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24 July 2012



Why use simple models in pest risk analysis?

- Conceptually transparent
- Generic, applicable to many classes of organisms
- Easier to collect relevant data (easier, not easy)
- Amenable to inverse modelling for parameter estimation and model comparisons
- Quicker in application setting

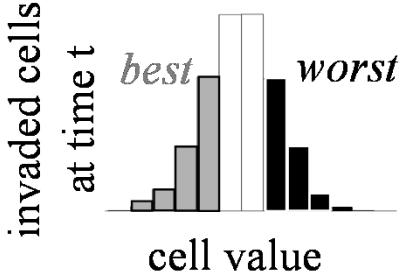
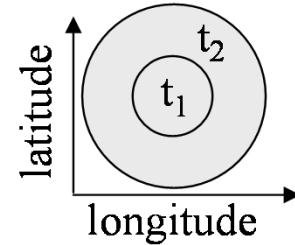
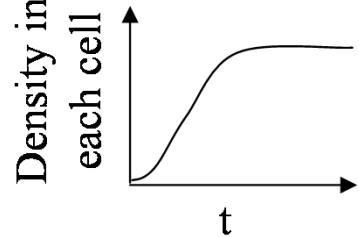
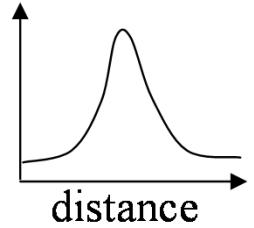
Our approach in the EU project PRATIQUE

- Different models for different objectives: a **suite of models**
- Develop concepts, program model codes in R, and apply models in case studies with experts
- Elicit expert opinion on ease-of-use, uncertainty, and potential usefulness of models

Kehlenbeck H, Robinet C, van der Werf W, Kriticos D, Reynaud P, Baker R (2012) Modelling and mapping spread in pest risk analysis: a generic approach. EPPO Bulletin, 42, 74–80. doi: 10.1111/j.1365-2338.2012.02550.x.

Robinet C, Kehlenbeck H, Kriticos DJ, Baker RHA, Battisti A, Brunel S, Dupin M, Eyre D, Faccoli M, Ilieva Z, Kenis M, Knight J, Reynaud P, Yart A, van der Werf W (2012) A suite of models to support the quantitative assessment of spread in pest risk analysis. PLoS ONE, in press.

Four models

Model dimension	Time	Time + space
Output variable		
Presence / absence	invaded cells at time t 	
Population density	Density in each cell 	Probability to disperse at each time t 

All models run on spatial maps representing climate suitability, and habitat availability and quality

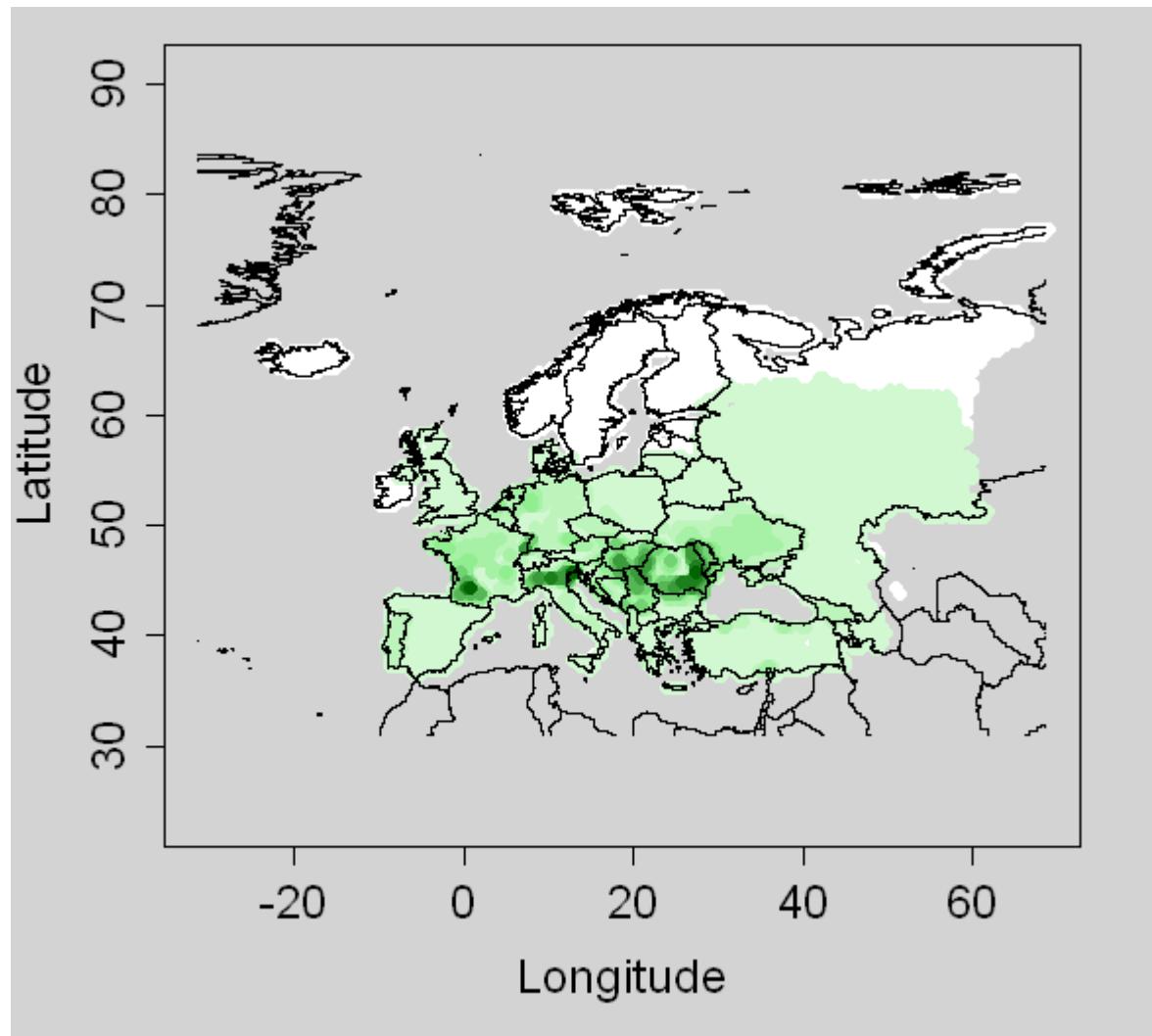
- Climatic suitability (CLIMEX outputs)
- Host, habitat or soil data (as appropriate)
- An elevation limit (as appropriate)

For example: western corn rootworm
Diabrotica virgifera

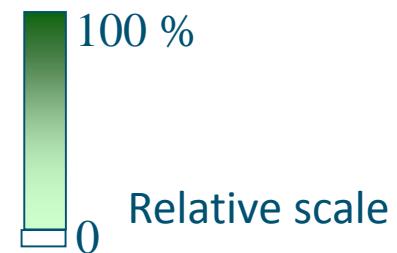


Source: Mihaly Czepo/ www.biosicherheit.de

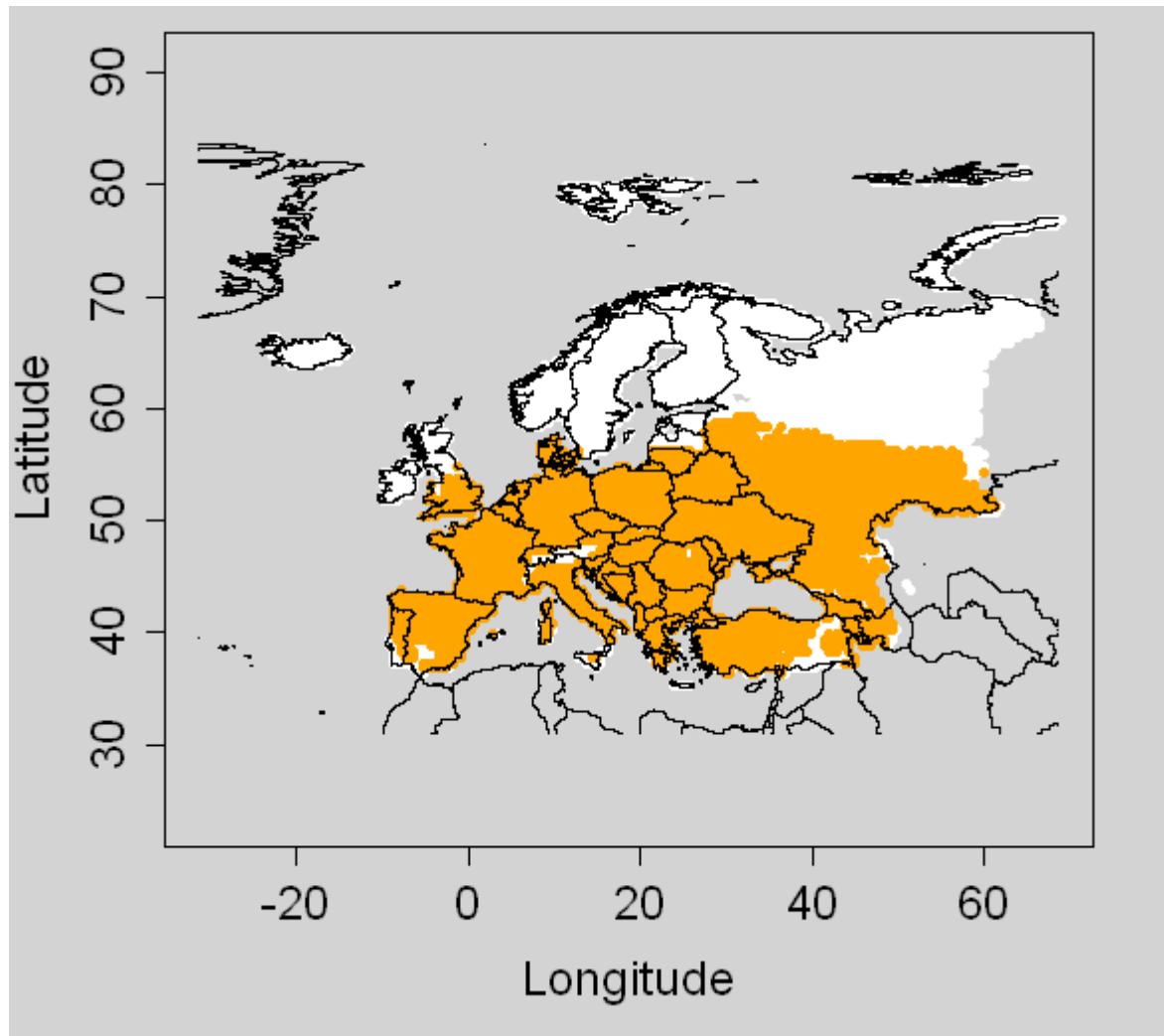
Host distribution for *Diabrotica virgifera*



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



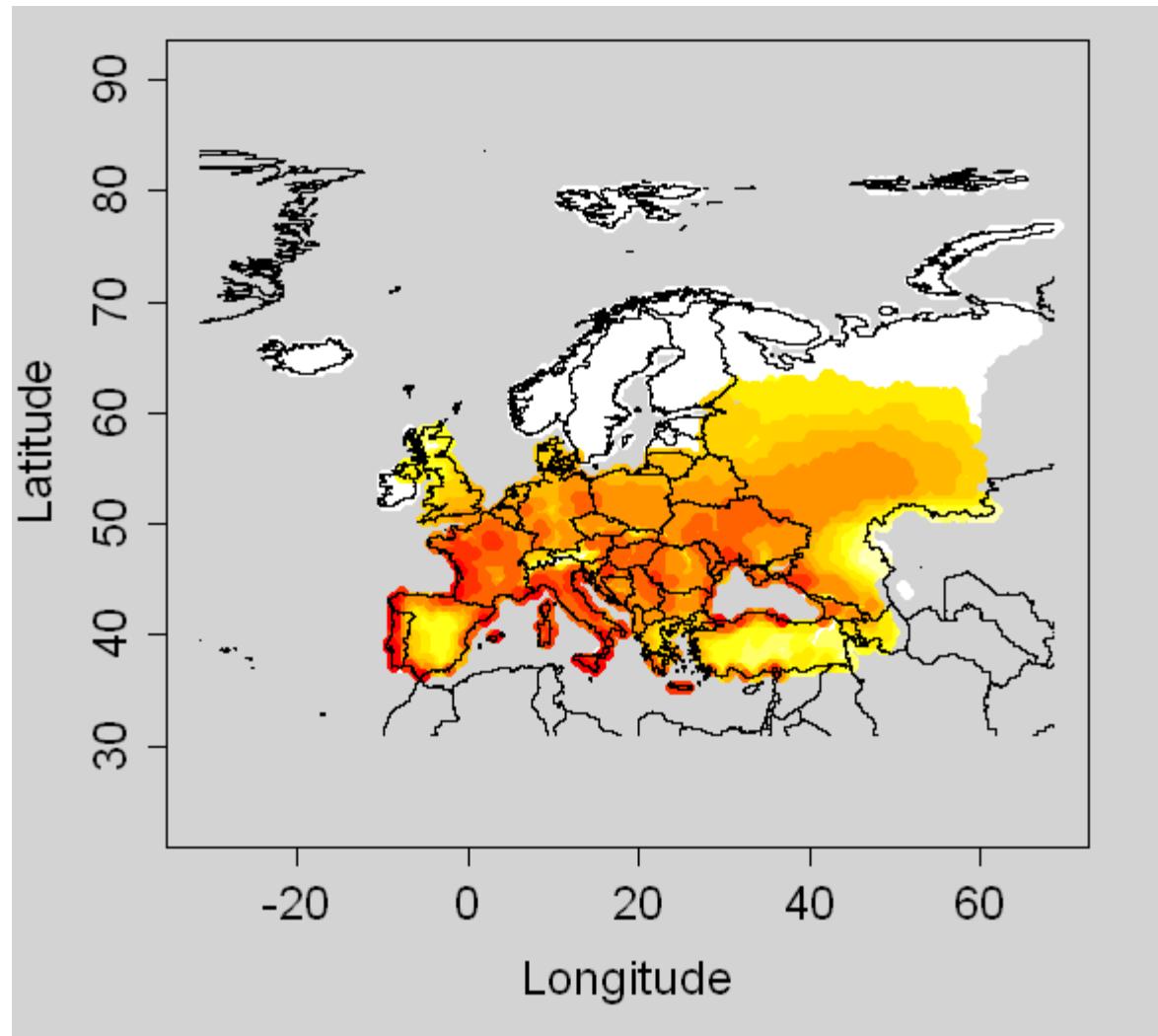
Area of potential establishment for *Diabrotica virgifera*



Area where

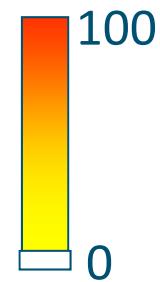
- 1) Host is present
(Grain+forage maize,
McGill University)
- 2) Ecoclimatic Index>0
(CLIMEX model,
P. Reynaud and D. Kriticos)

Population growth potential for *Diabrotica virgifera*



**CLIMEX Growth Index GI
re-scaled from 0 to 100**

CLIMEX model: P. Reynaud
and D. Kriticos, EPPO Bull.
2012



Presence/absence models

- A. Time: logistic increase in number of invaded cells
- B. Time and space: radial range expansion

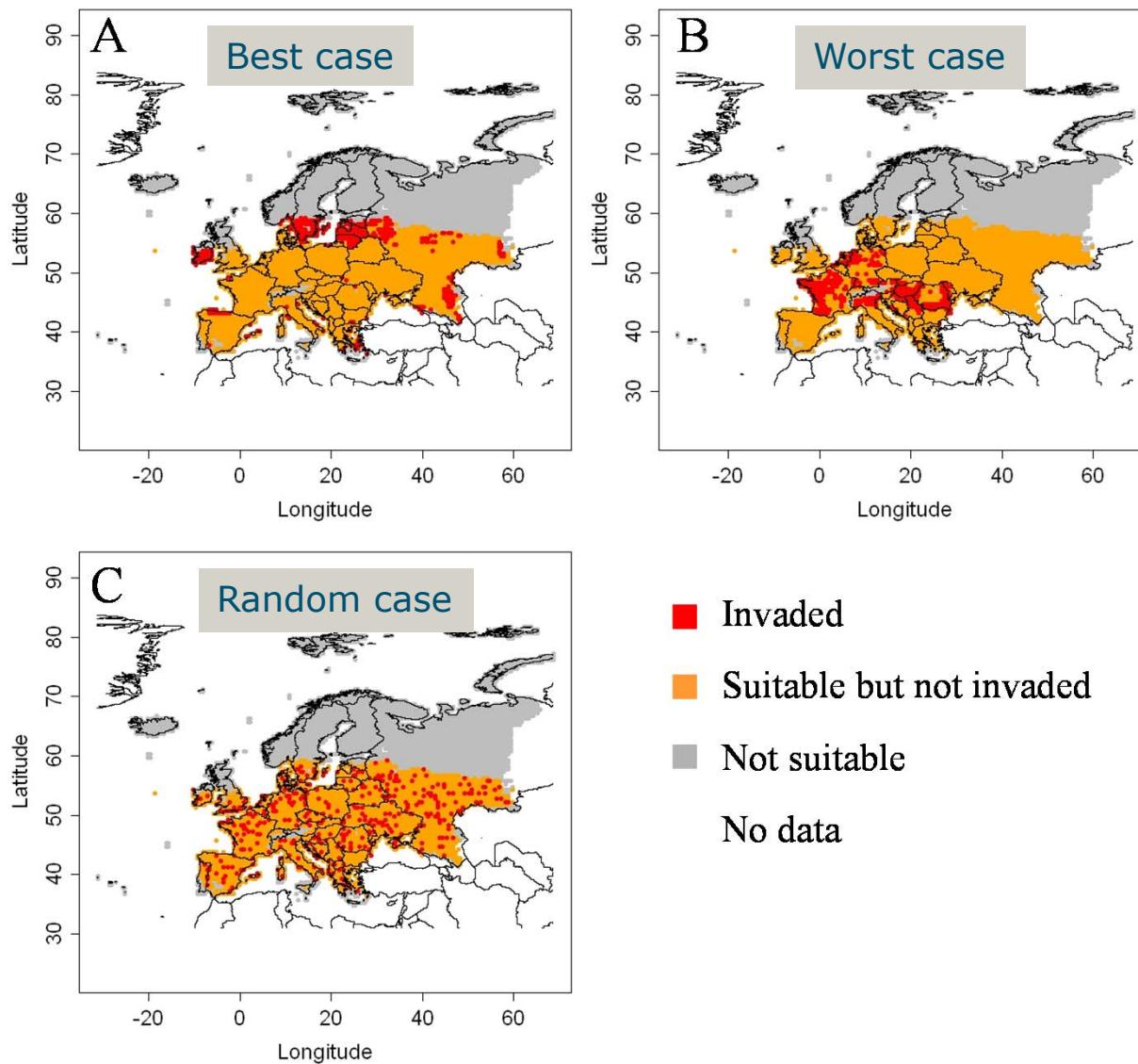
Model A

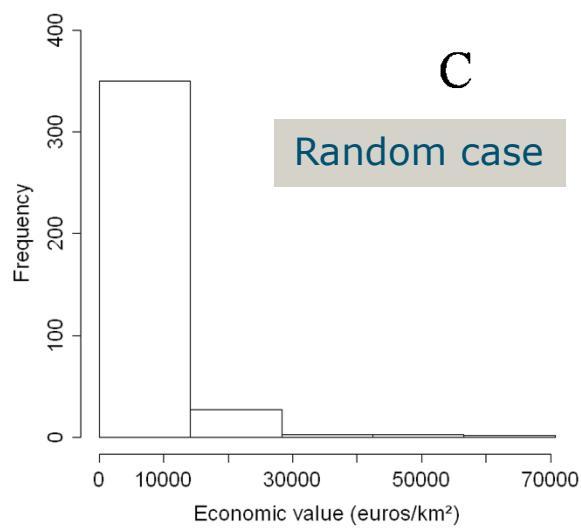
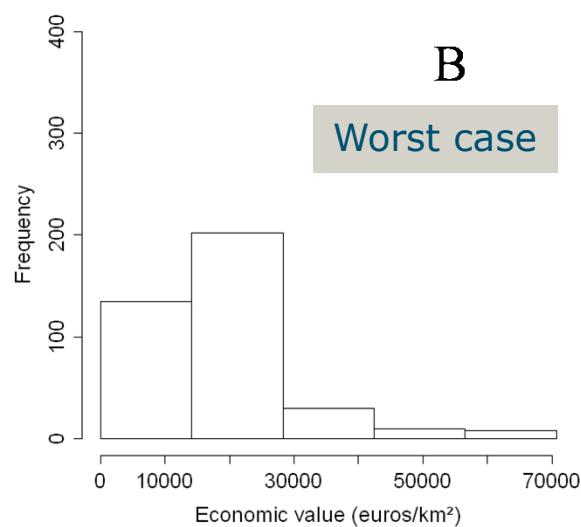
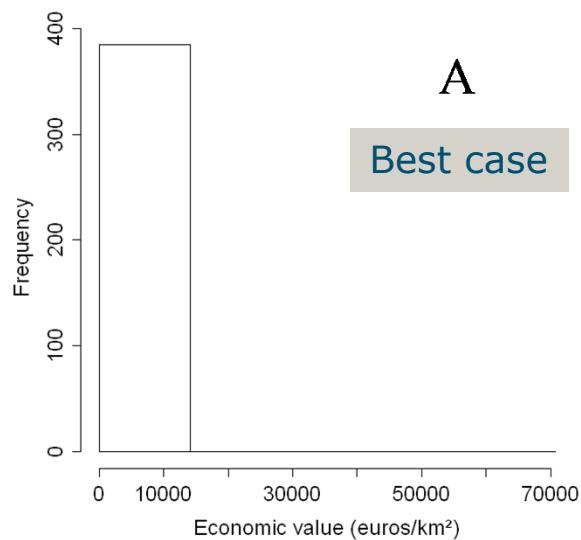
- Logistic growth of the number of invaded “cells” in Europe as a function of time.
- Required inputs:
 - Initial proportion of invaded cells within the area of potential establishment
 - Relative rate of increase of the number of invaded cells
 - If available: spatial data on value of assets per cell can be taken into account

Three economic scenarios

- A. Best case: cells with lowest value of assets are invaded first
- B. Worst case: cells with highest value of assets are invaded first
- C. Random case: cells are invaded randomly across Europe

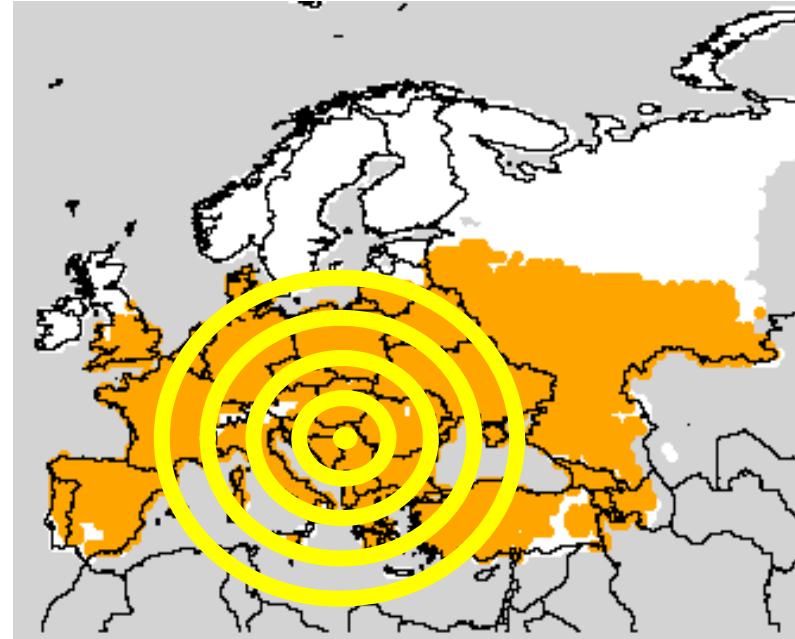
These scenarios give insight in the sensitivity of continental scale impact to *where* the spread is taking place. They do not realistically represent the biological process of spread (Models B and D are more suitable for that)

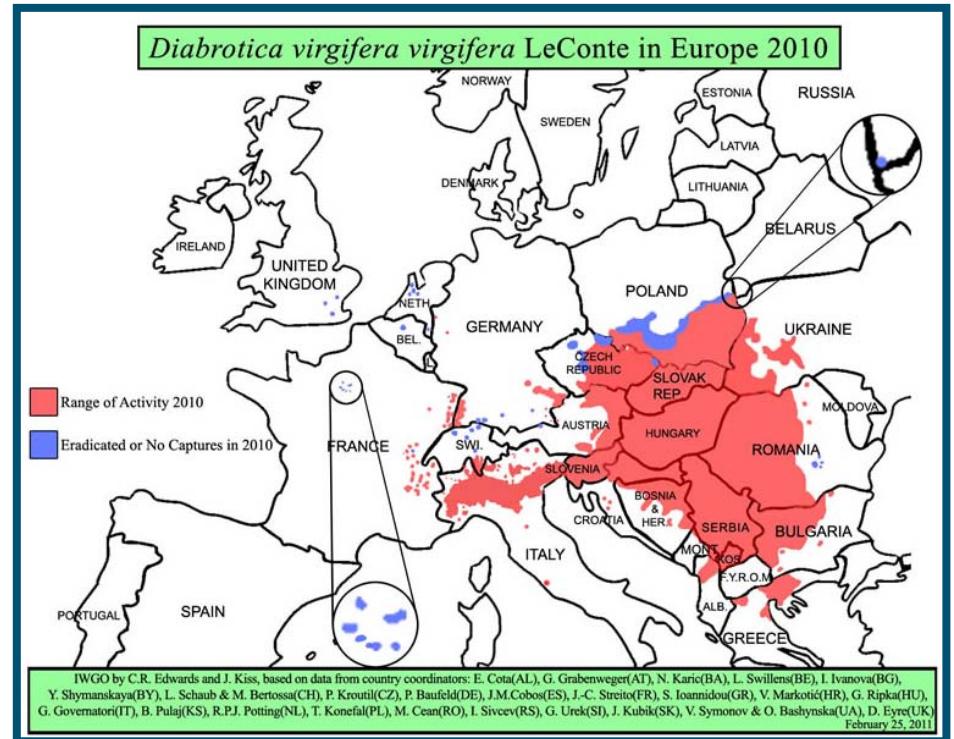
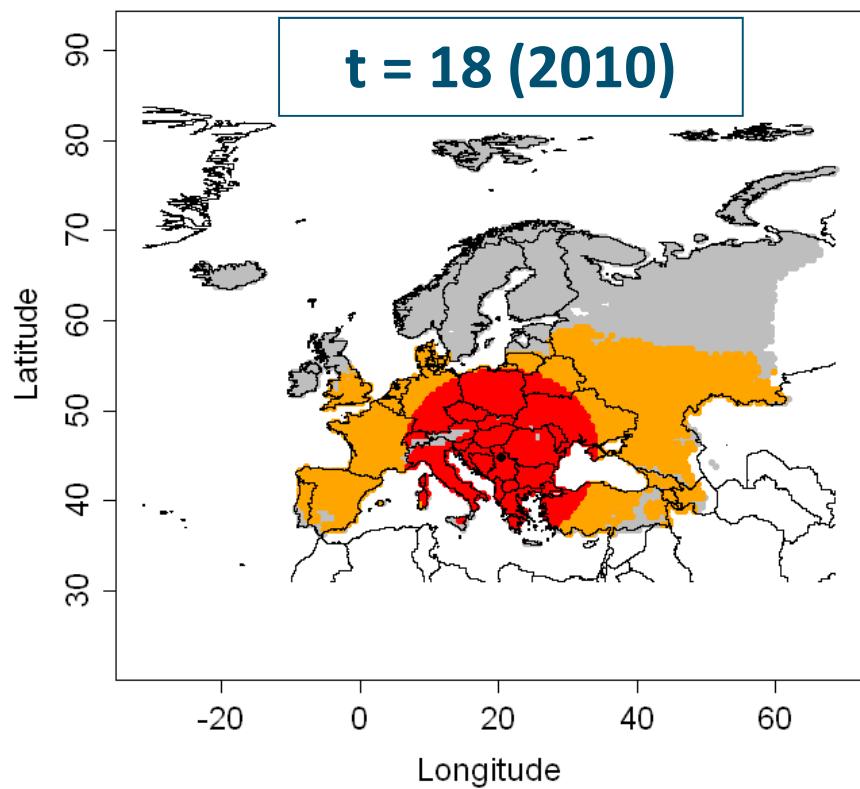




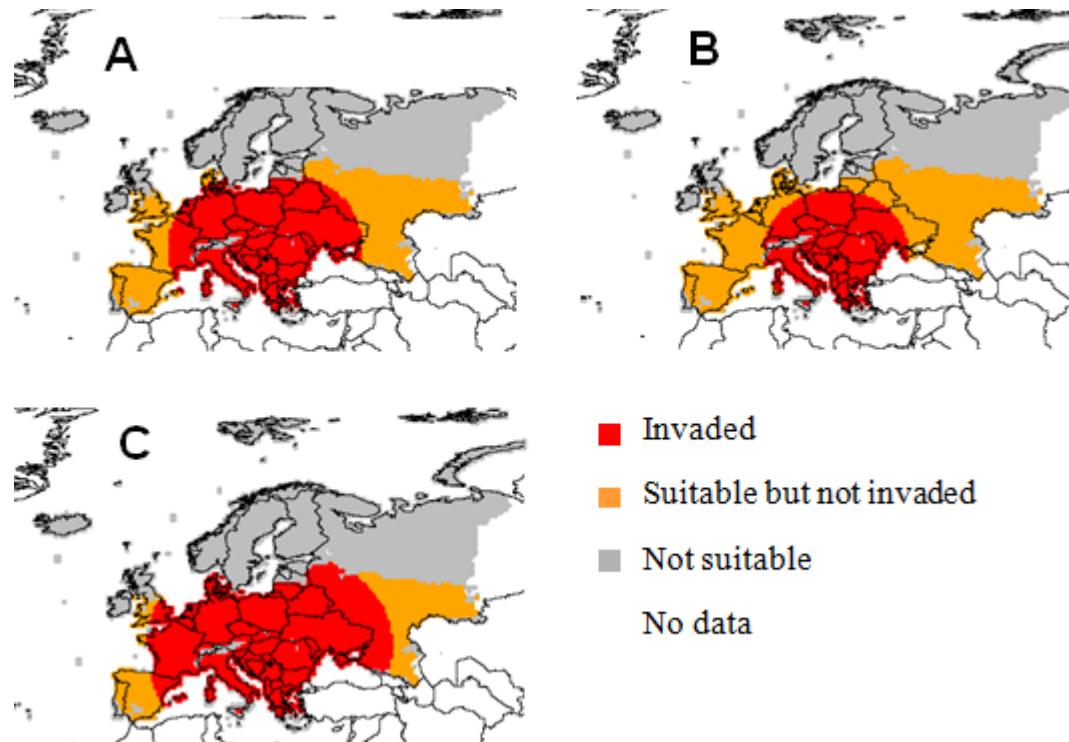
Model B

- Presence/absence – time & space
- Radial rate expansion
- Required inputs:
 - Rate of radial rate extension (km/year)
 - Entry point(s)





Rate of range expansion = 60 km/year
Point of entry: Belgrade (Serbia) (in 1992)



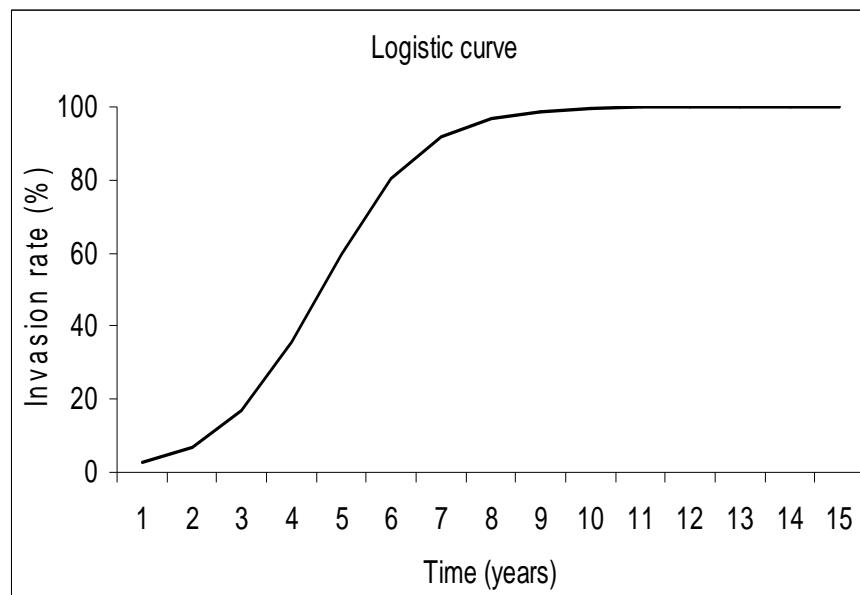
Spread simulation of *Diabrotica virgifera virgifera* for the year 2010 using model B for (A) the baseline value of c (80 km/yr), (B) the best case (- 25%), and (C) the worst case (+25%).

Density models

- C. Time: logistic increase in density in each cell
- D. Time and space: local logistic growth in combination with spatial dispersal

Model C

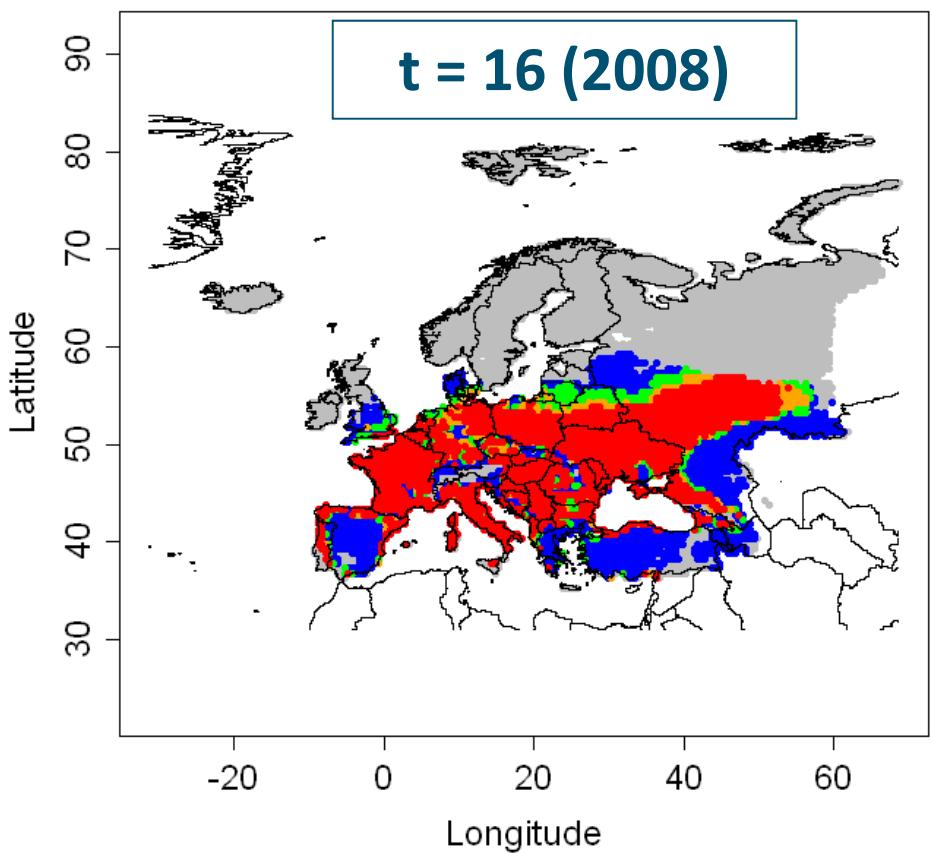
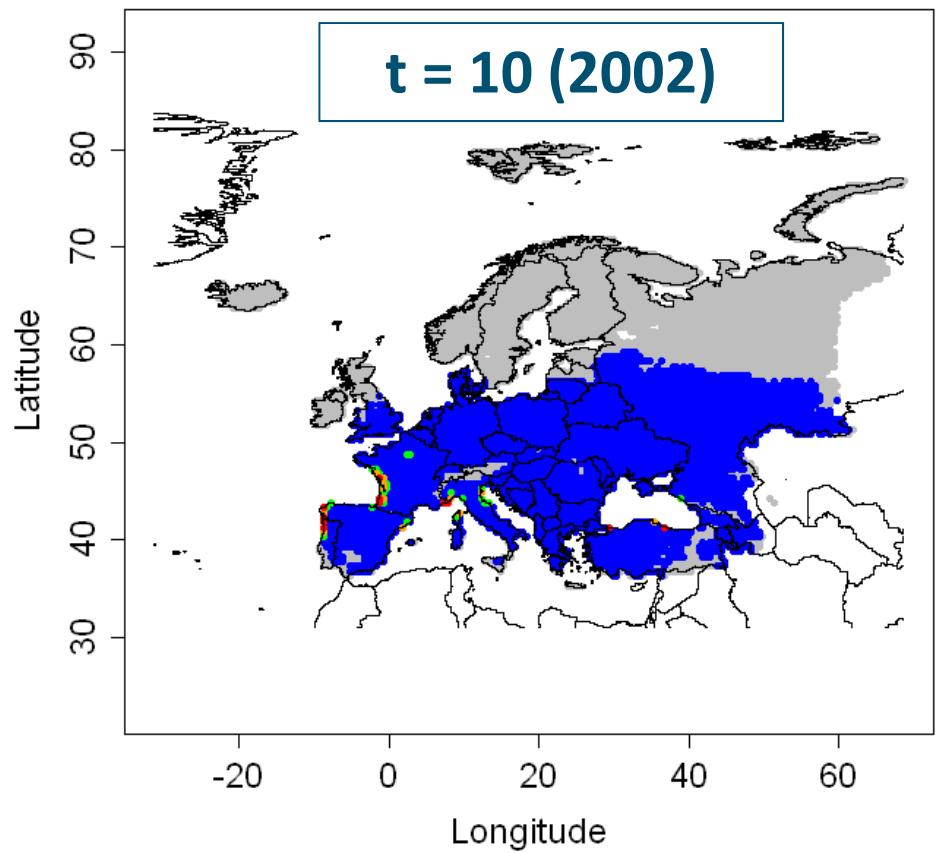
- Pest density – time
- Logistic growth of density
- Within each cell, the increase of the population is calculated with a logistic growth function



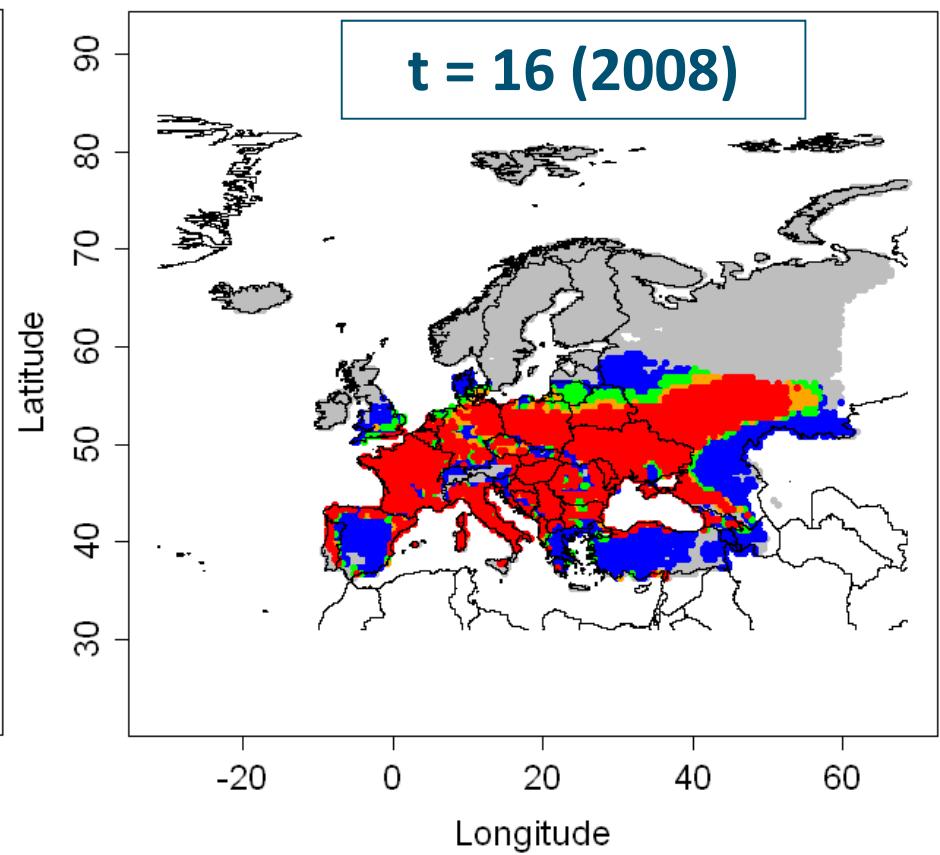
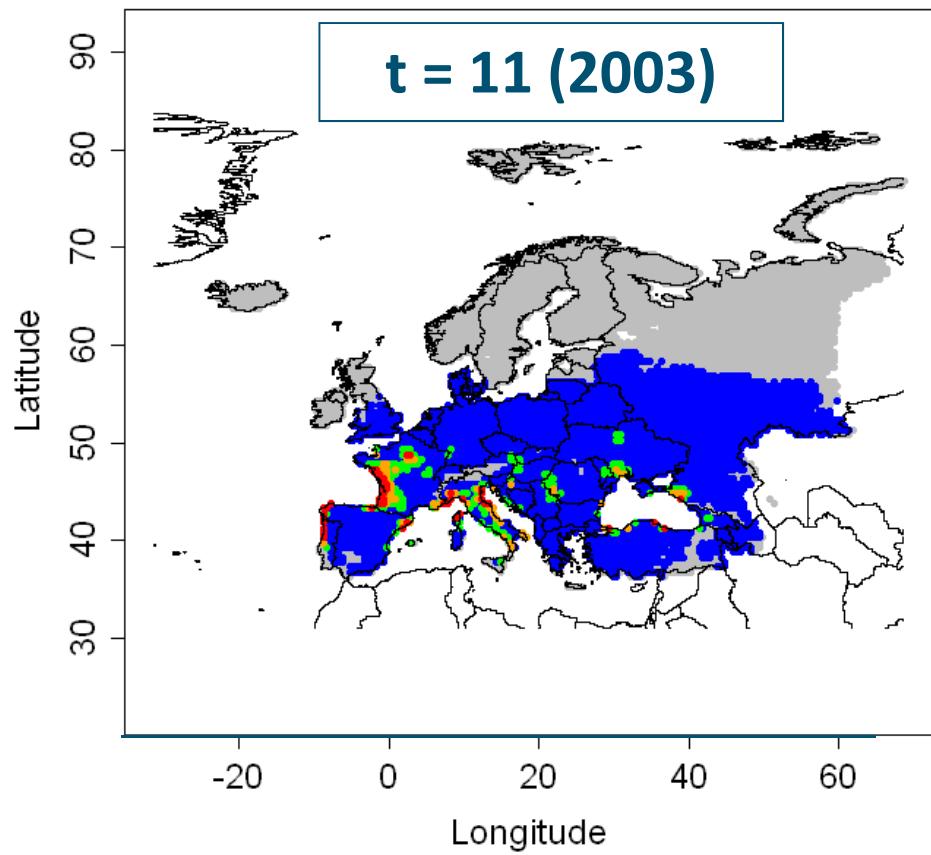
Model C

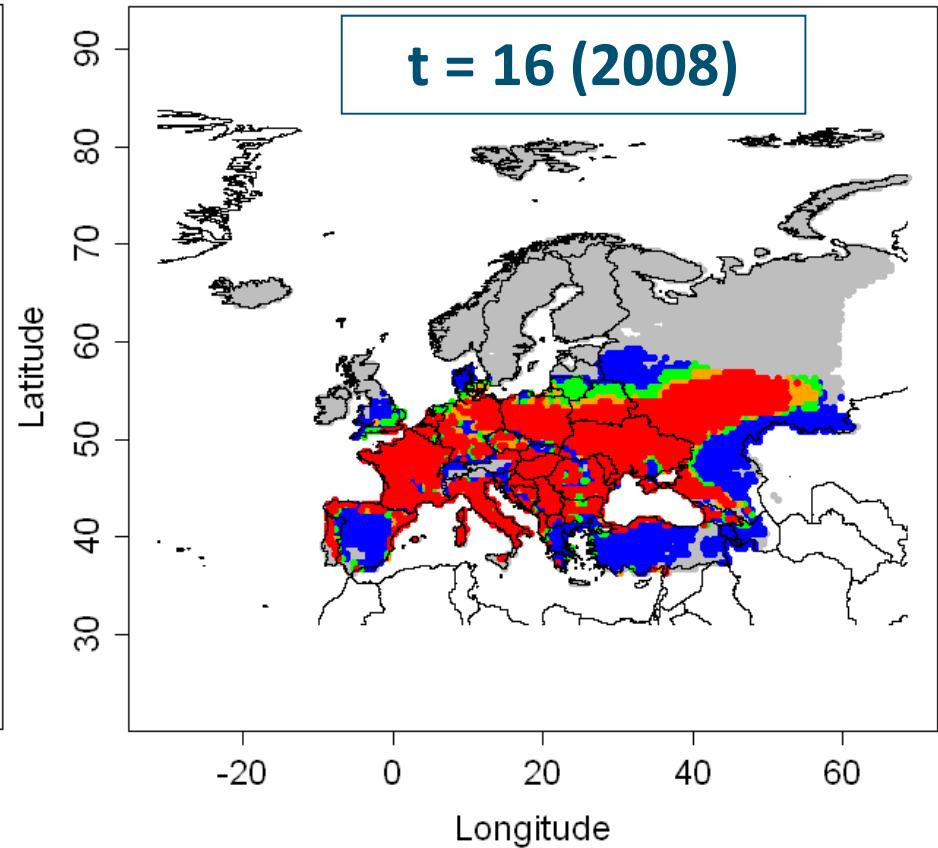
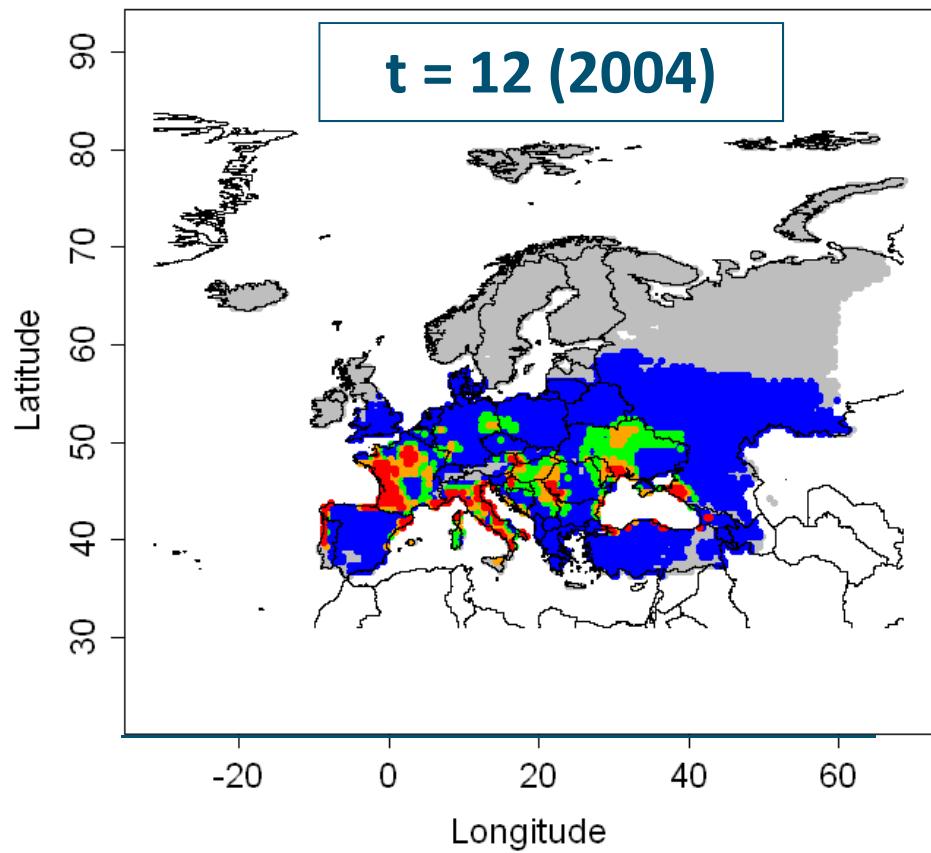
Required inputs

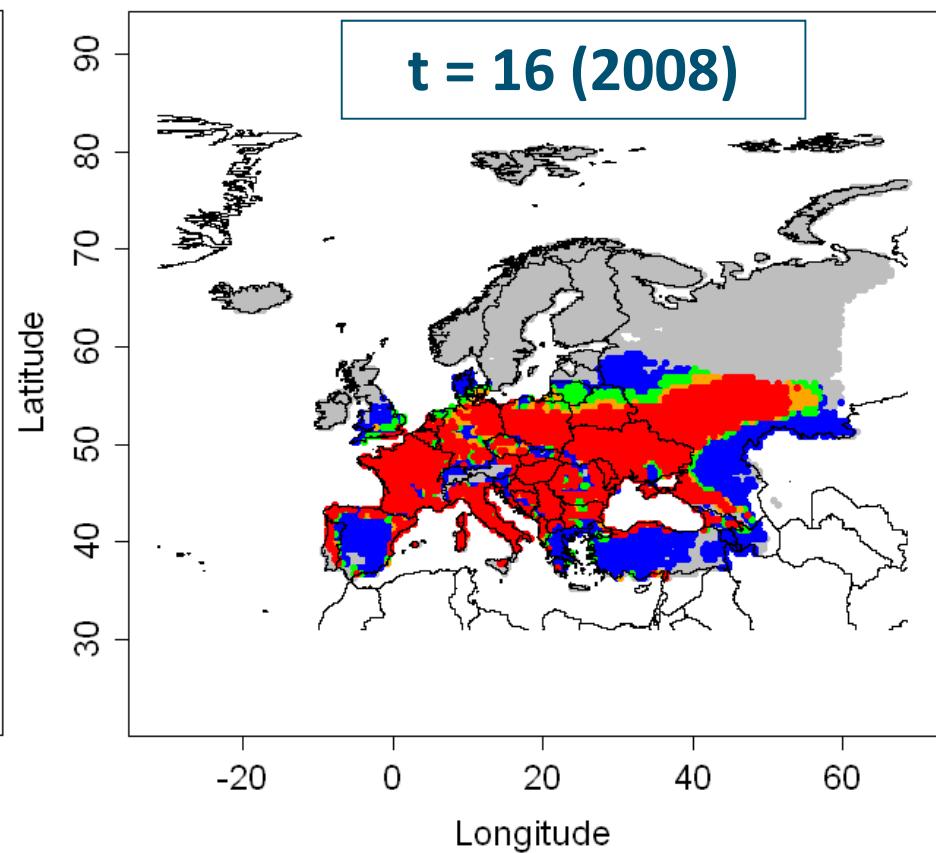
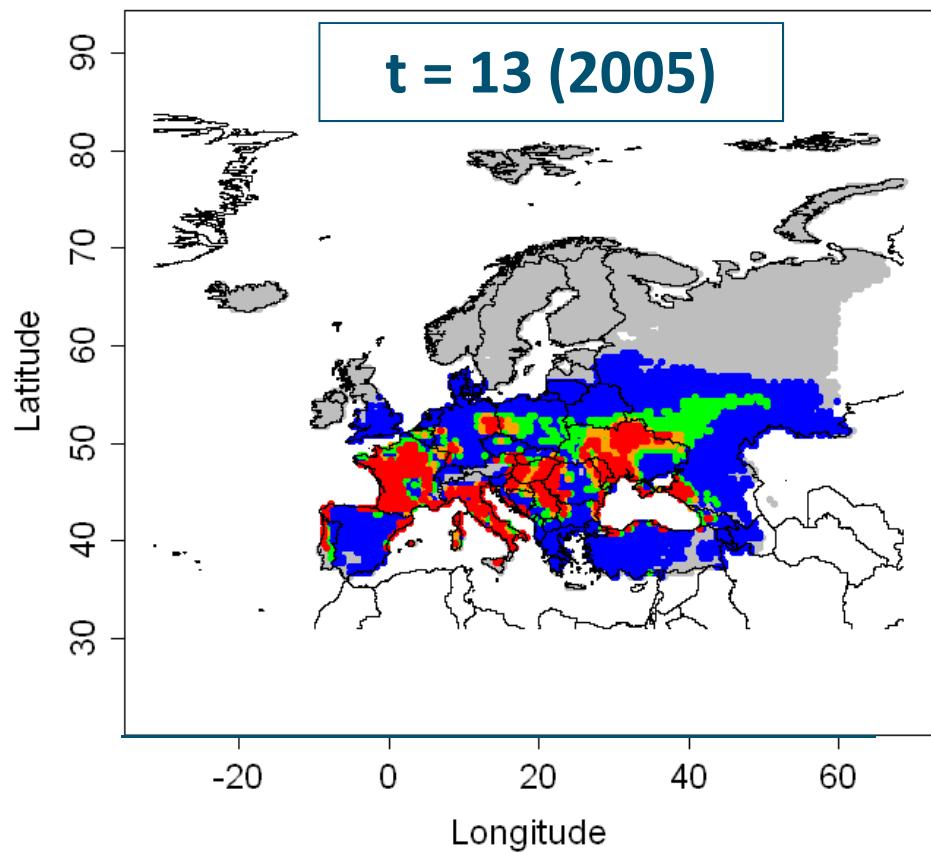
- Initial density in each cell, expressed as a proportion of carrying capacity
- Estimate of carrying capacity (per unit of host area -> per cell)
- Maximum growth rate in the most suitable area in Europe (where GI_{scaled} is 100)
- Growth rate is expressed as a yearly multiplication factor: λ_{max}

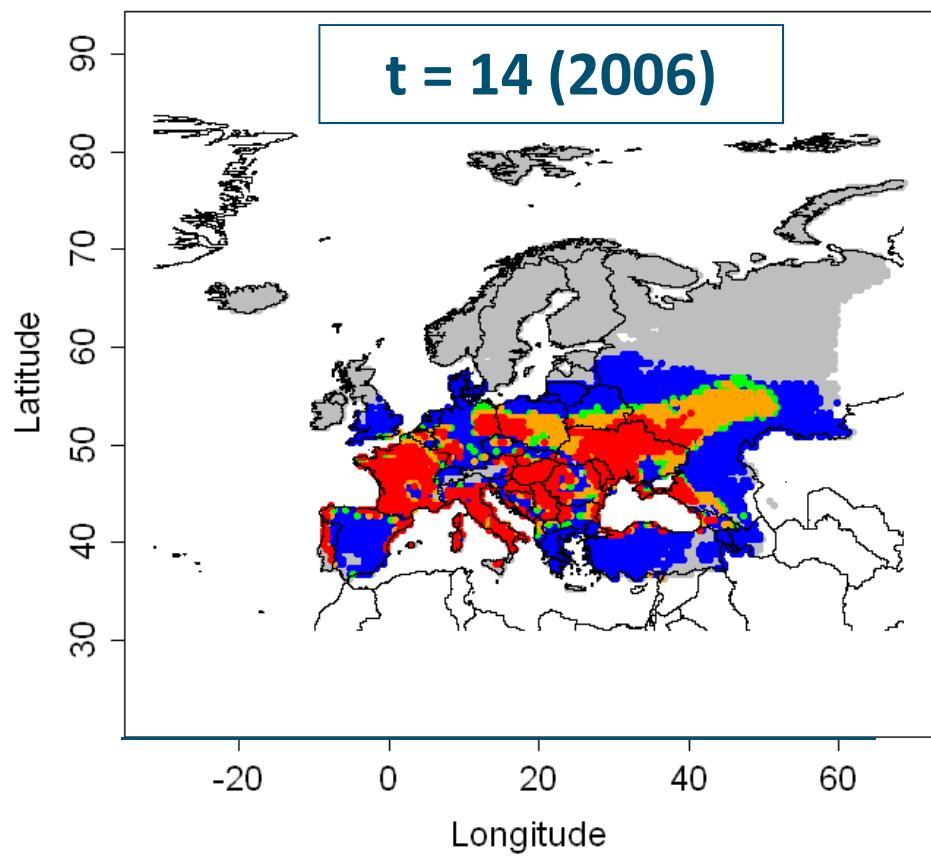


$$N_0 = 1.6 \times 10^{-7}, \lambda_{\max} = 10$$

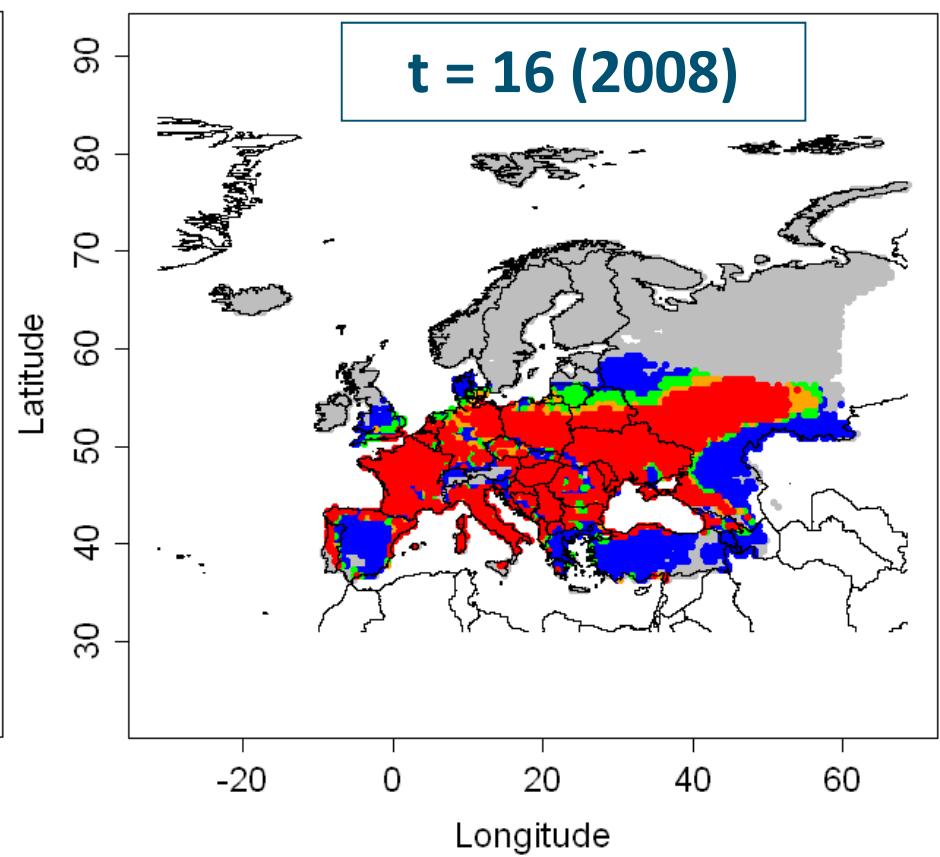




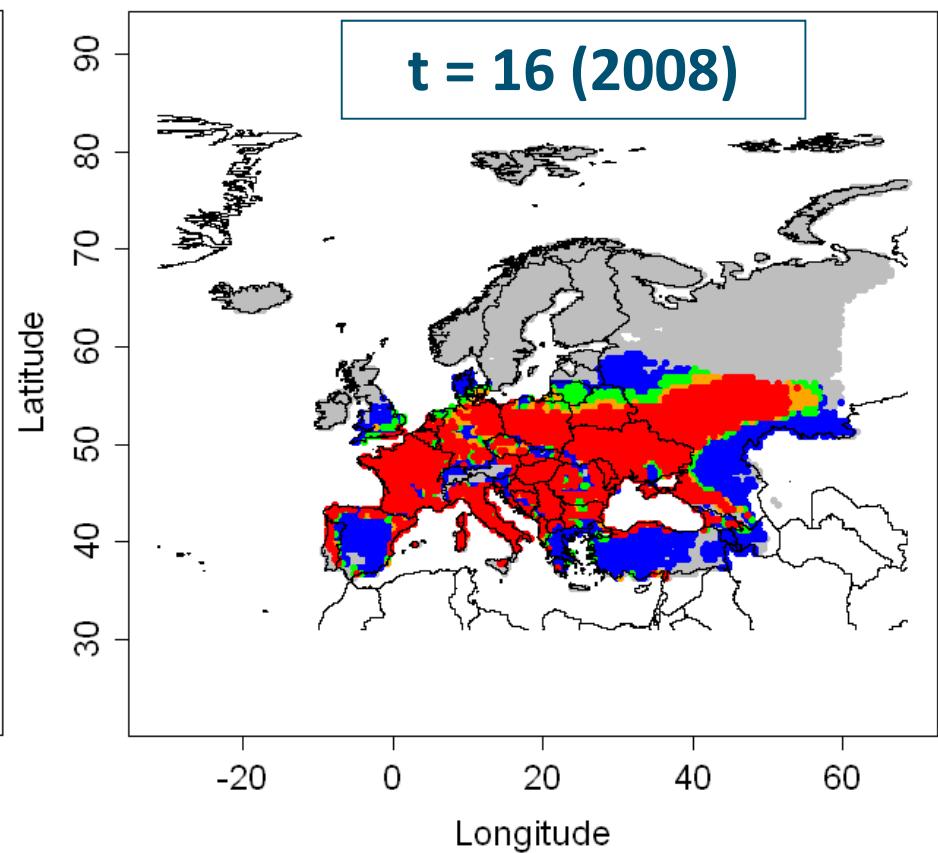
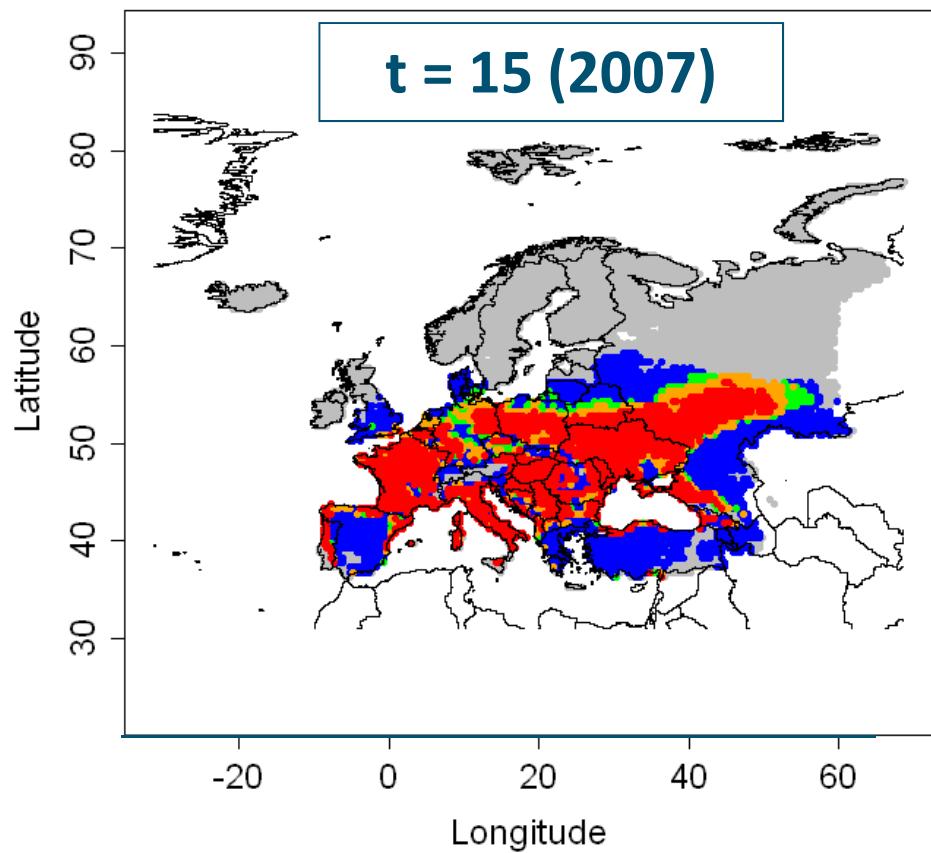




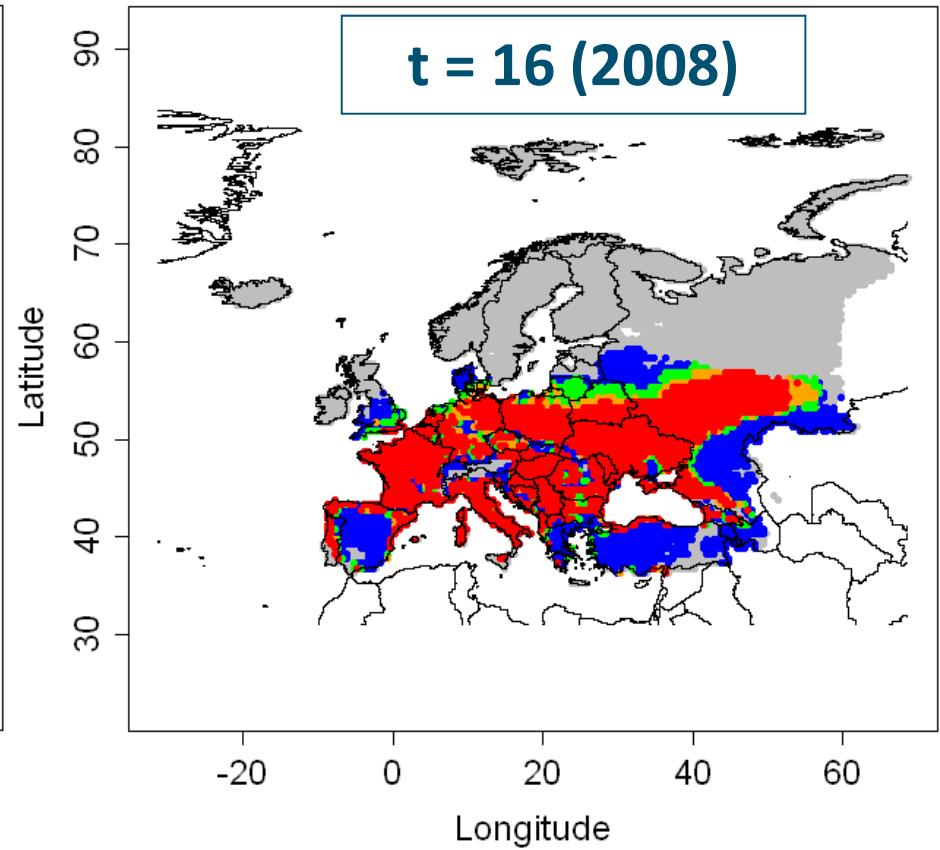
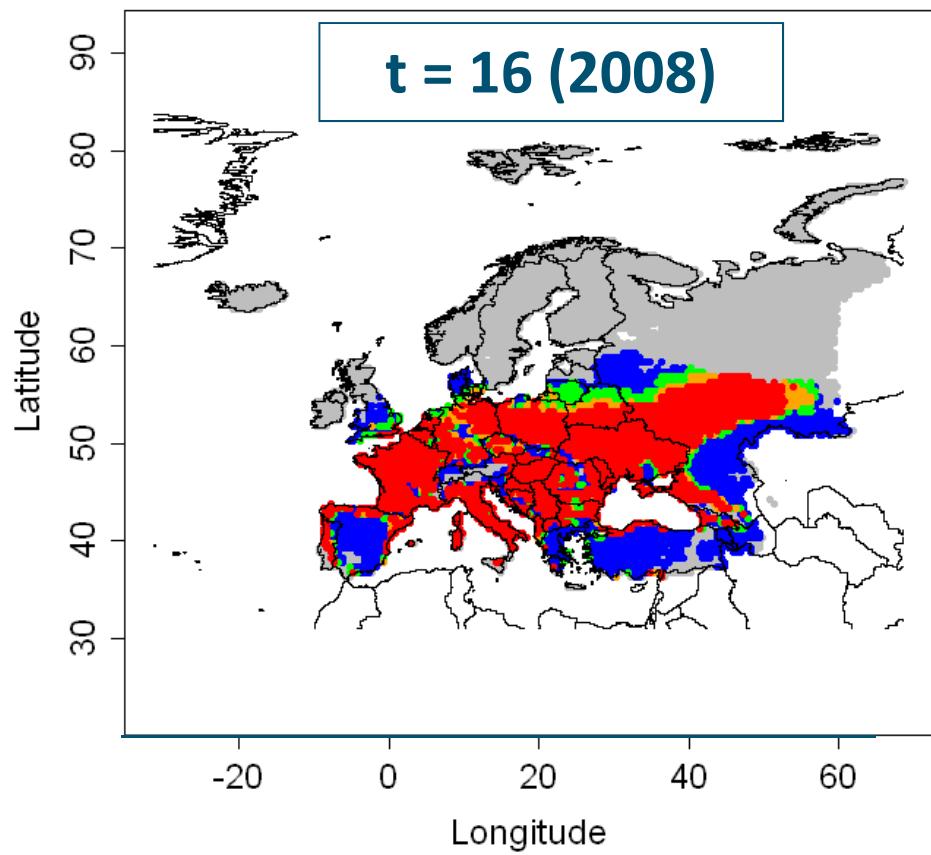
$t = 14$ (2006)



$t = 16$ (2008)



$$N_0 = 1.6 \times 10^{-7}, \lambda_{\max} = 10$$

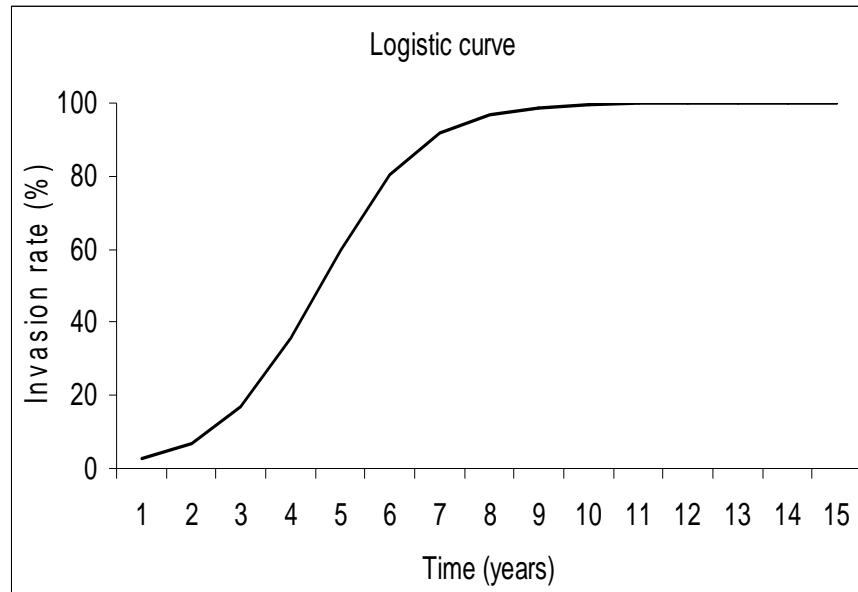


Model C

- Shows in space the emergence of a pest when it is initially introduced at very low density over a very large area
- Based on temporal growth processes (logistic growth) only –dispersal is not accounted for

Model D

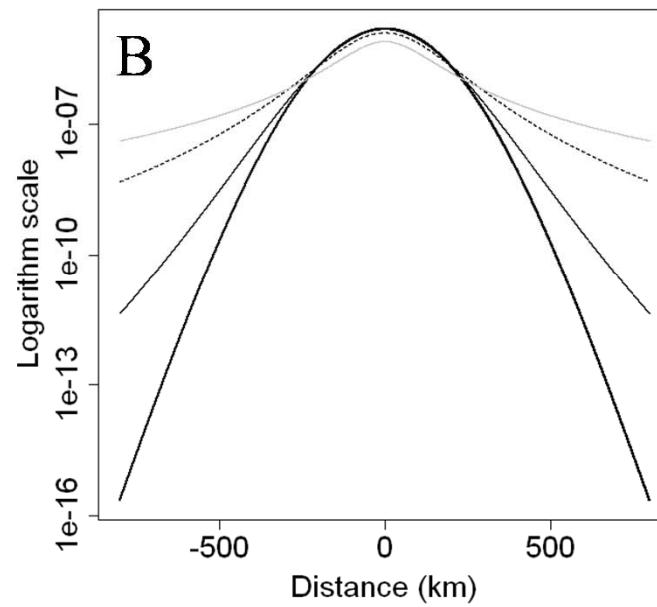
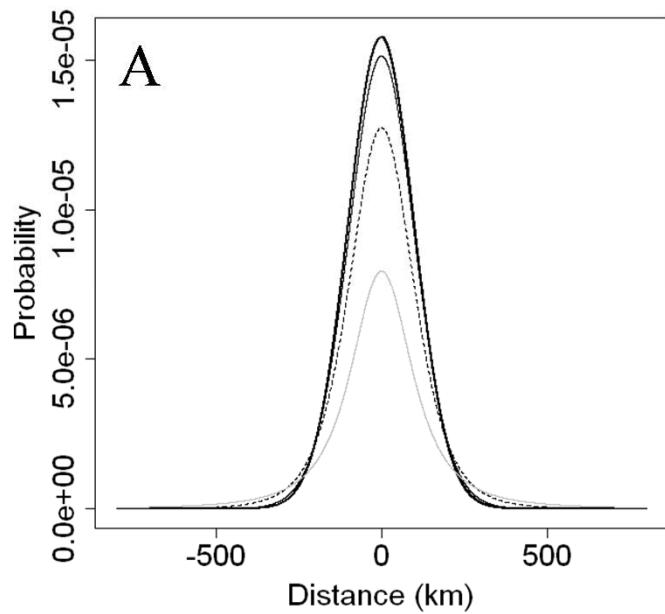
- Pest density – time & space
- Logistic growth of density in cells (same as model C)
- Probability distribution (dispersal kernel) for dispersal



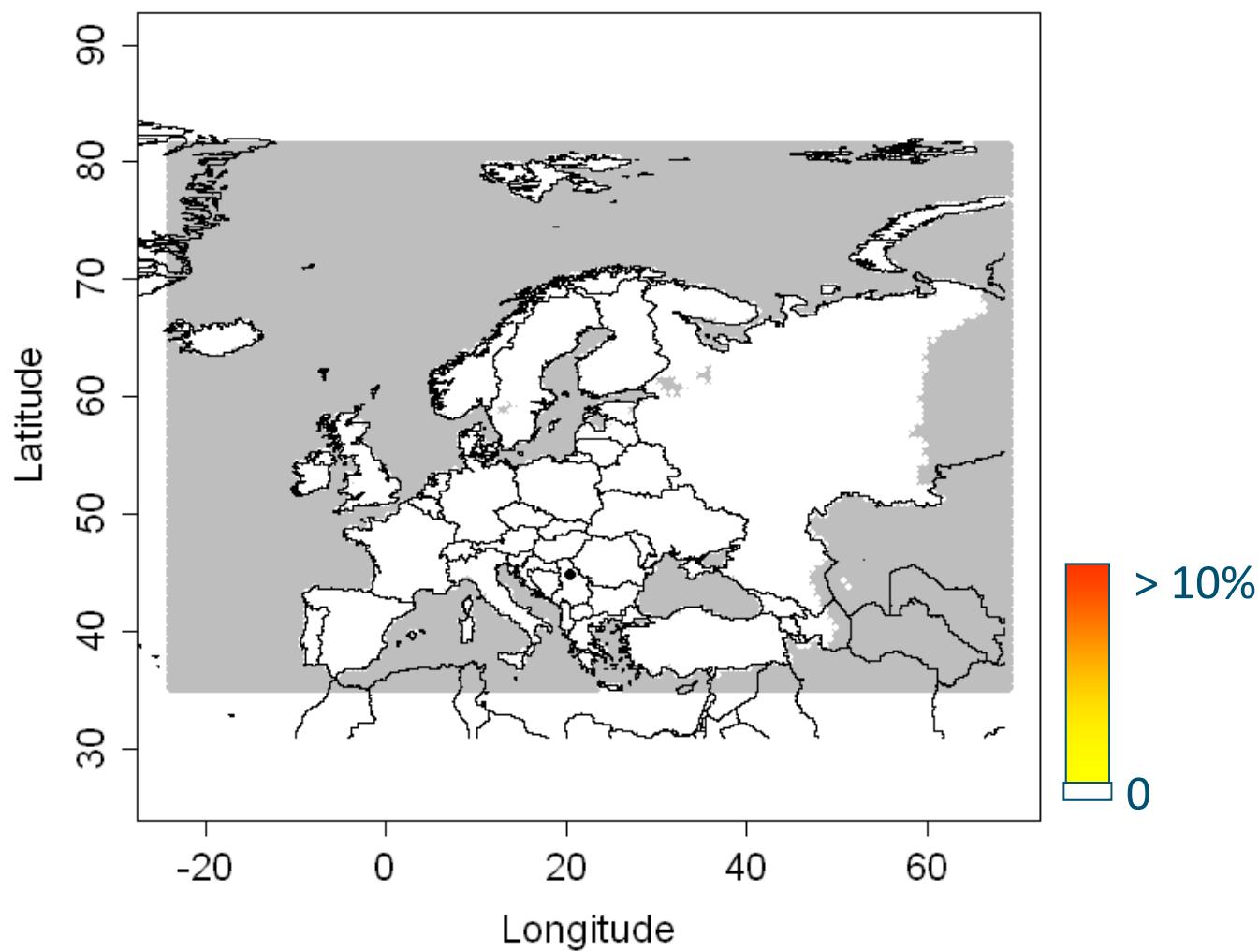
Dispersal kernel

Rotated t-distribution with two parameters

- Length scale (u ; km)
- Shape parameter (v , -)

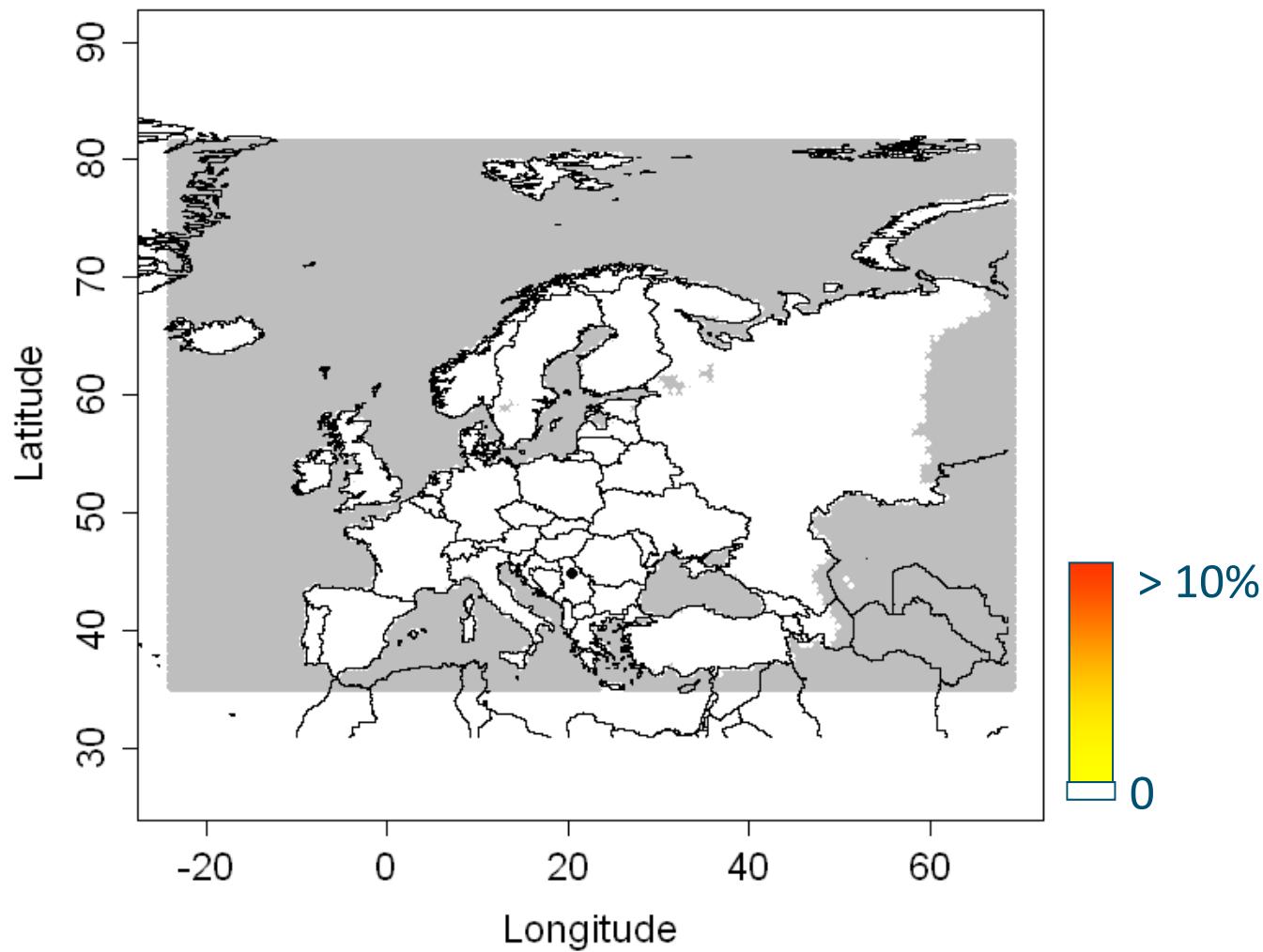


t= 1 (1993)



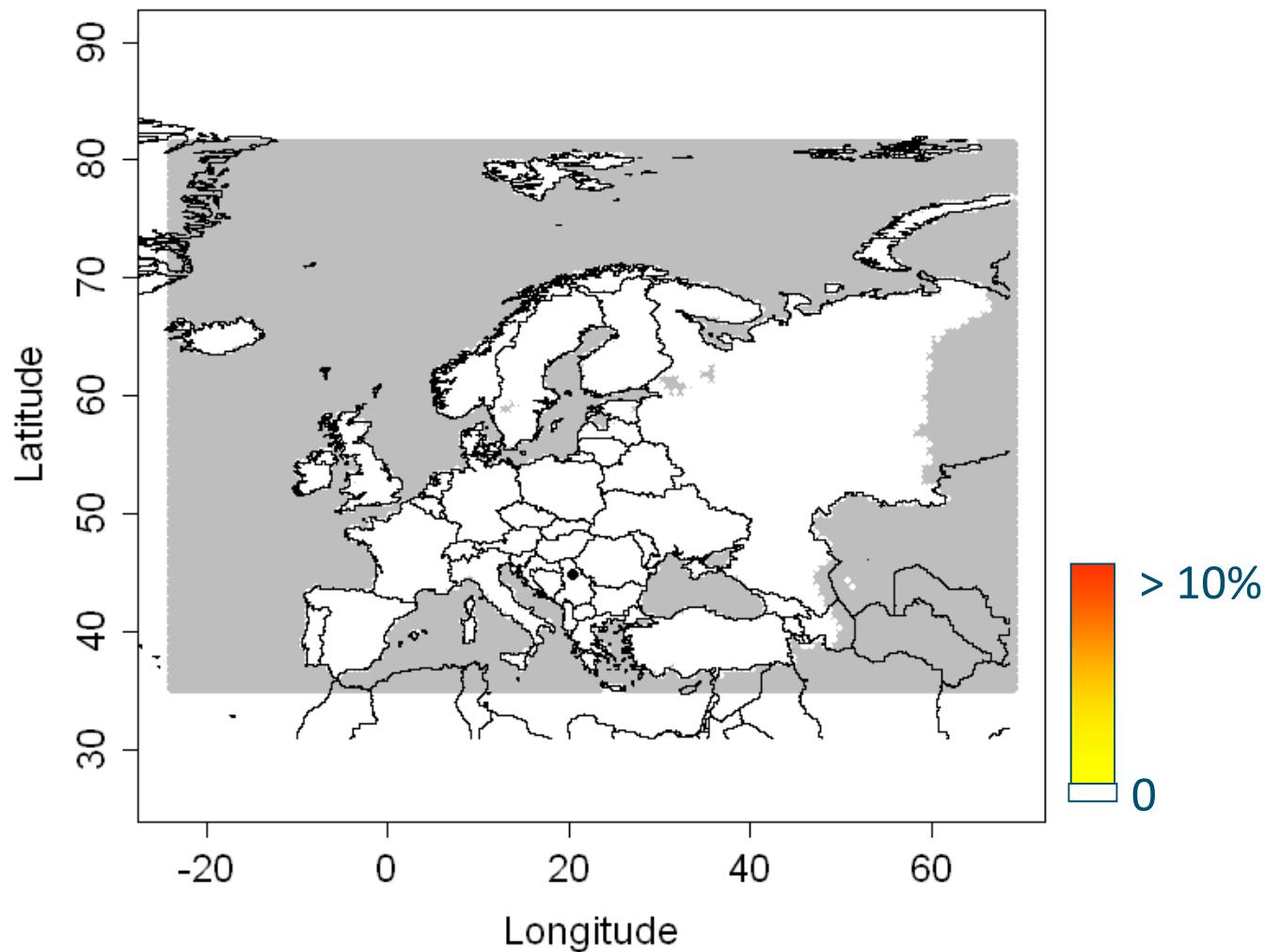
p=5, u=60

t= 2 (1994)



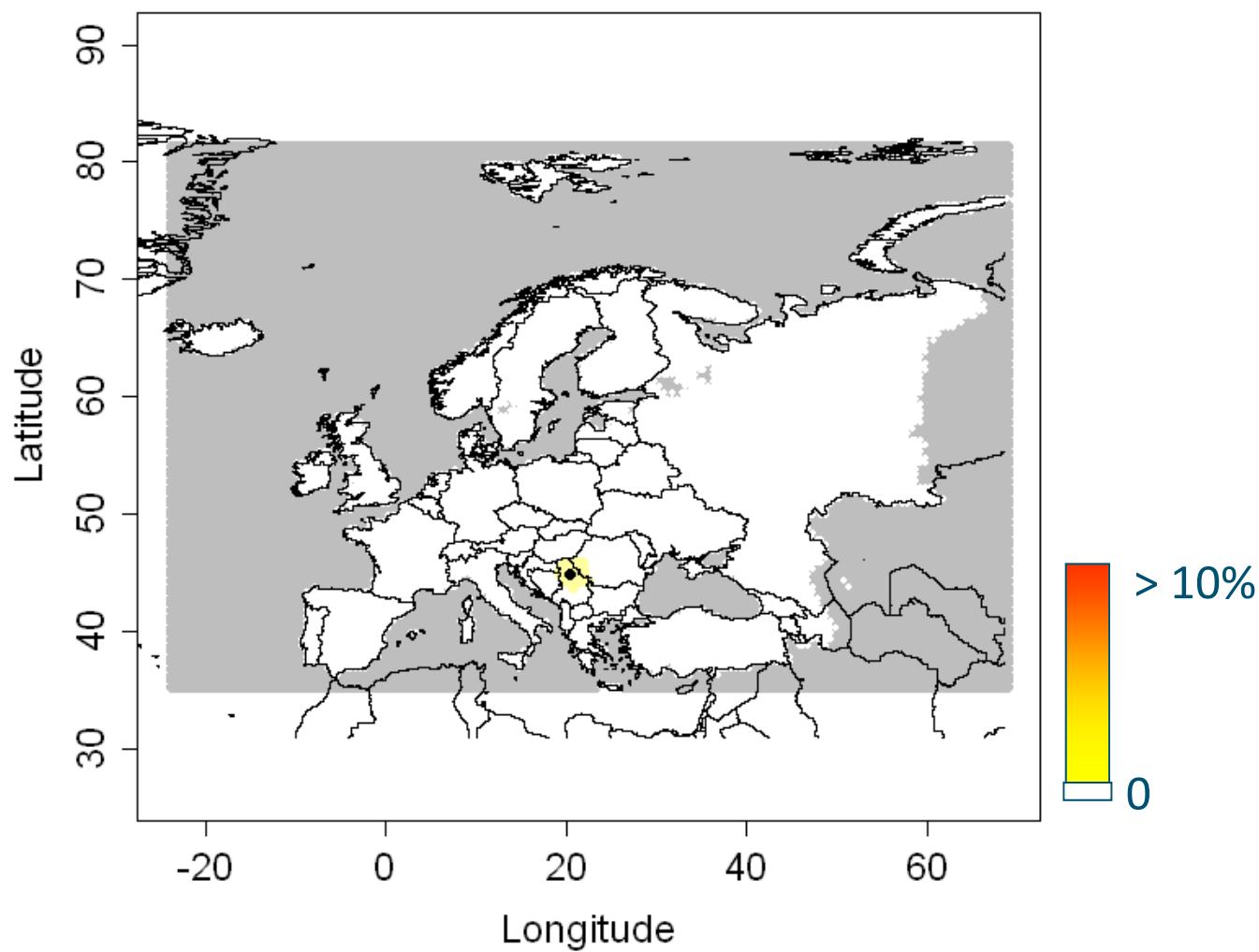
p=5, u=60

t= 3 (1995)



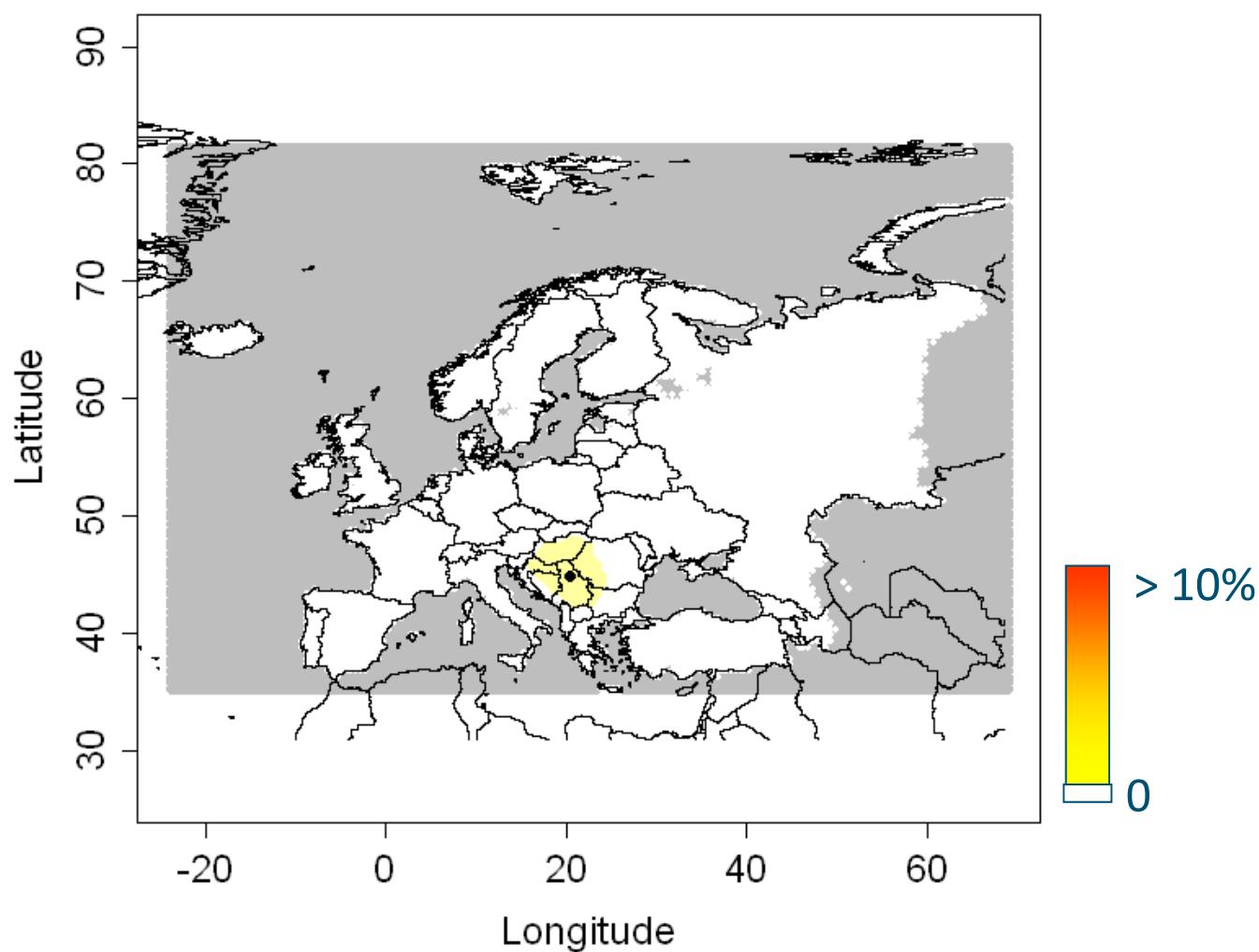
p=5, u=60

t= 4 (1996)



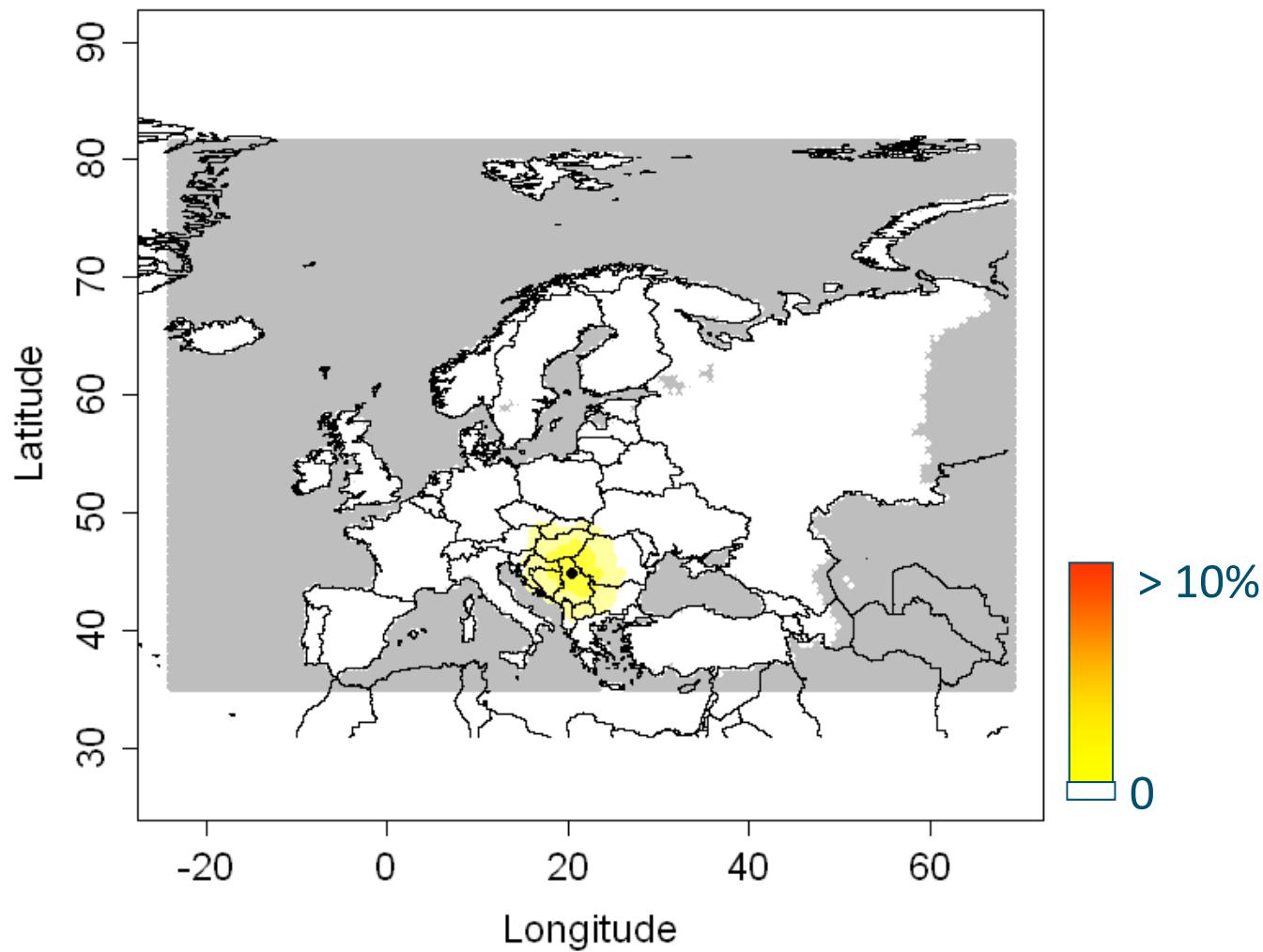
p=5, u=60

t= 5 (1997)



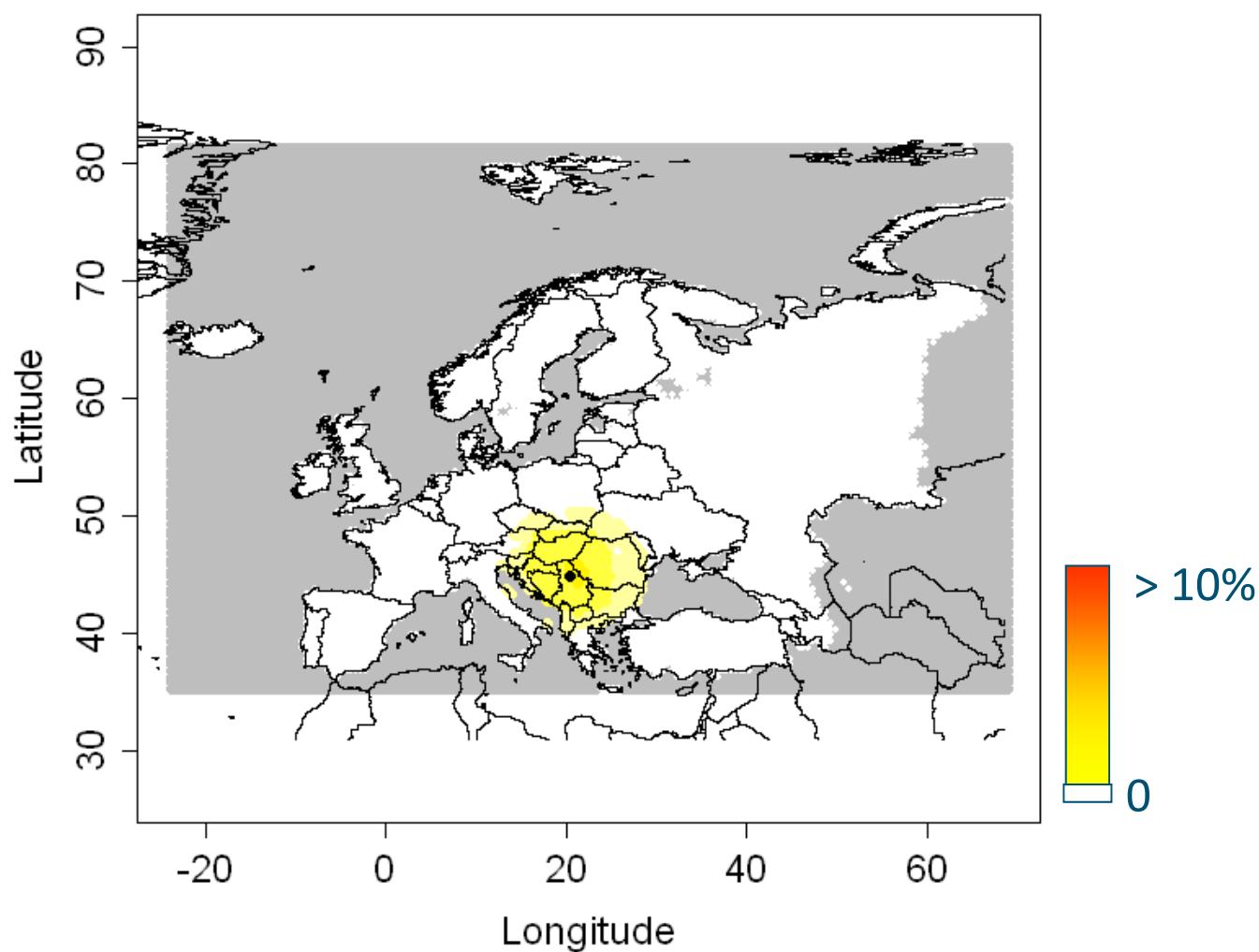
p=5, u=60

t= 6 (1998)



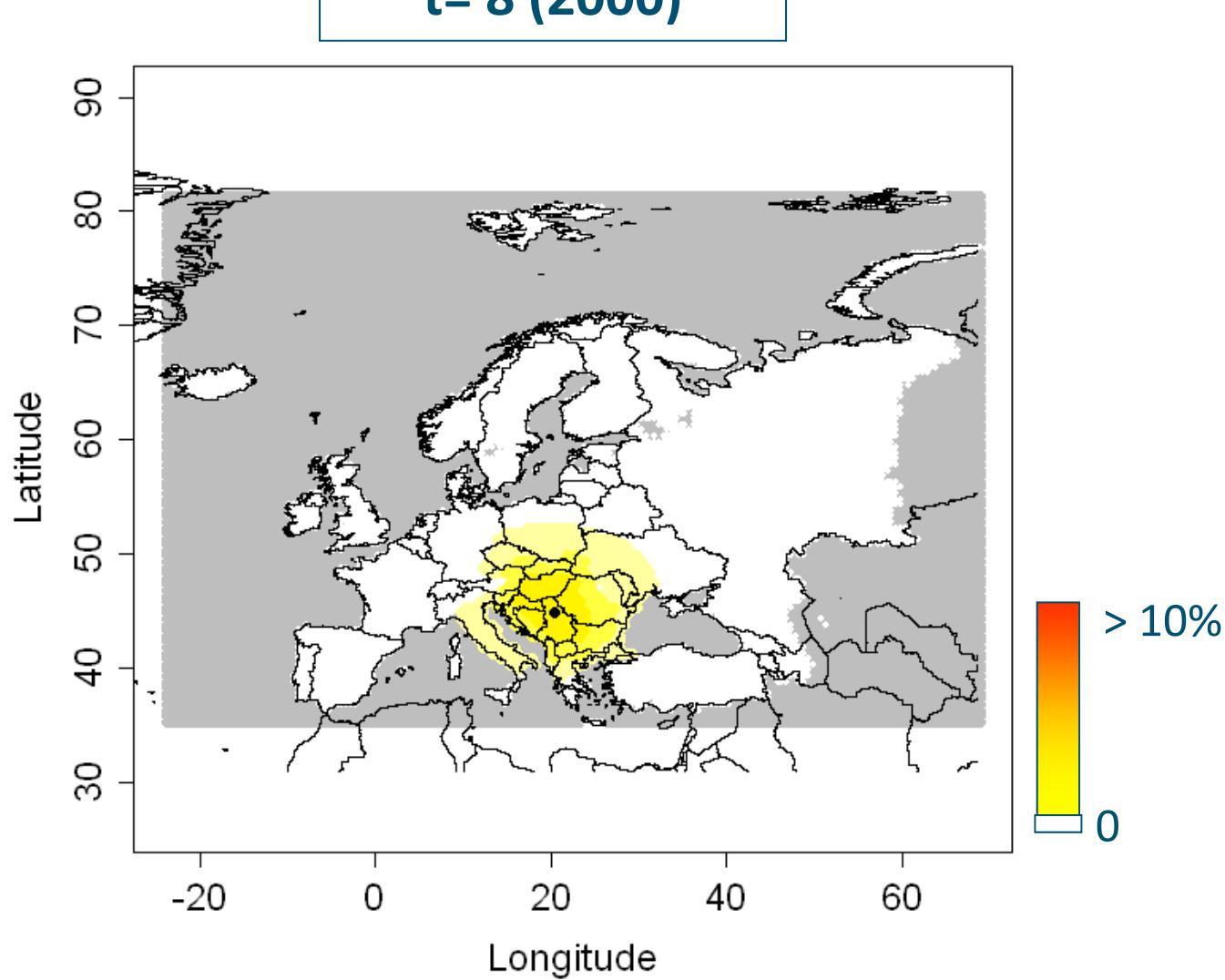
p=5, u=60

t= 7 (1999)



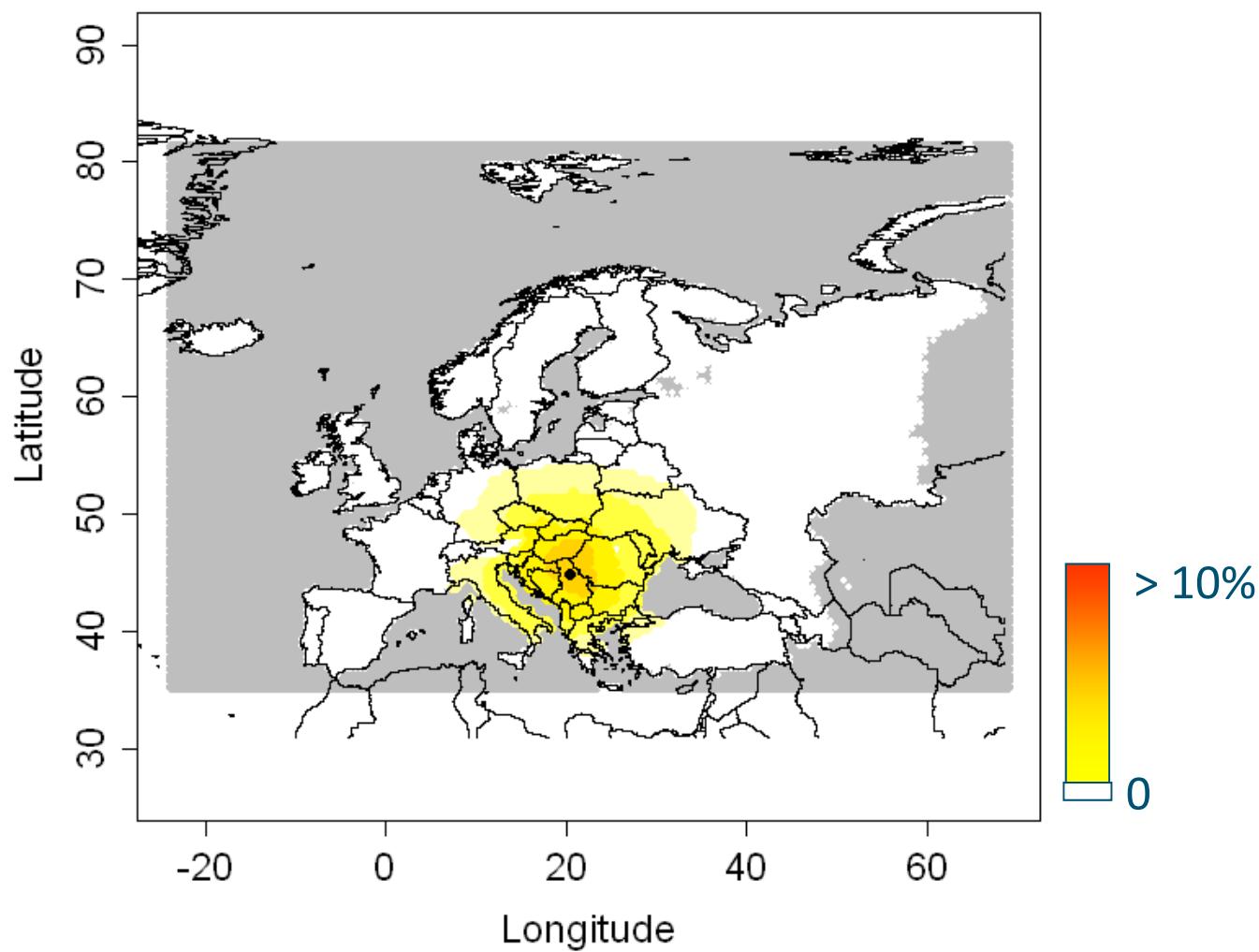
p=5, u=60

t= 8 (2000)



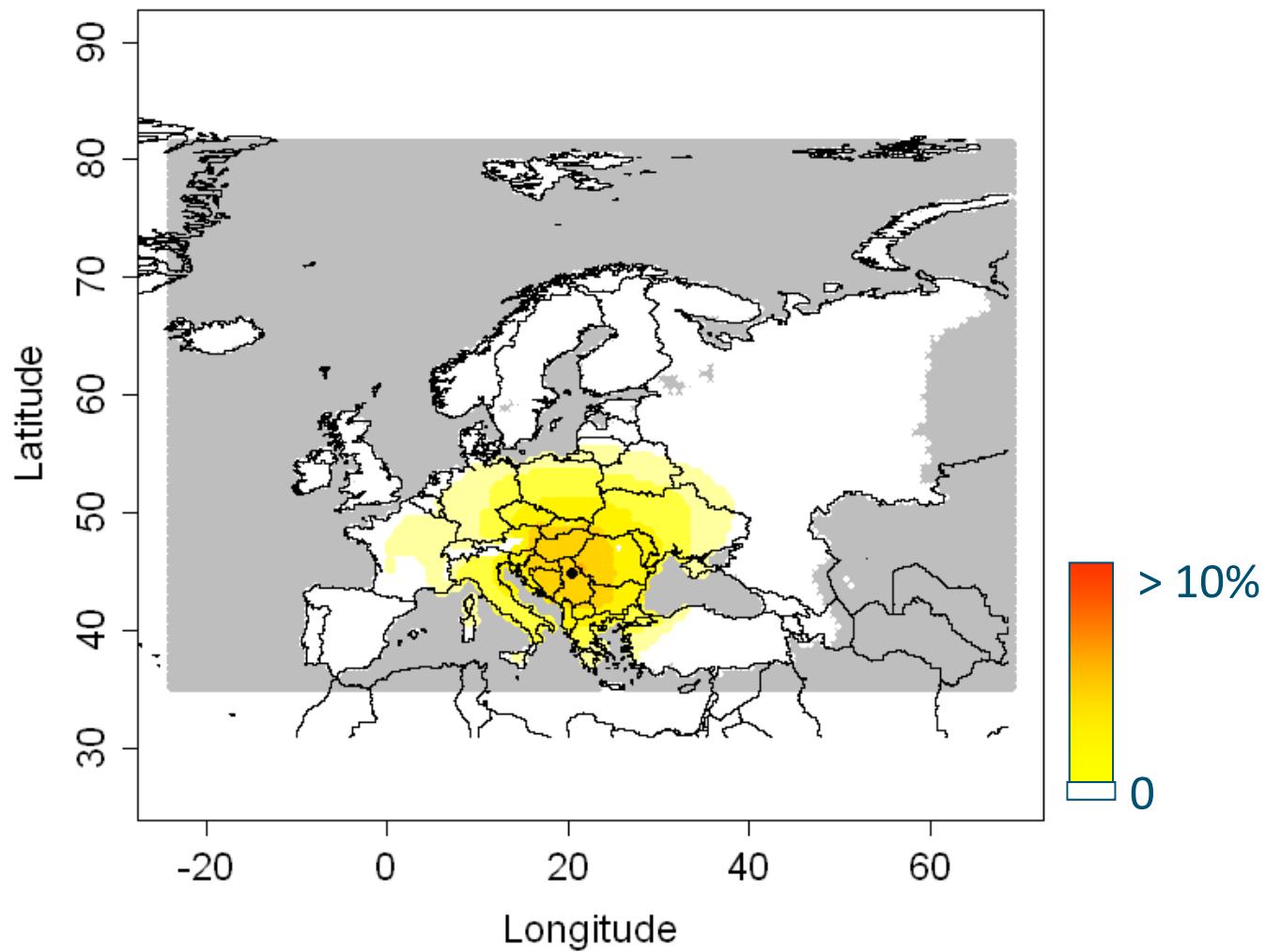
p=5, u=60

t= 9 (2001)



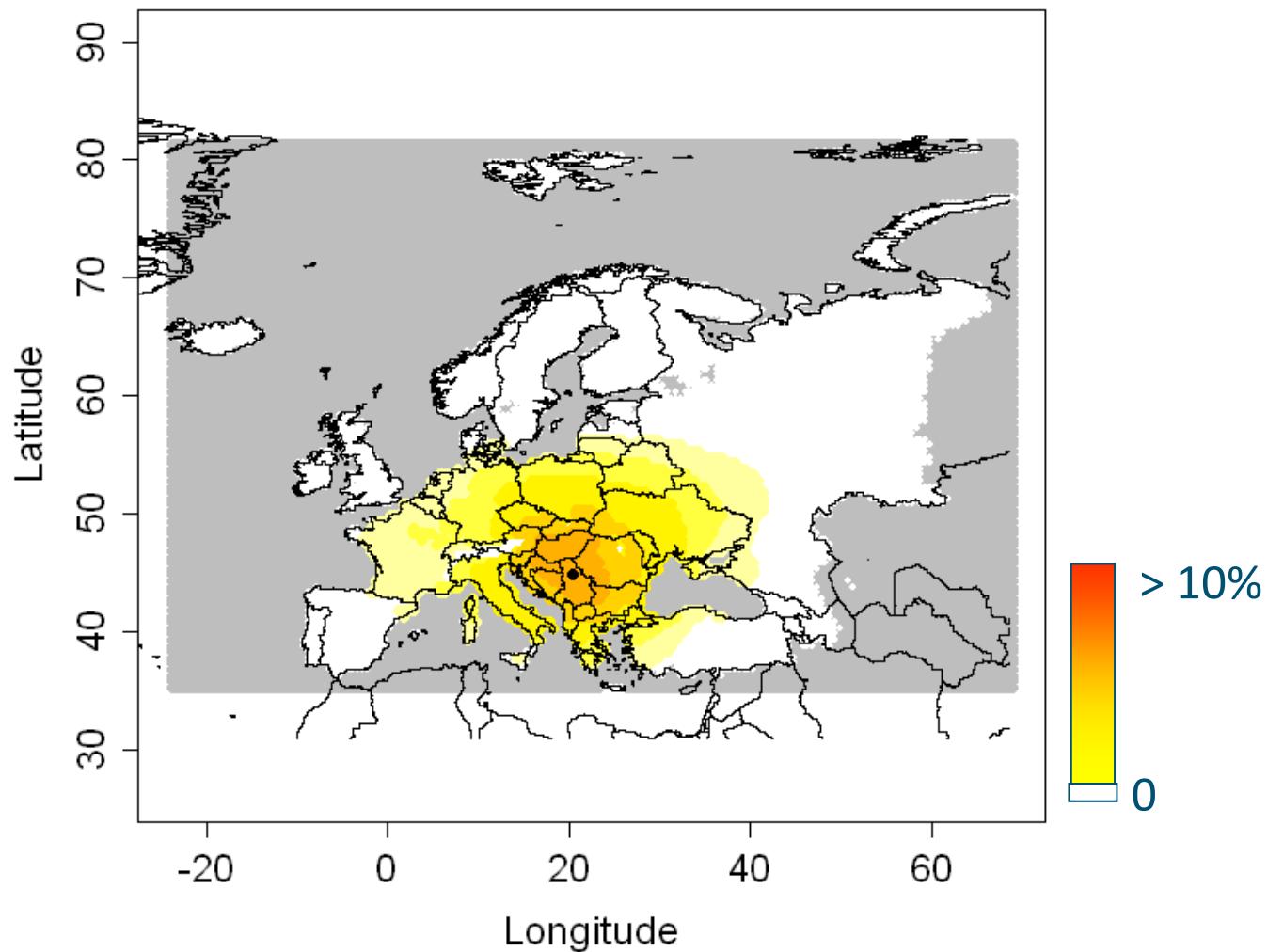
p=5, u=60

t= 10 (2002)



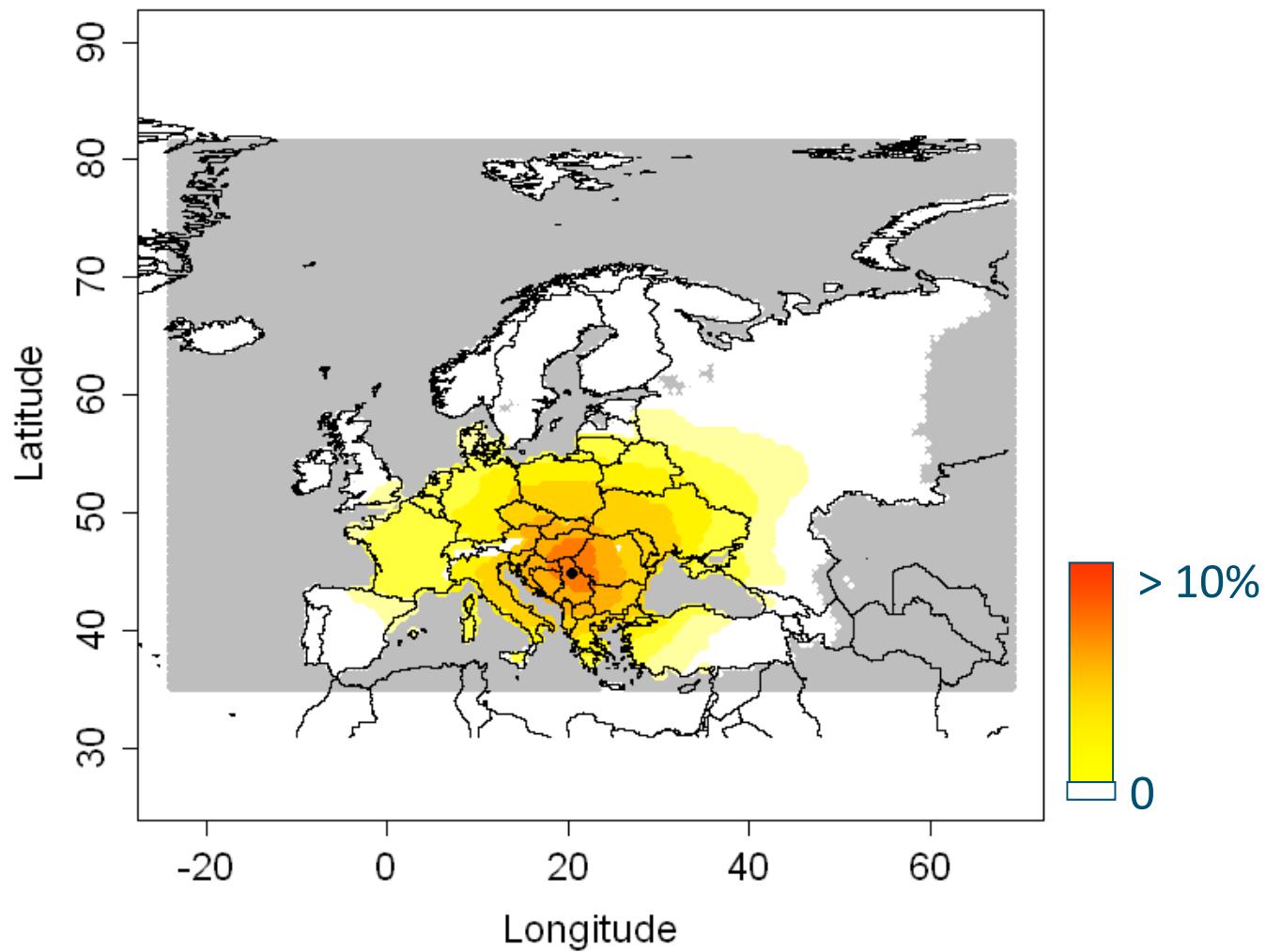
p=5, u=60

t= 11 (2003)



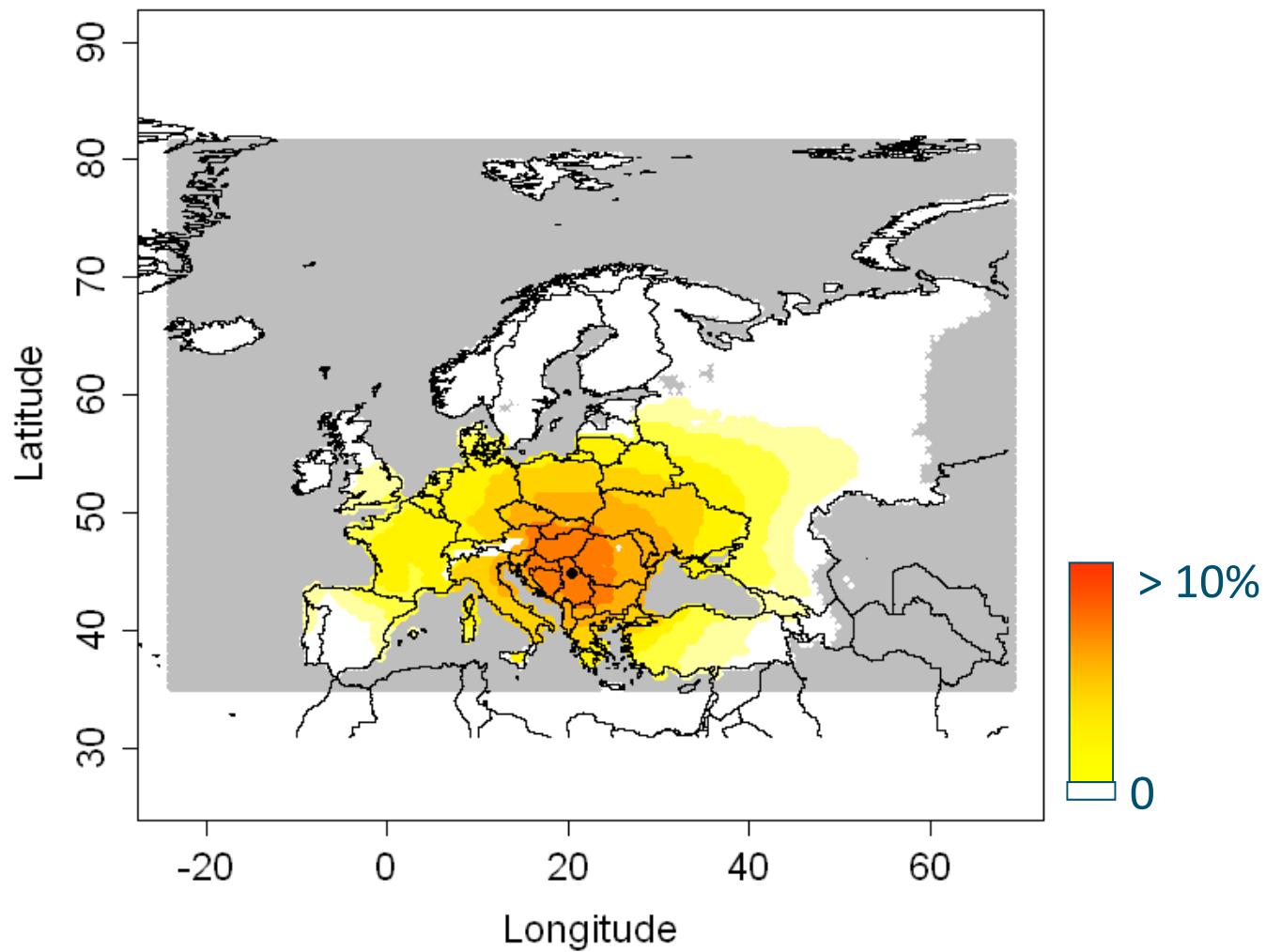
p=5, u=60

t= 12 (2004)



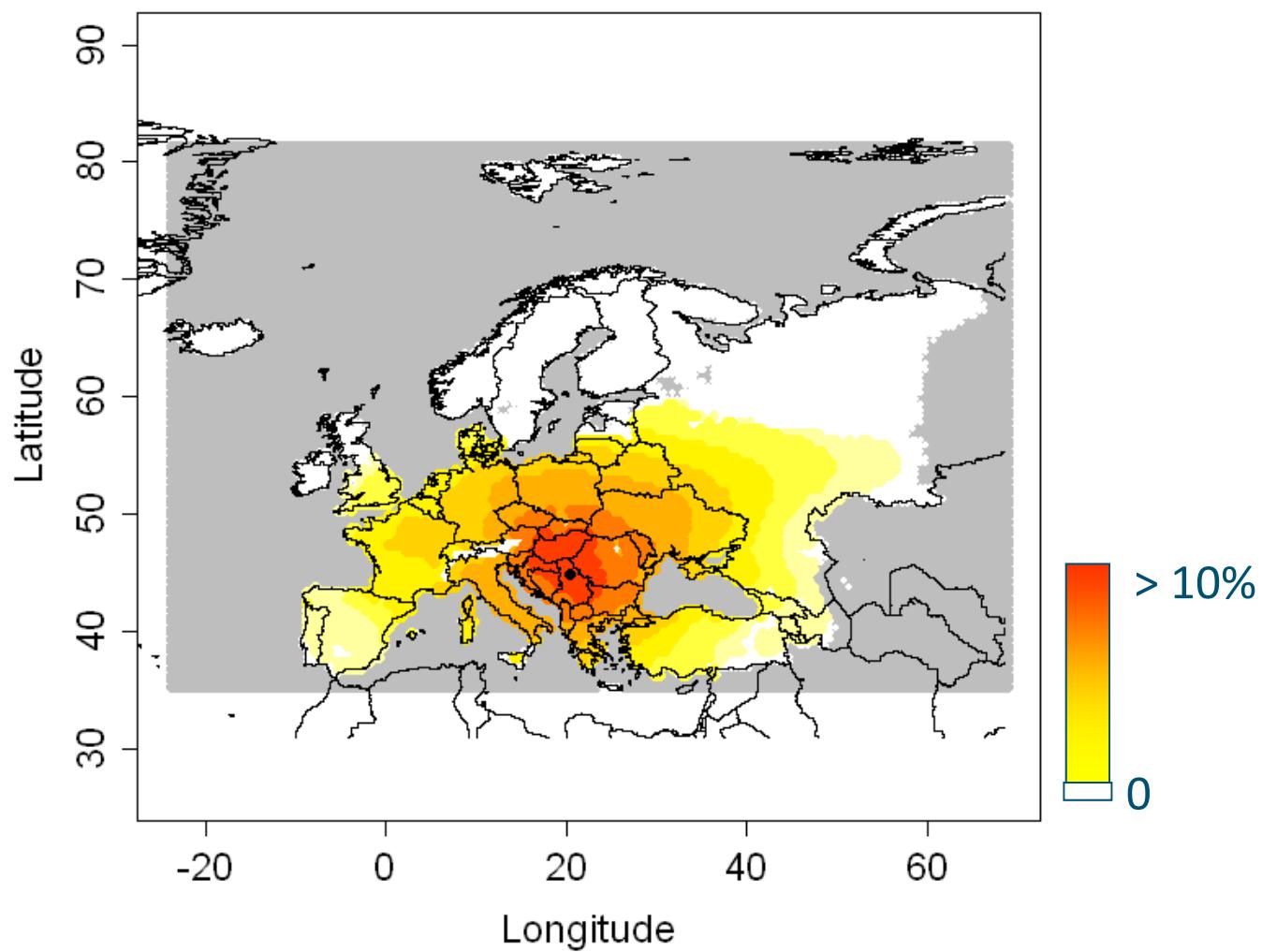
p=5, u=60

t= 13 (2005)



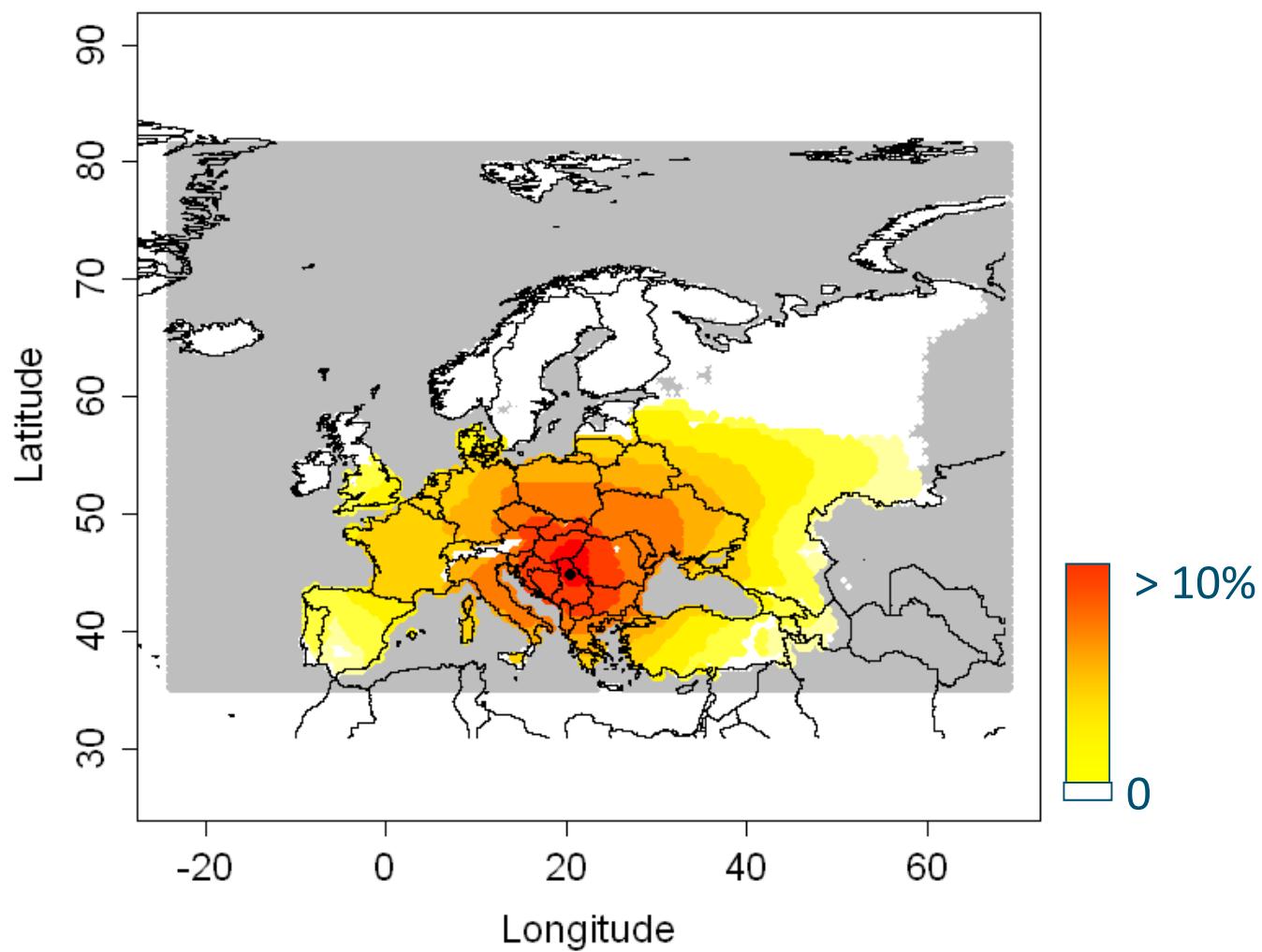
p=5, u=60

t= 14 (2006)



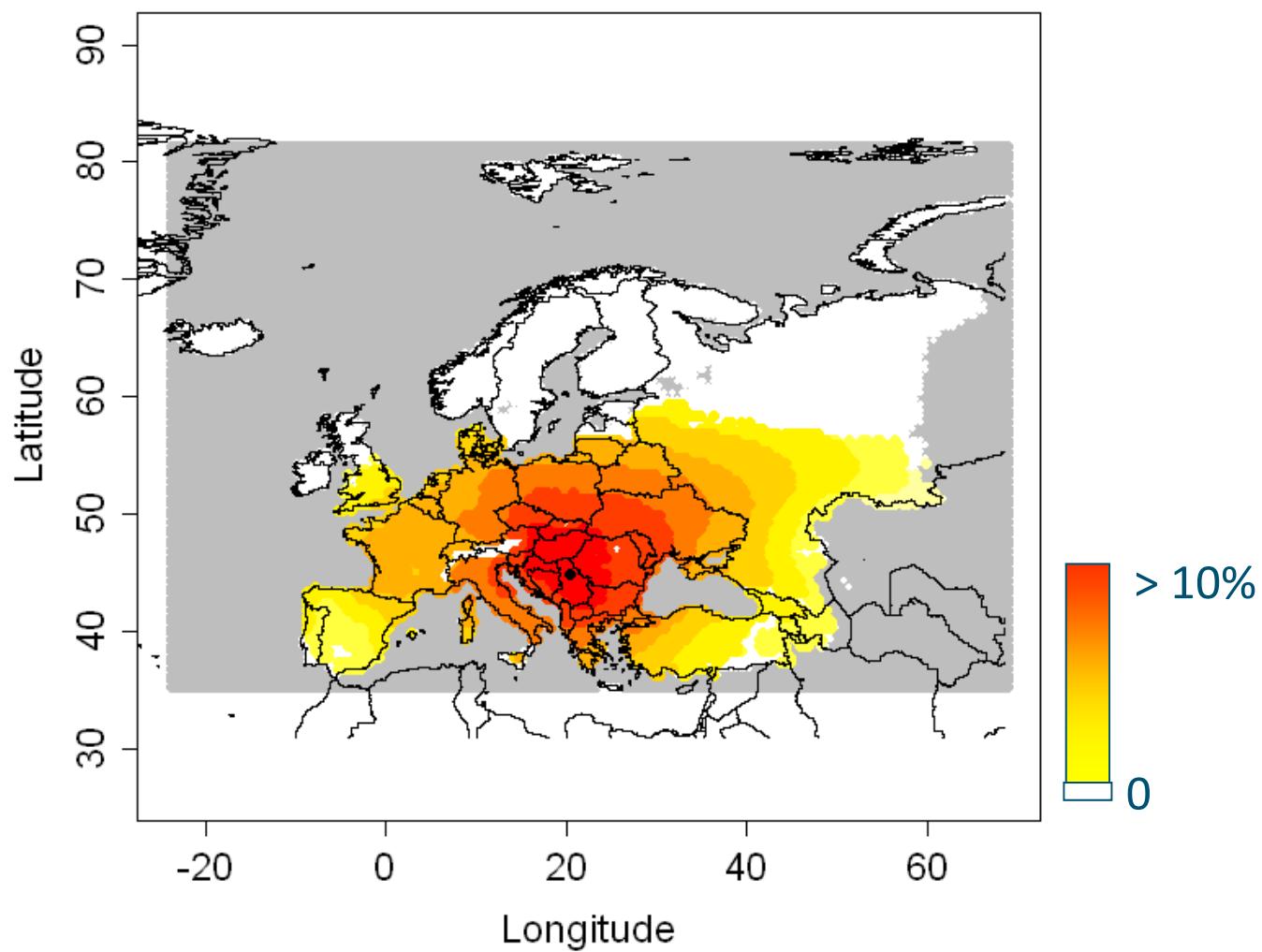
p=5, u=60

t= 15 (2007)



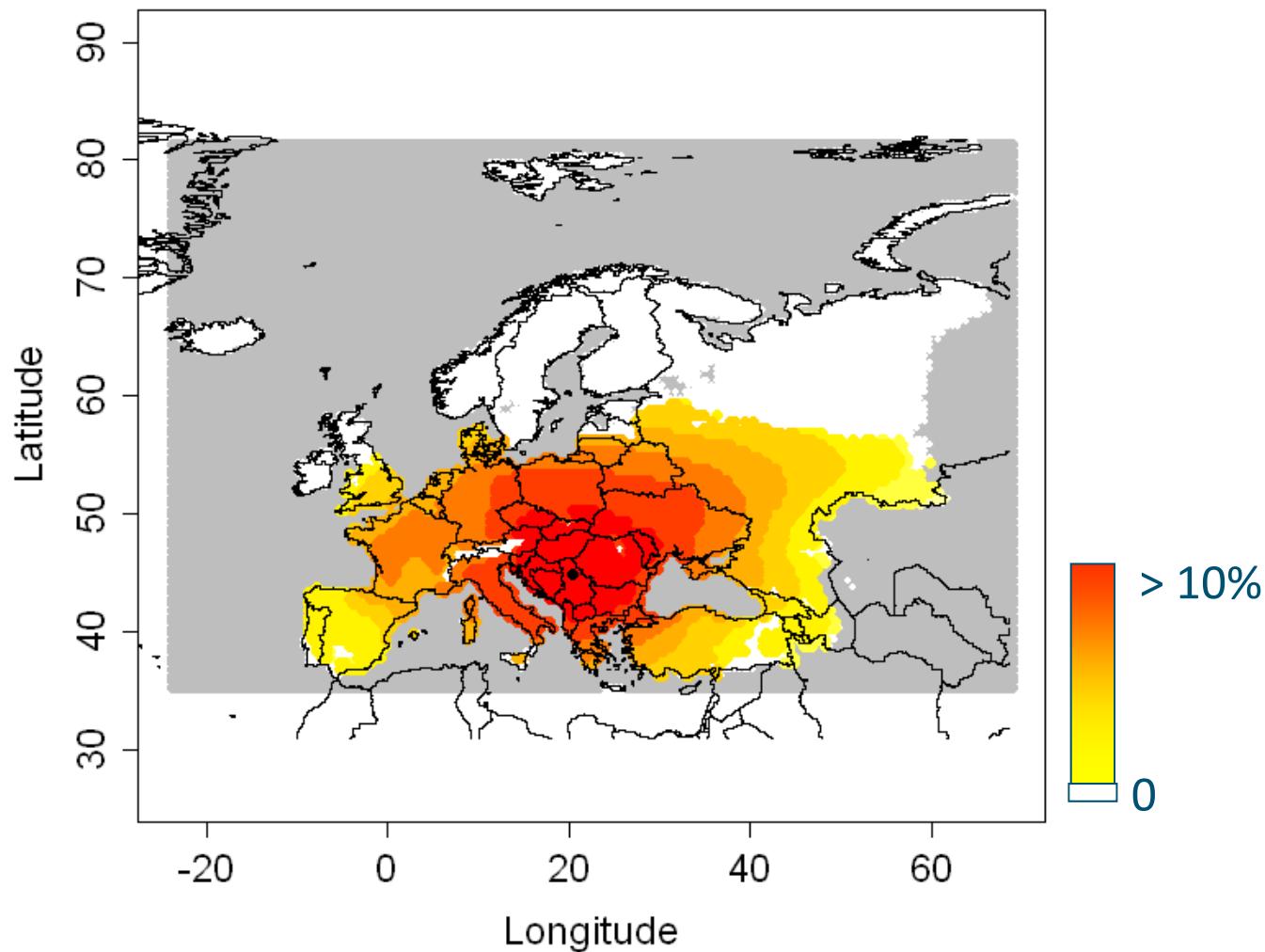
p=5, u=60

t= 16 (2008)



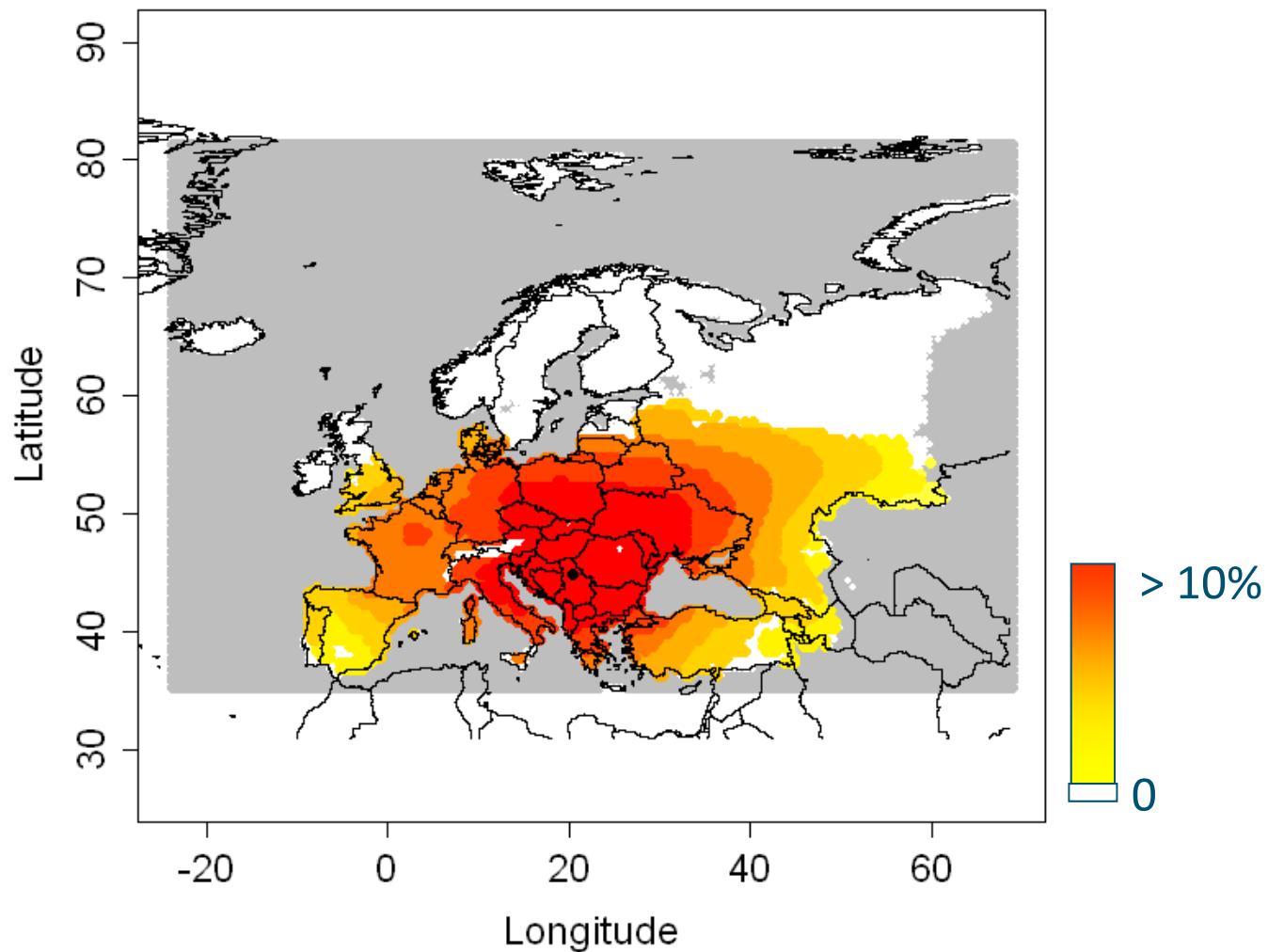
p=5, u=60

t= 17 (2009)



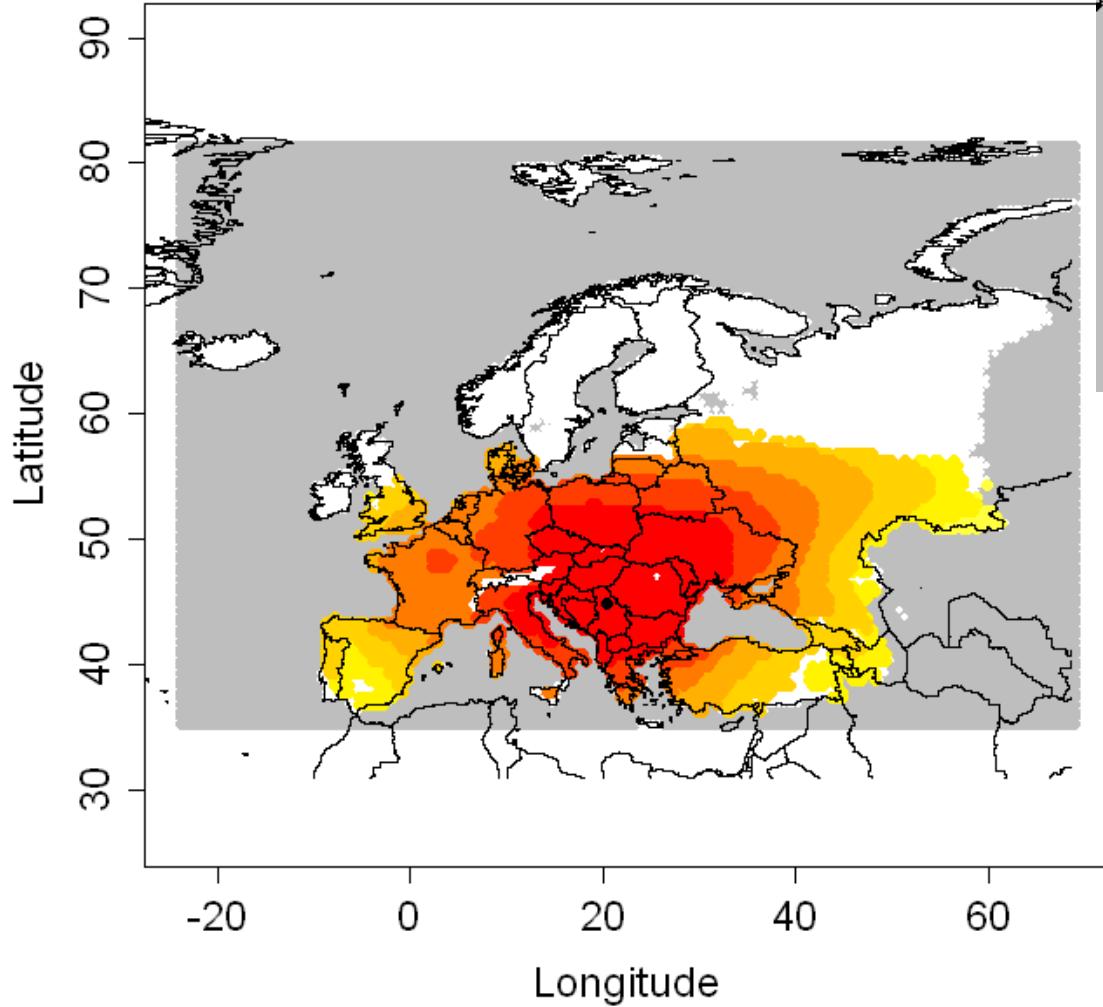
p=5, u=60

t= 18 (2010)

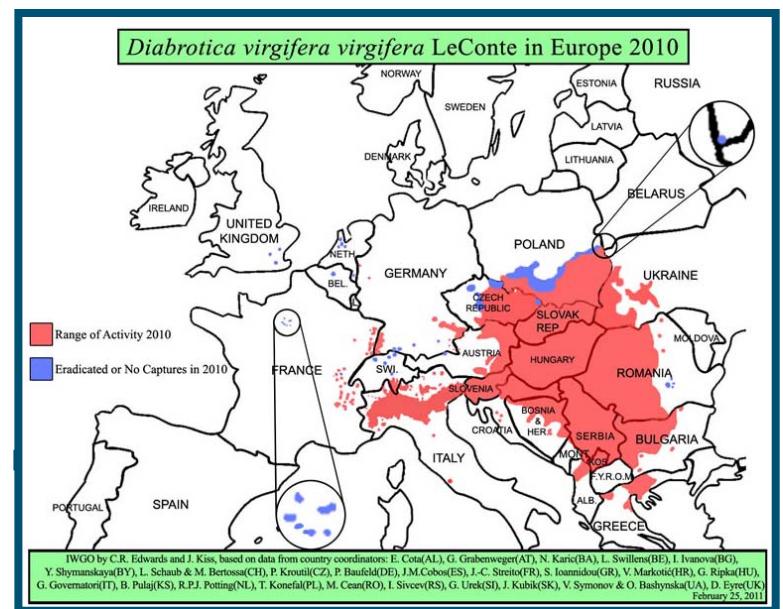
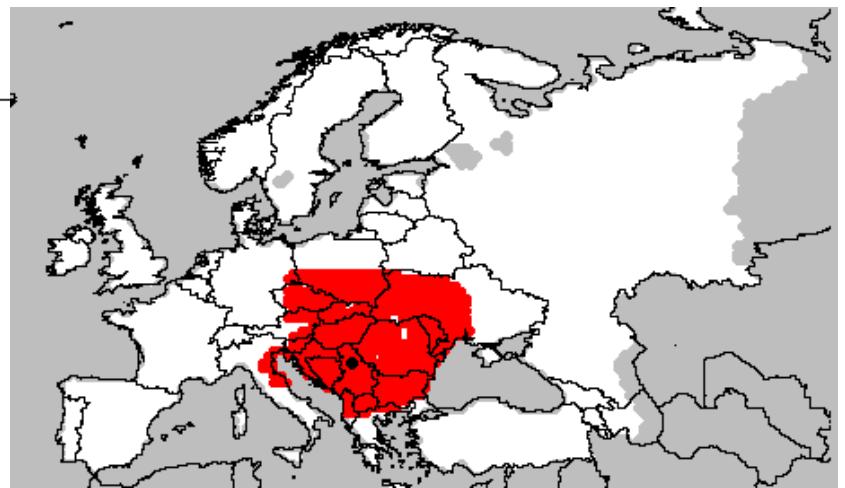


p=5, u=60

t= 18 (2010)



Population density > 15% of K



Model D

- Local population growth + dispersal
- Logistic growth + flexible dispersal kernel (t -distribution) with thin or fat tails
- Contains the model of Waage et al. (2005) "A new agenda for biosecurity": logistic growth + dispersal according to a normal distribution (diffusion-based)
- Credible results
- Shape parameter difficult to understand and estimate
- Computation-intensive

Sensitivity analysis and scenario studies

- For each parameter: only one value
- Sensitivity analysis



One-at-a-time analysis

Change the value of the parameters

Compare the output changes

→ Comparison done considering each model separately

parameter change: -25%, -10%, +10%, +25%

output: total area invaded, total pest population or
total economic damage

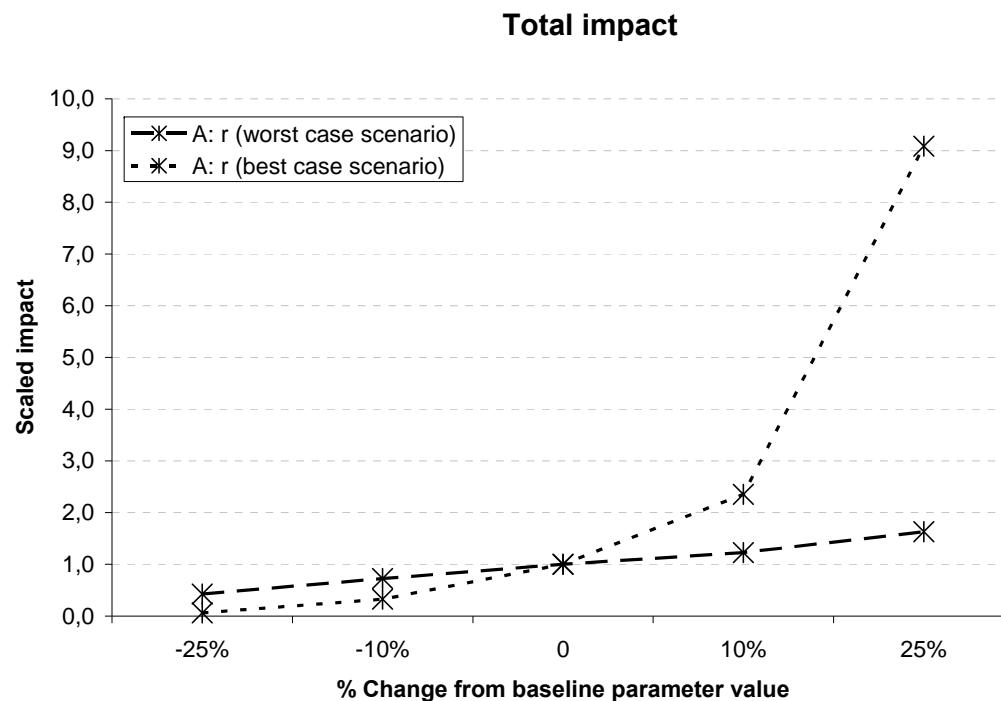
→ Comparison across the models

parameter change: +/- 10%

common output: total invaded area

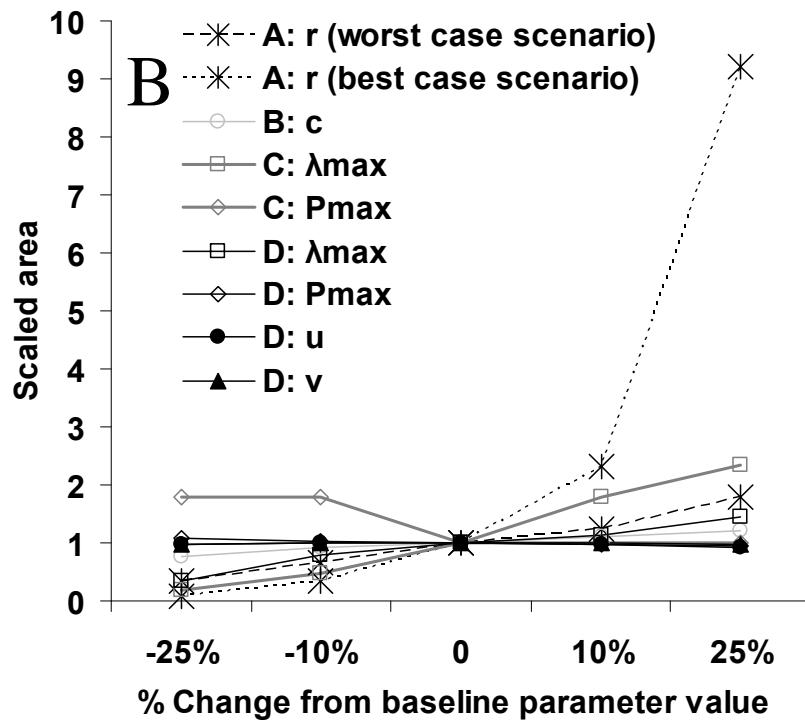
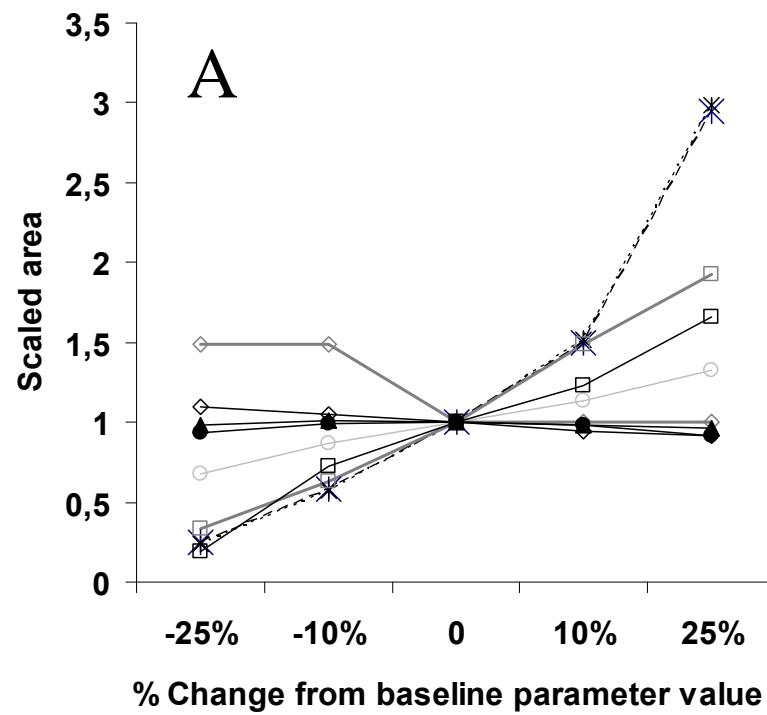
One-at-a-time analysis

Model A: Effect of changing growth parameter r on impact



One-at-a-time analysis

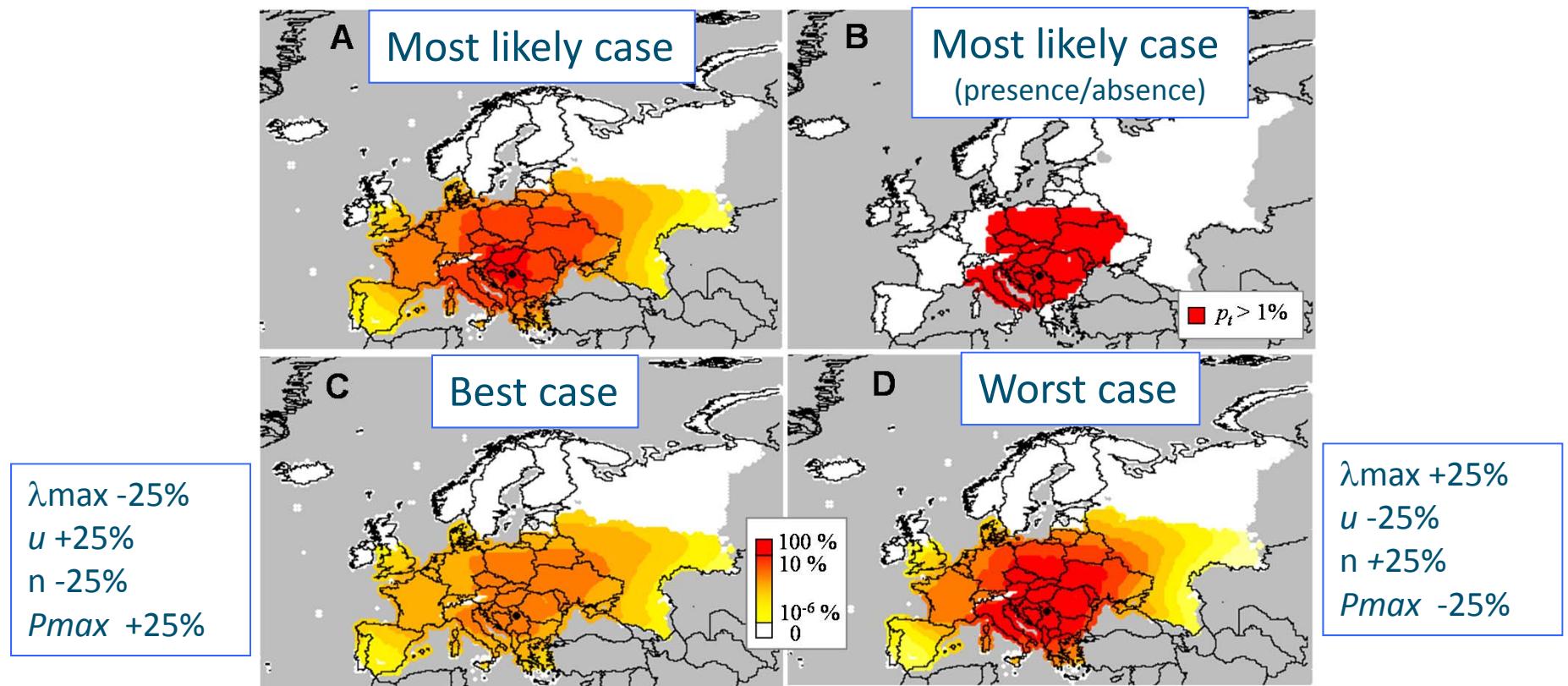
Example: total area invaded (A) and total invaded maize area (B)
Model A (parameter r) is the most sensitive



Multi-parameter changes (scenarios)

Comparison done considering each model separately

Example: model D (prev model 5)



Experts' assessment regarding the level of difficulty of parameter estimation in their case study (numbers indicate how often a score was given)

Model	Parameters	Easy	Somewhat difficult	Difficult	Impossible	n
Model A	Relative rate of r increase	-	2	-	1	3
Model B	Spread rate c	3	2	2	1	8
Model C	Yearly multiplication factor λ_{\max}	-	2	6	-	8
	Carrying capacity P_{\max}	1	3	4	-	8
Model D	Shape parameter v	-	-	8	-	8
	Scale parameter u	4	1	3	-	8

Experts' assessment of the uncertainty of parameter estimates in their case study (numbers indicate how often a score was given)

Model	Parameters	Low uncertainty	High uncertainty	n
Model A	Relative rate of r increase	1	1	2
Model B	Radial rate of c range expansion	4	3	7
Model C/D	Carrying capacity P_{\max}	4	4	8
	Yearly multiplication factor λ_{\max}	2	6	8
Model D	Shape parameter v	-	8	8
	Scale parameter u	4	4	8

Experts' assessment of the level difficulty to obtain data for model parameterisation in their case study (numbers indicate how often a score was given)

Model	Easy	Feasible	Difficult	Very difficult	Model not applicable ¹	n
Model A	-	1	1	-	6	8
Model B	4	3	-	-	1	8
Model C	-	4	4	-	-	8
Model D	-	3	3	2	-	8

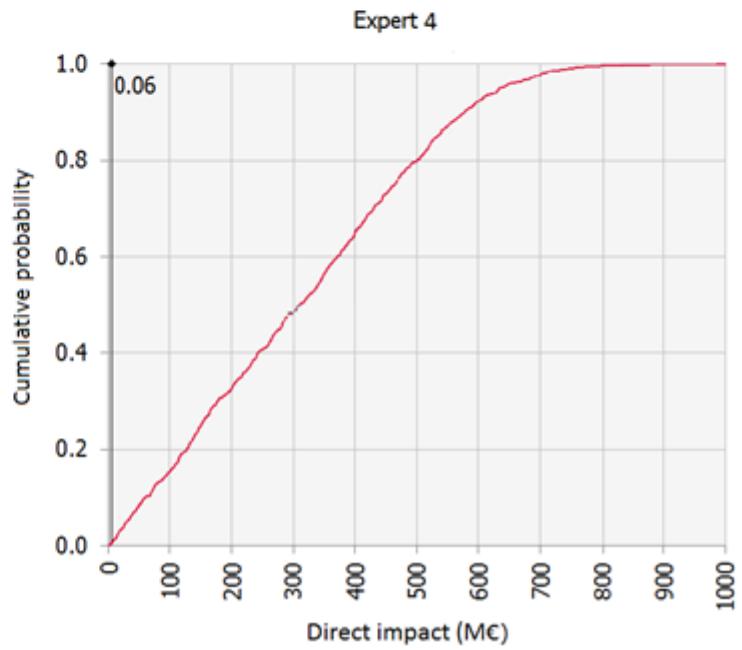
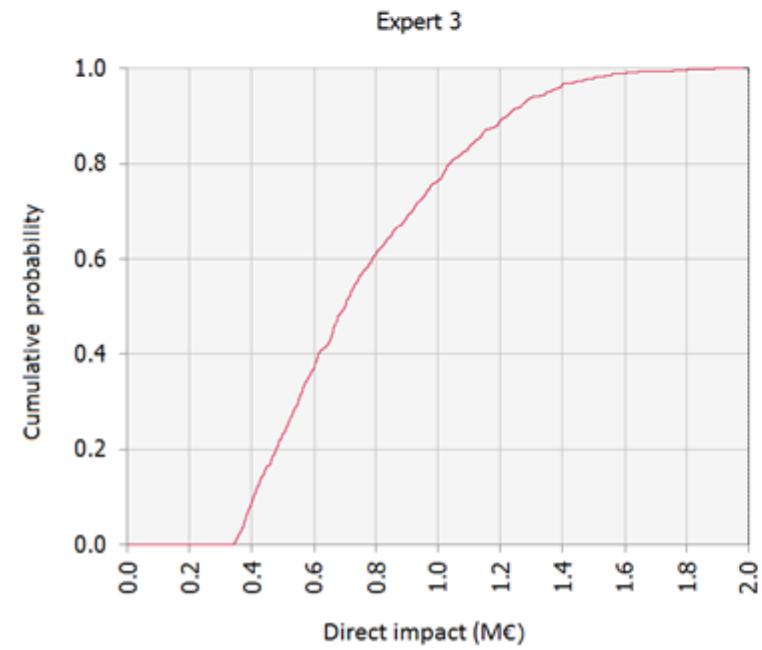
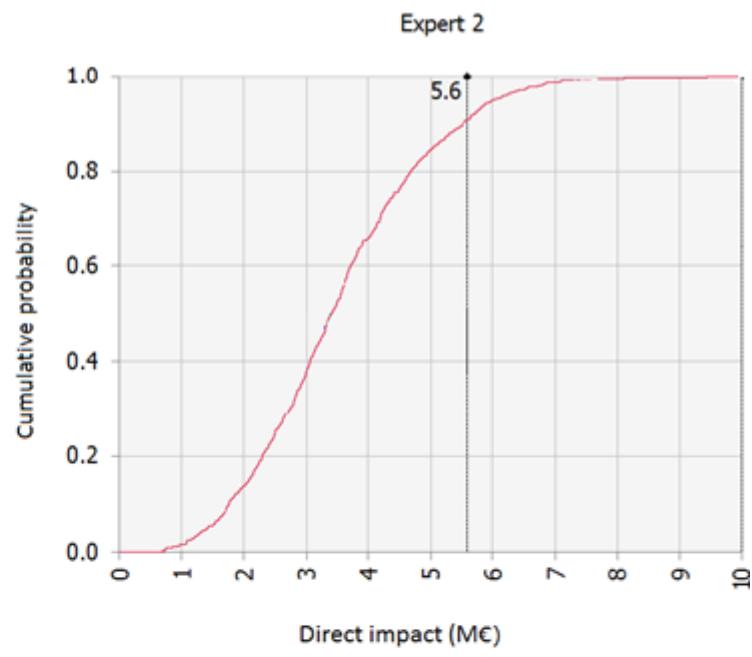
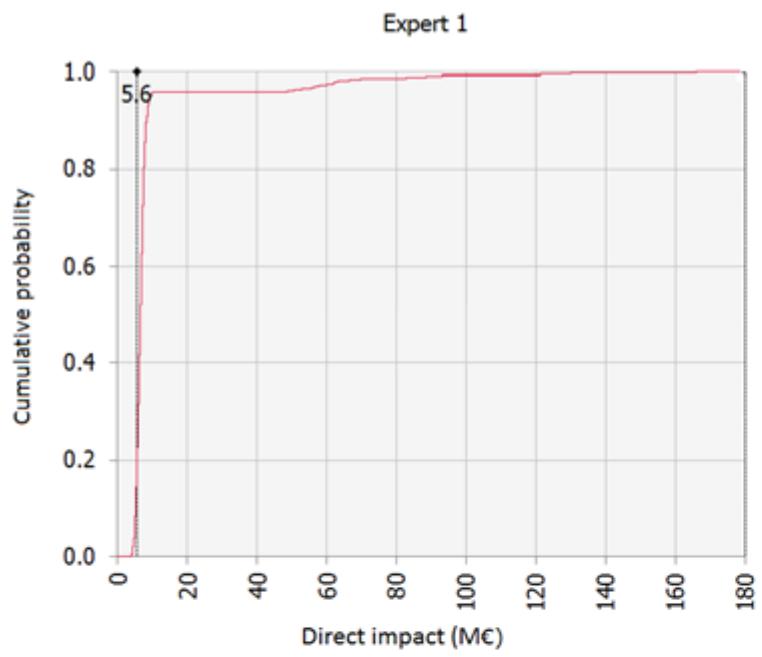
¹Model A was deemed not applicable in 6 out of 8 cases, mostly because of the effort involved in obtaining spatially explicit data on the value of assets at risk. The spread model component of model A is relatively simple to apply, but was not tested separately.

Experts' feedback on the suitability of four models in practical pest risk assessment based on their experience on specific case studies (numbers indicate how often a score was given)

Model	Suitable for PRAs and should become a common tool in PRAs	Suitable for PRAs and I may use it in the future	Suitable for PRAs but needs improvement(s)	Not suitable for PRAs	<i>n</i>
Model A	-	1	-	1	2
Model B	3	3	-	1	7
Model C	-	6	2	-	8
Model D	2	2	3	1	8

Expert assessments of spread risk can be quite diverging

- Three case studies in thesis of Tarek Soliman (2012)
- Next slide: assessment of impact of PSTVd outbreak, based on assessments of four experts of likely incidence in the case of “no control”



Issues

- Sensitivity analysis measures model response to inputs of initial conditions and biological (or economic) parameters
- Gives no insight in the uncertainty of the inputs
- Meta-analysis of biological parameters could quantify uncertainty in those inputs
- Scenario analysis “what if” are an efficient means to assess uncertainty in model outcomes considering uncertainty in inputs
- However, scenario choices depend on expert judgement
- Experts can differ widely in estimates of uncertainty and plausibility of scenarios
- Uncertainty can be narrowed down by working more with spread models and building familiarity and a database of historic case analyses

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Thank you

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