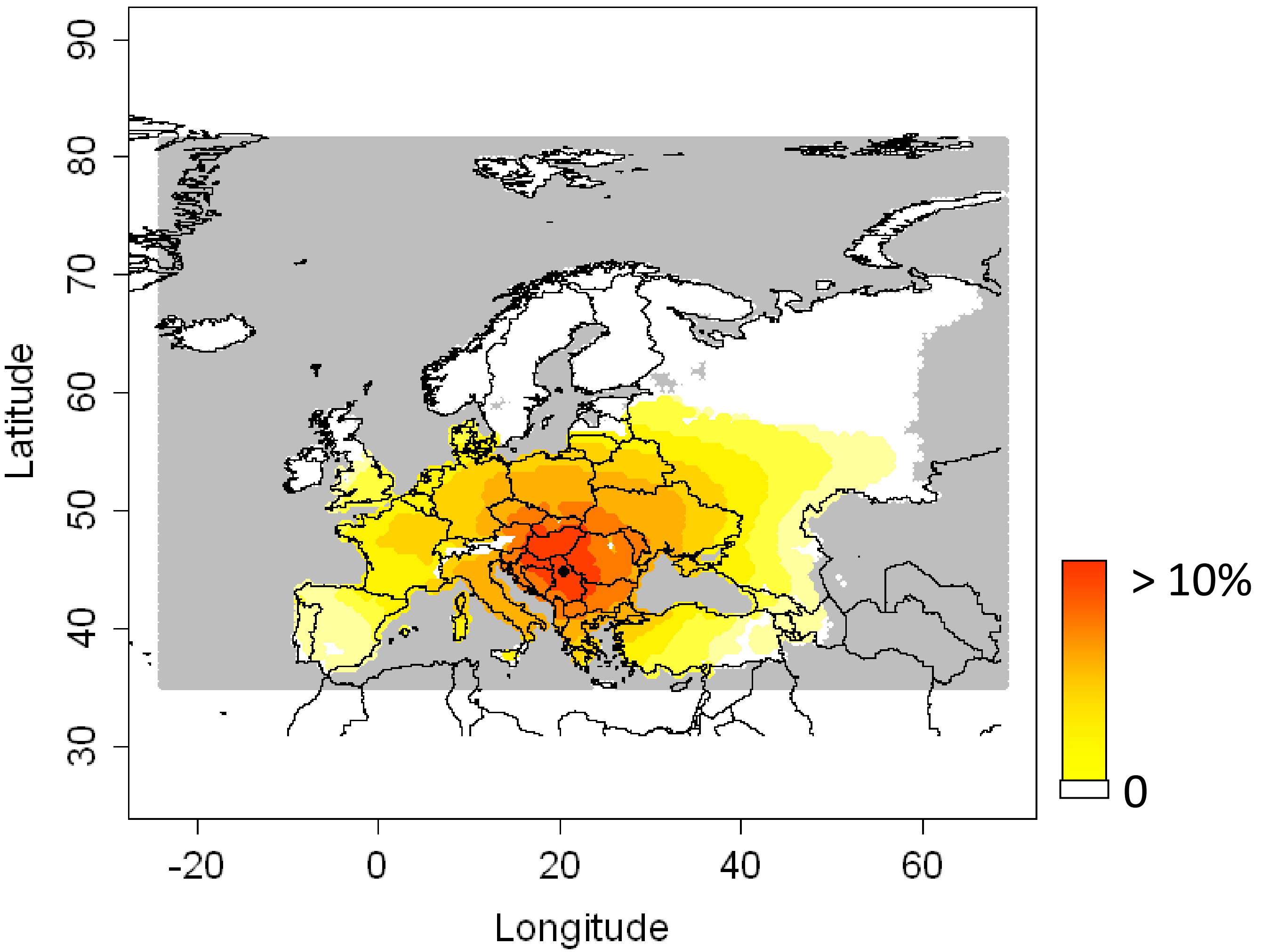


PRATIQUE

Spatial process models

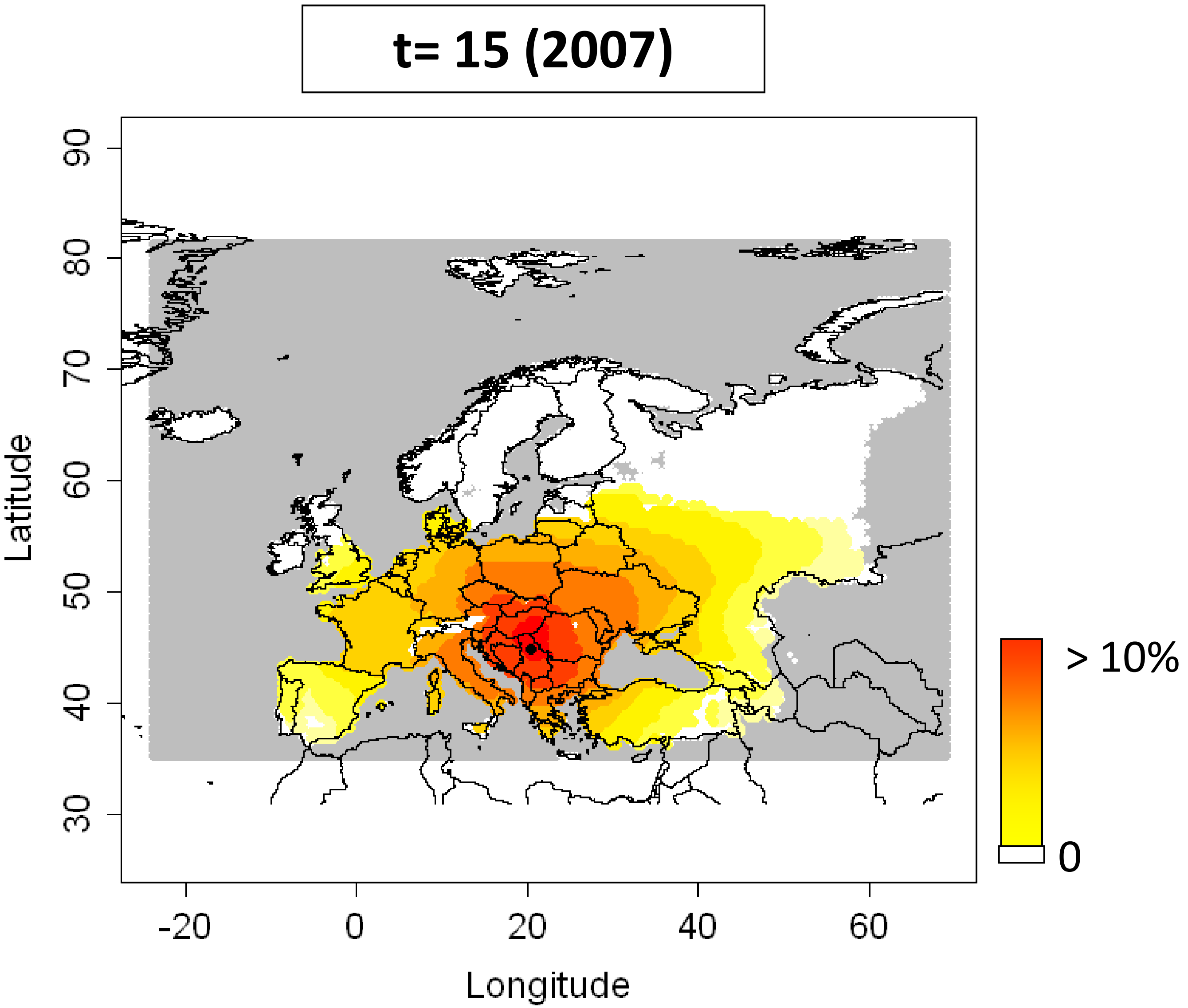
Model 5. Dispersal kernel model

t= 14 (2006)

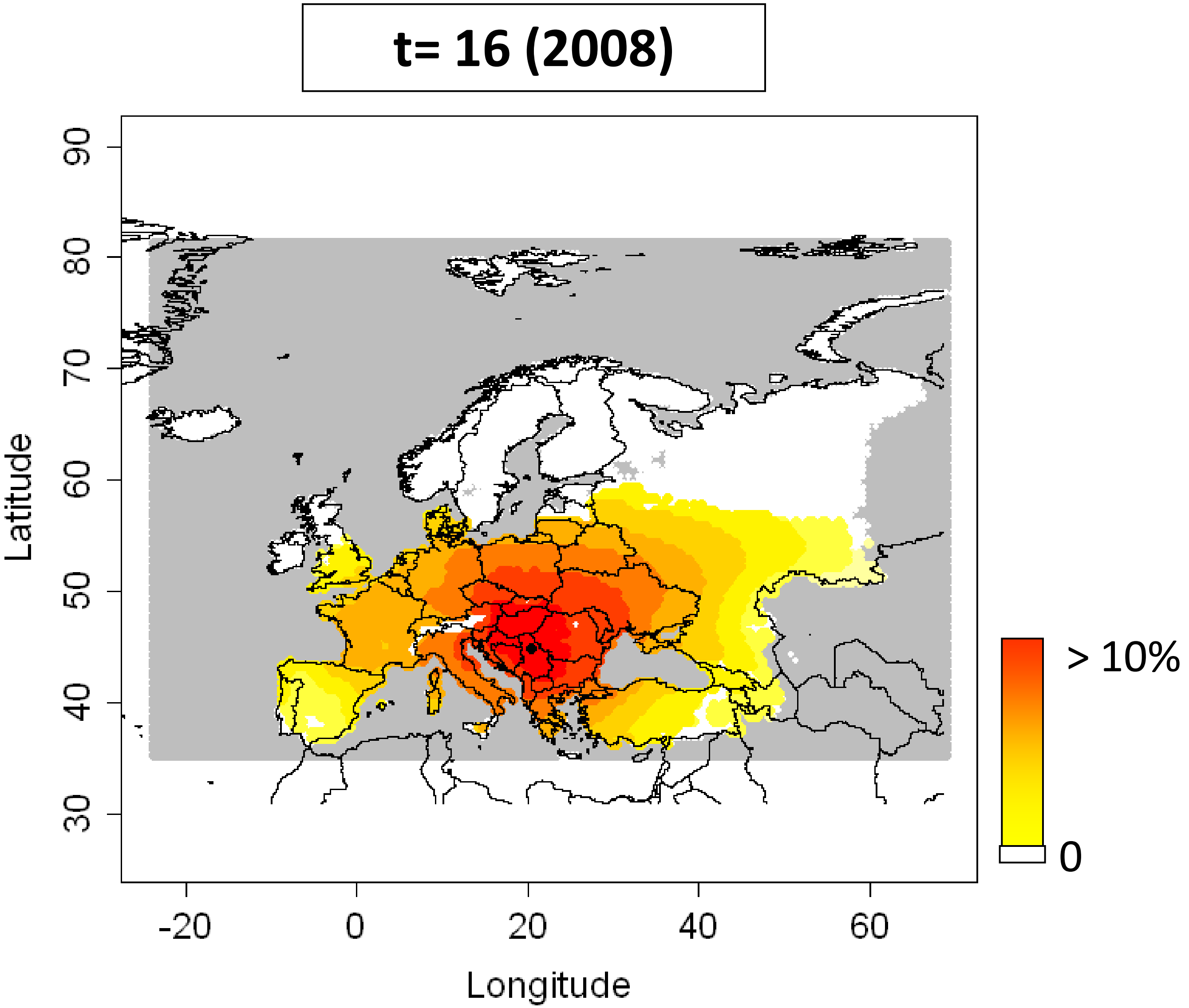


PRATIQUE

Spatial process models
Model 5. Dispersal kernel model

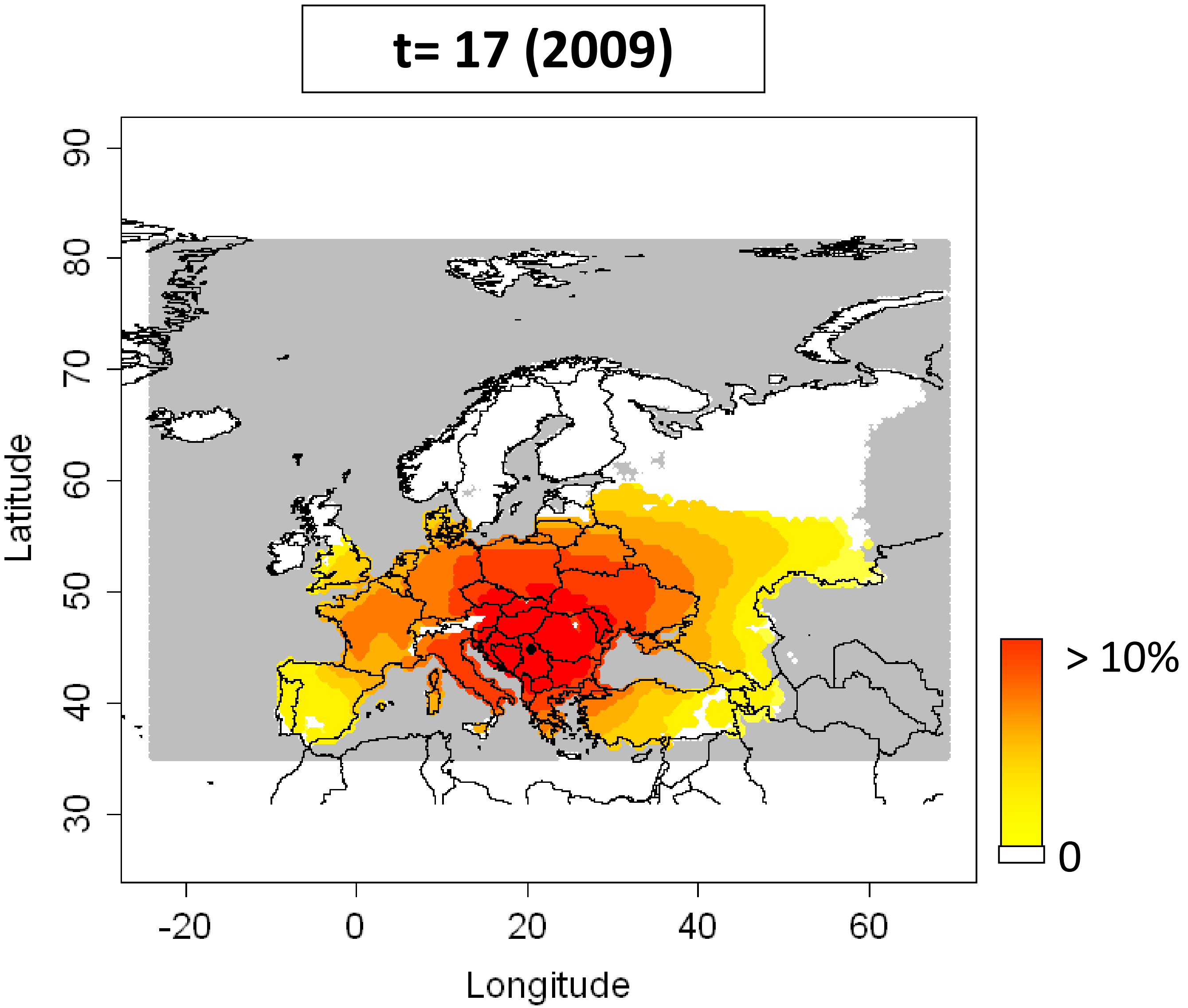


Spatial process models
Model 5. Dispersal kernel model



PRATIQUE

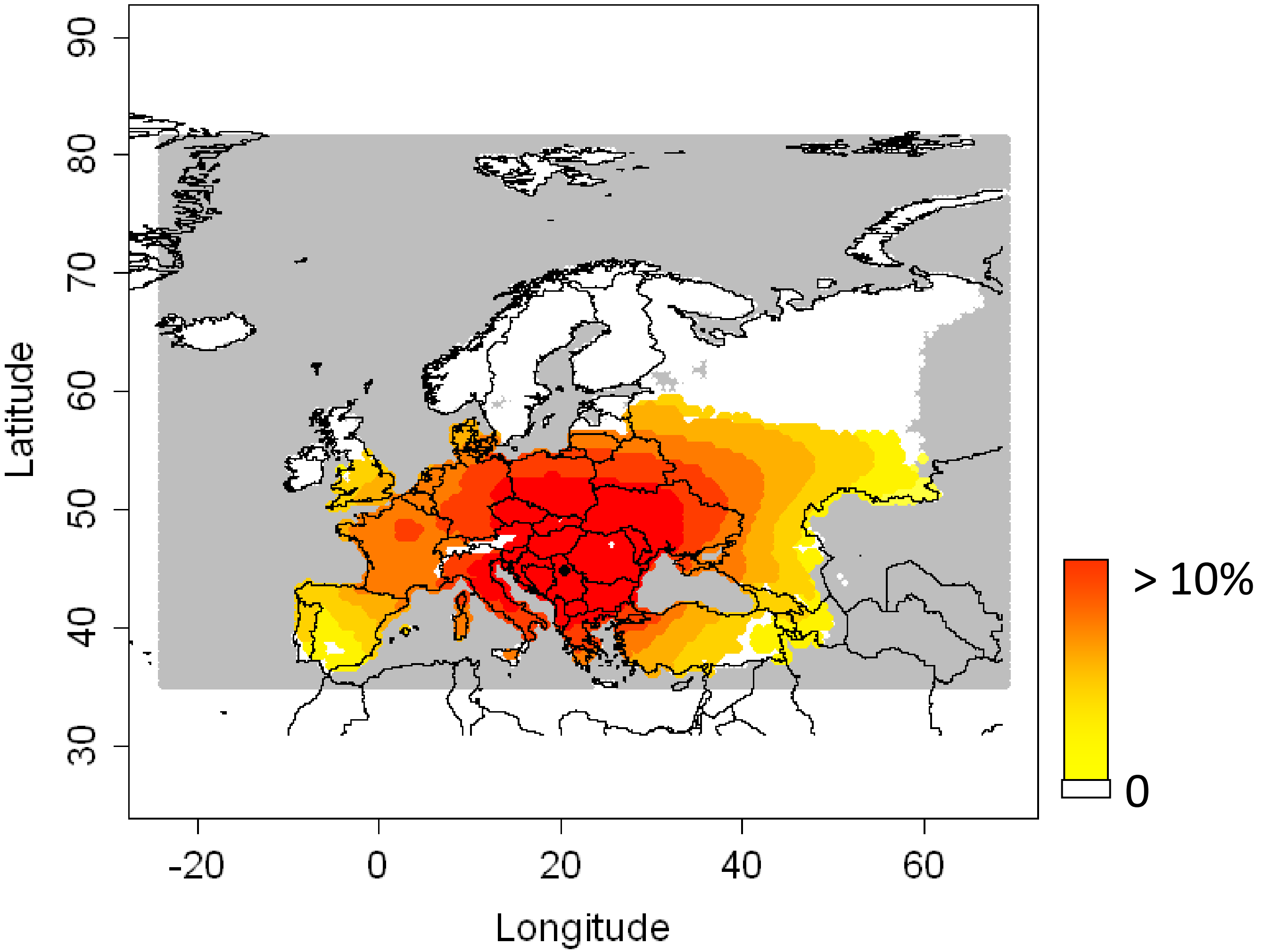
Spatial process models
Model 5. Dispersal kernel model



PRATIQUE

Spatial process models
Model 5. Dispersal kernel model

t= 18 (2010)

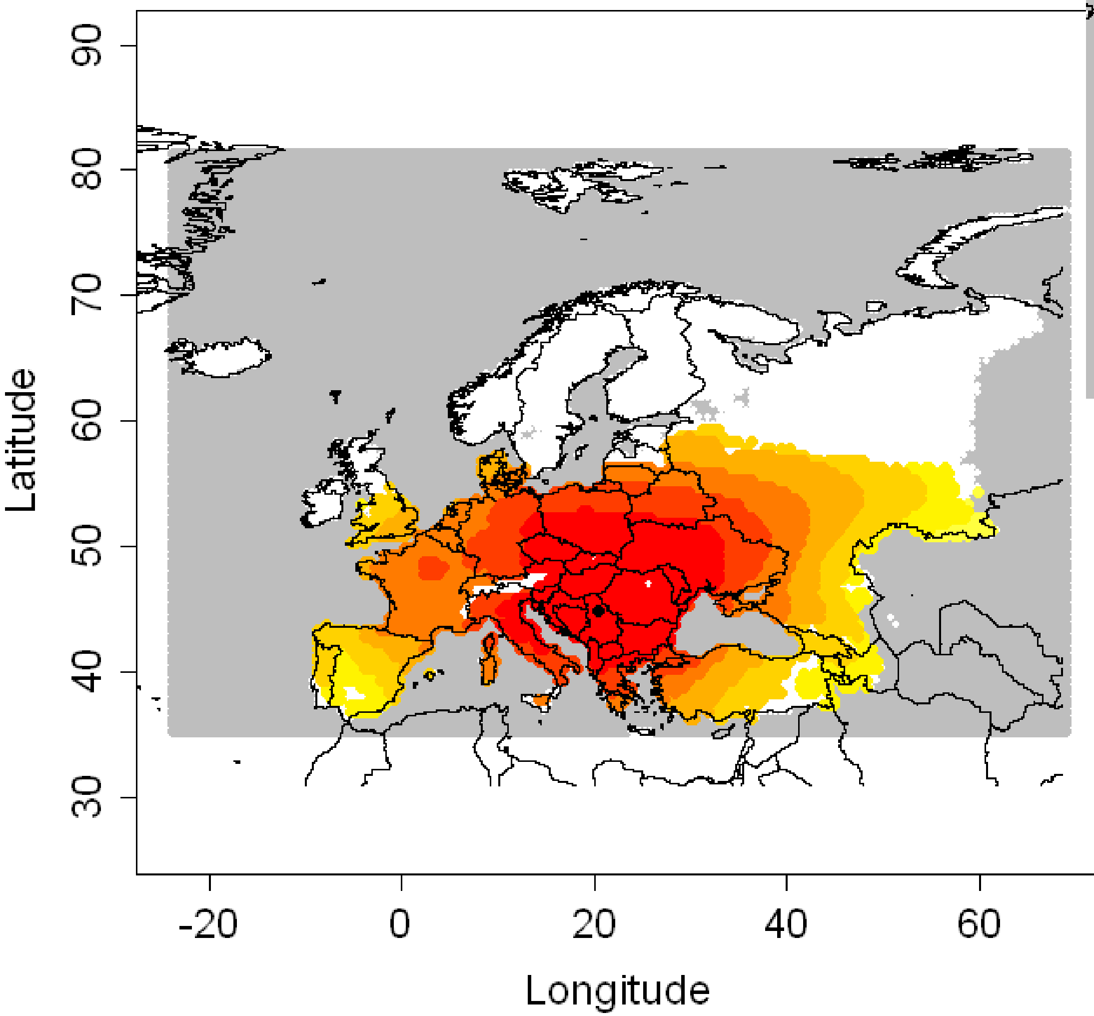


PRATIQUE

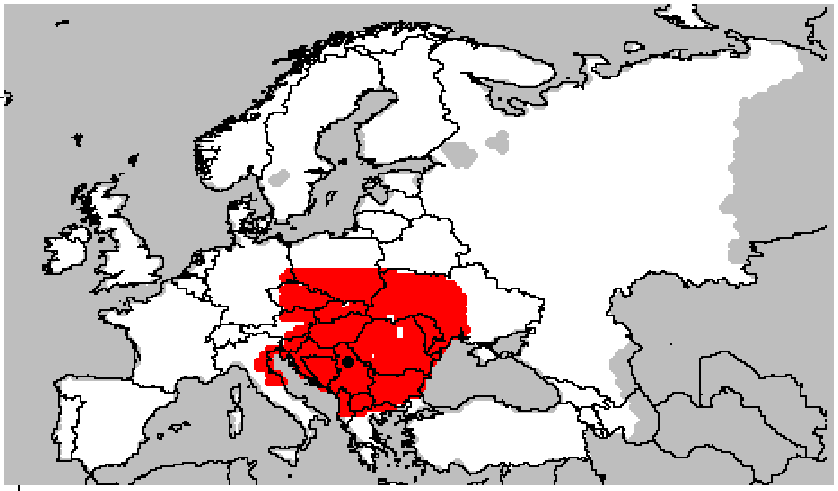
Spatial process models

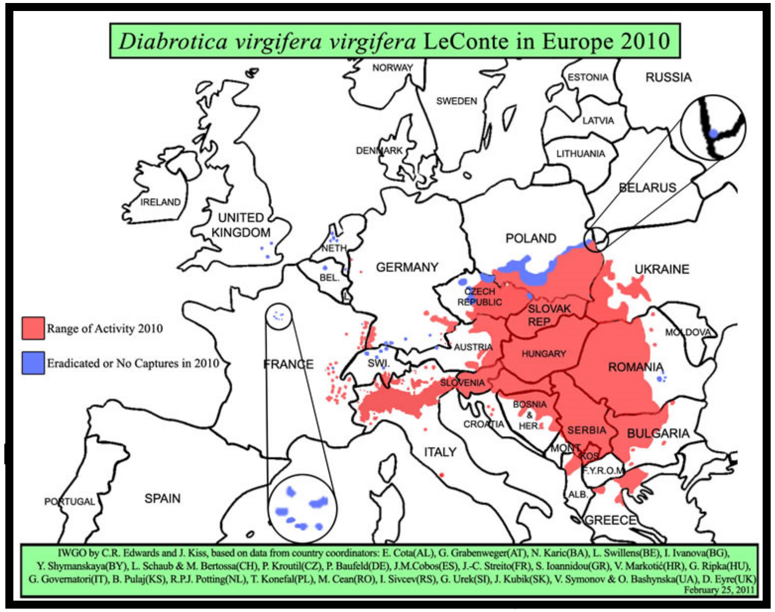
Model 5. Dispersal kernel model

t= 18 (2010)



Population density > 15% of K





Spatial process models

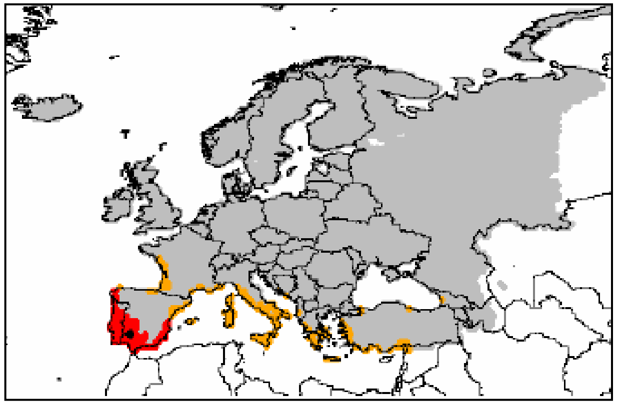
Model 5. Dispersal kernel model

Results

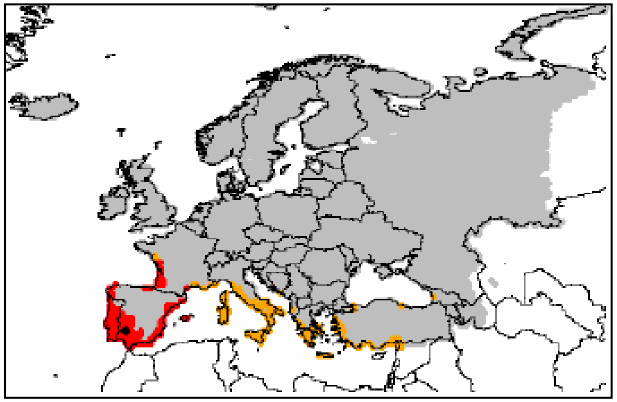
- Most sophisticated model: provides information on the **potential expansion** and **abundance** of a pest
- **Reasonable results** for several tested insect species
- Estimation of shape parameter p:
  needs some time and guidance
- **Takes more time** to run the model (e.g., 12 min in DD version)

3- General comments

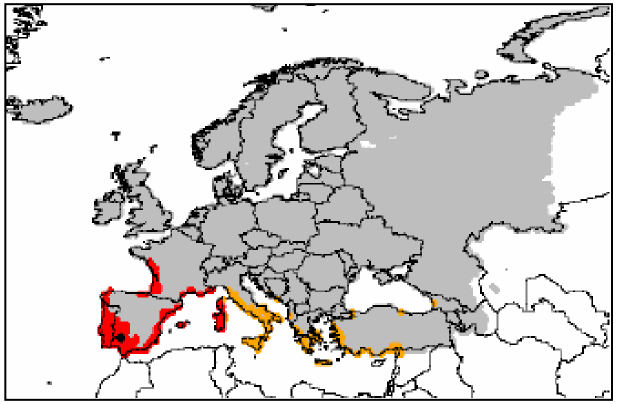
- For each parameter: only one value
- To draw **uncertainty maps**, possible to play on the potential range of the parameters



Best case:
RR = 30 km/yr



Likely case:
RR = 50 km/yr

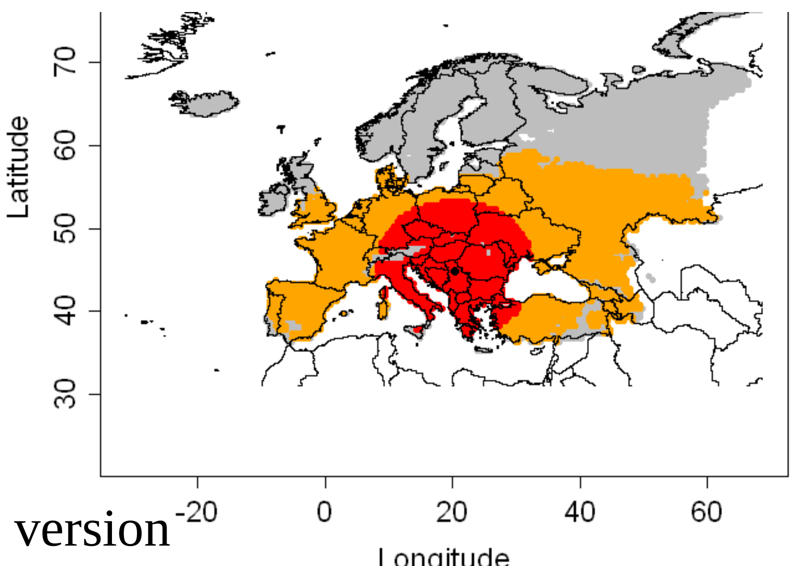


Worst case:
RR = 70 km/yr

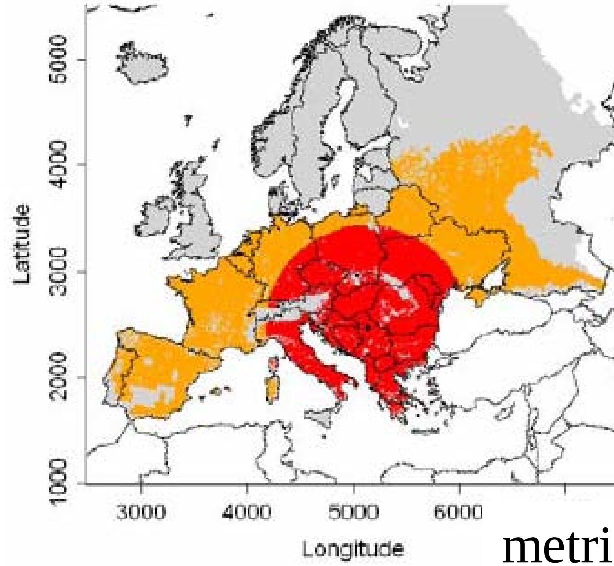
E crassipes case study, 2.6 report, PRATIQUE

3- General comments

- For each parameter: only one value
- To draw **uncertainty maps**, possible to play on the potential range of the parameters
- In practice, **2 versions** of the spread module are available
  - DD version (Decimal Degree)
  - metric version (LAEA – European metric projection)



DD version



metric version

4- Vision for the future

- No universal method to estimate the parameters
  => we should test the spread models on numerous species to **build a database** for risk assessors to choose parameters based on **similar species**
- Analysis of historical cases for **validation** and **guidance**
- Further testing with risk assessors will help us to **improve** the module

5- TAKE-HOME MESSAGE

- **A prototype of spread module is available** for risk assessors to draw scenarios and quantify the potential spread of pests
- This module requires the output of a **CLIMEX** model for the climate suitability
- **Uncertainty maps** can be generated showing the best, most likely and worst cases.
- The outputs can be exported and **combined to other risk maps** (in MCAS, see Richard Baker's presentation)

Would you like to use/test the spread module ?

Contact me: christelle.robinet@orleans.inra.fr

Your feedback is welcome

Acknowledgements:

Darren Kriticos, Maxime Dupin, Zhenya Ilieva, Olia Karadjova, Sarah Brunel, Andrea Battisti, Massimo Faccoli, Dominic Eyre, Marc Kenis, Annie Yart, Philippe Reynaud, Johan Bremmer, Annemarie Breukers, Jon Knight, Alan MacLeod and Richard Baker

Participants of the EPPO workshop on PRAs in Hammamet (Tunisia, Nov 2010) who tested the spread module.

The financial support from the EU project PRATIQUE.

PRATIQUE