Modelling the continental-scale spread of Schmallenberg virus in Europe

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BBSRC bioscience for the future
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Part I

Introduction

Schmallenberg virus (SBV)

- First detected in Germany and The Netherlands in summer 2011
- Affects cattle and sheep:
  - mild or no clinical signs in adults
  - malformation in calves/lambs (referred to as AHS cases)
- Transmitted by *Culicoides* biting midges

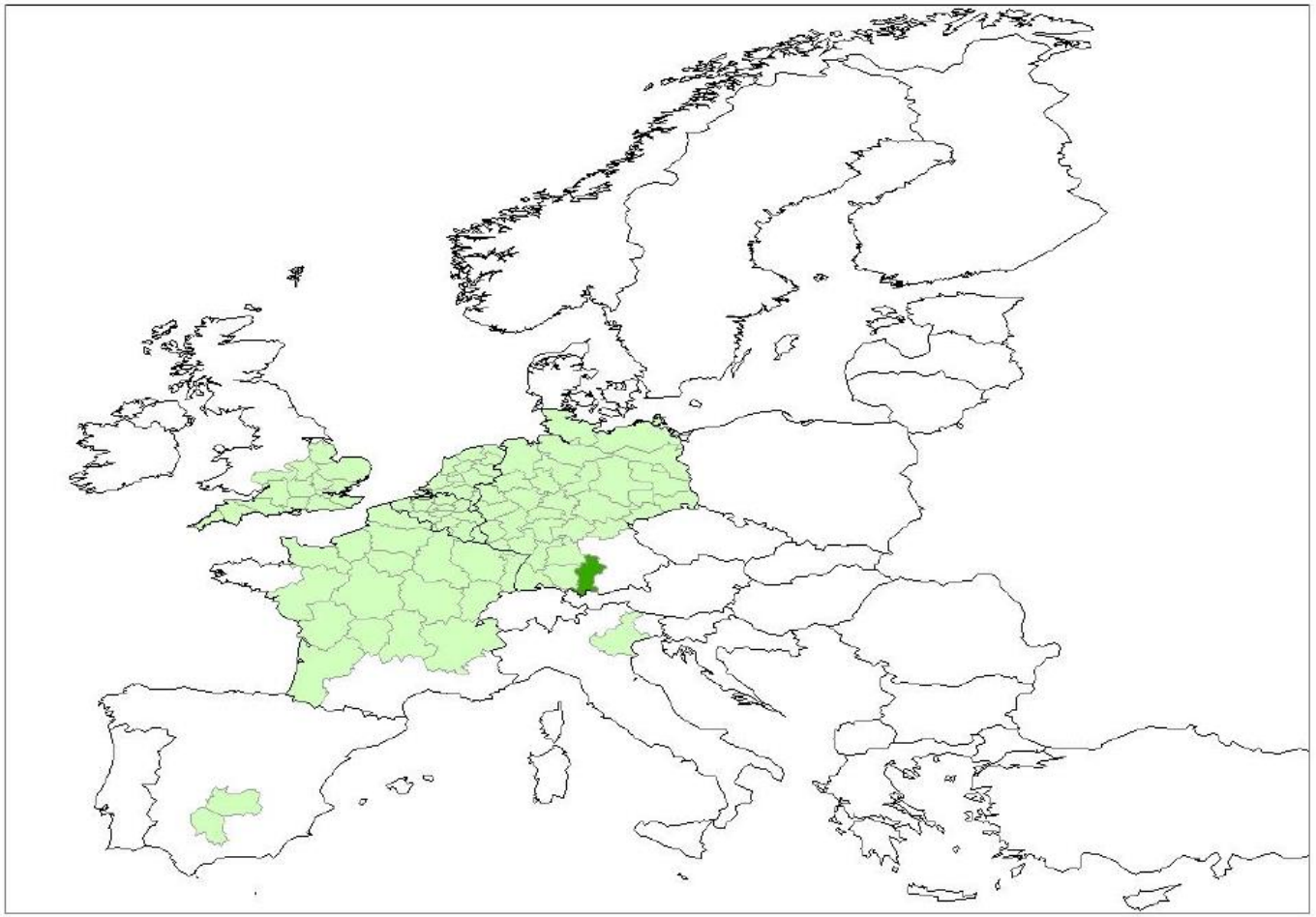
from Garigliany et al. (2012) Antiviral Research, 95, 82-87

What epidemic data?

- Member states reported cases to EFSA
- For each NUTS2 region, date and number of cattle and sheep farms reporting AHS cases:
  - not all cases confirmed as SBV
  - possibility of under-ascertainment
- Demographic data available from Eurostat at same scale

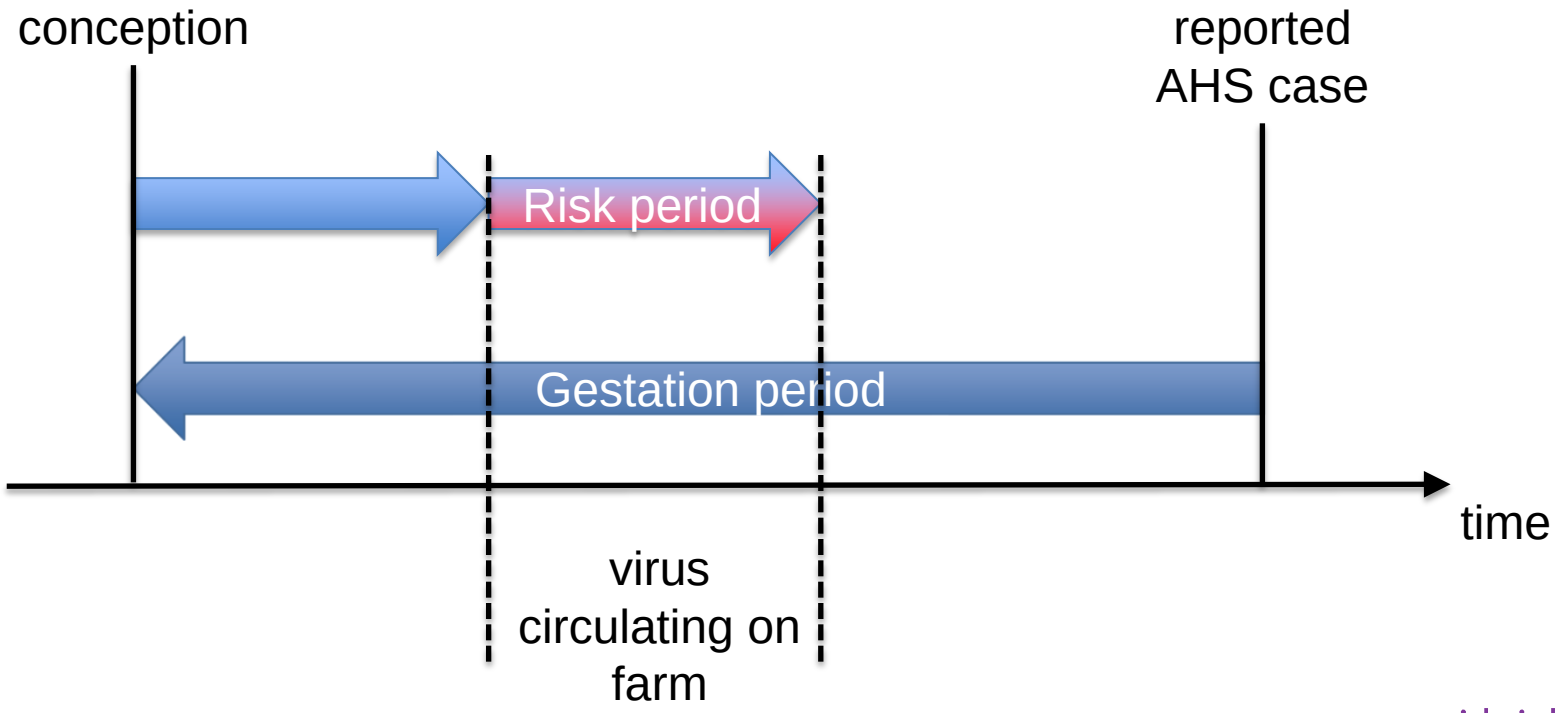
Regions reporting AHS cases

Up to end April 2012



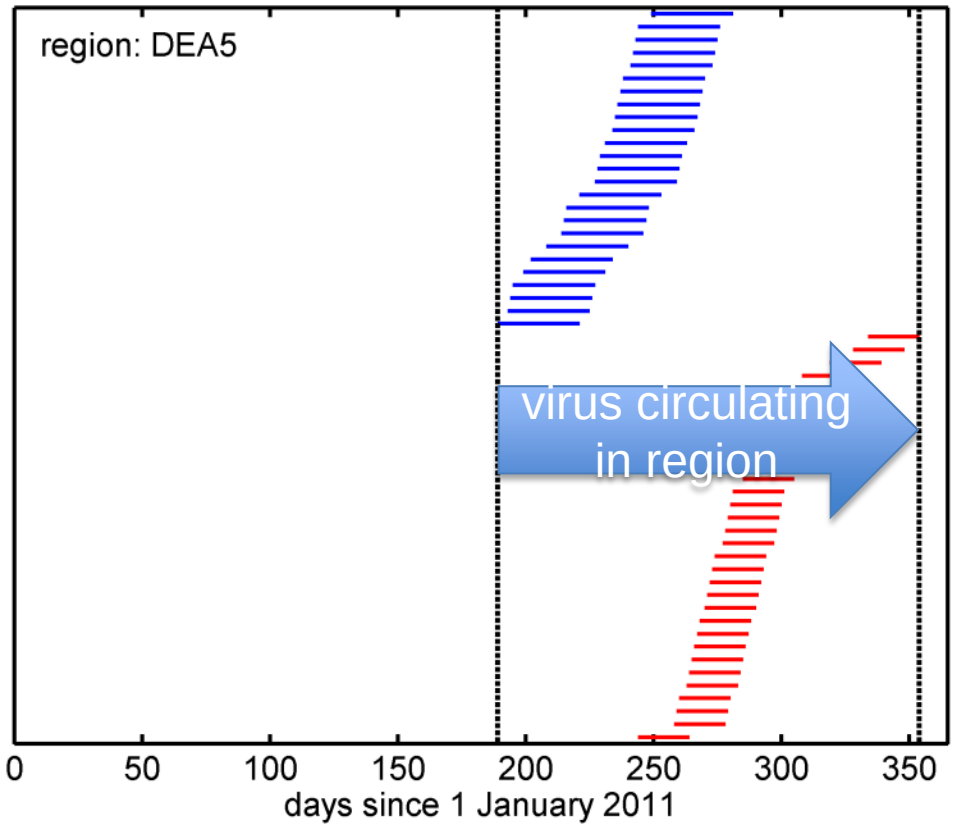
Reconstructing the epidemic (1)

- How can we infer when SBV was circulating from reported AHS cases?
  - based on Akababe virus, there is a risk period during gestation for AHS cases



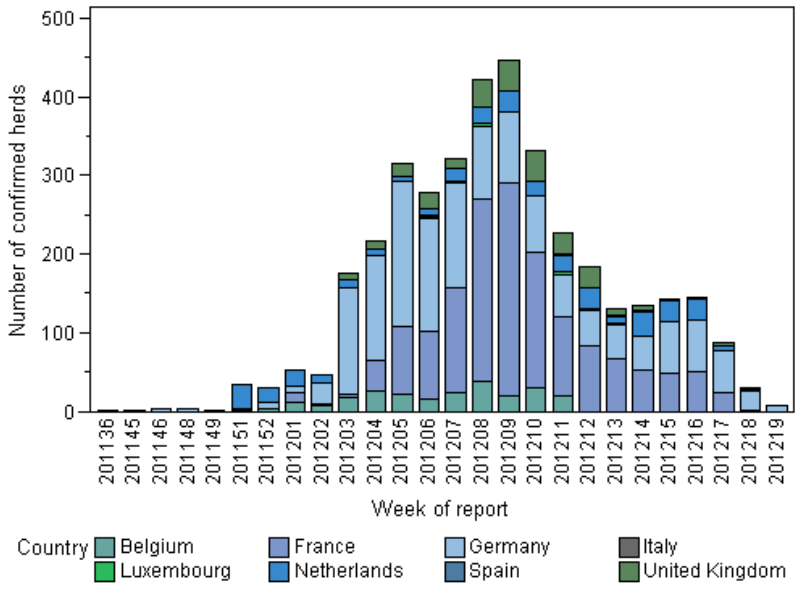
Reconstructing the epidemic (2)

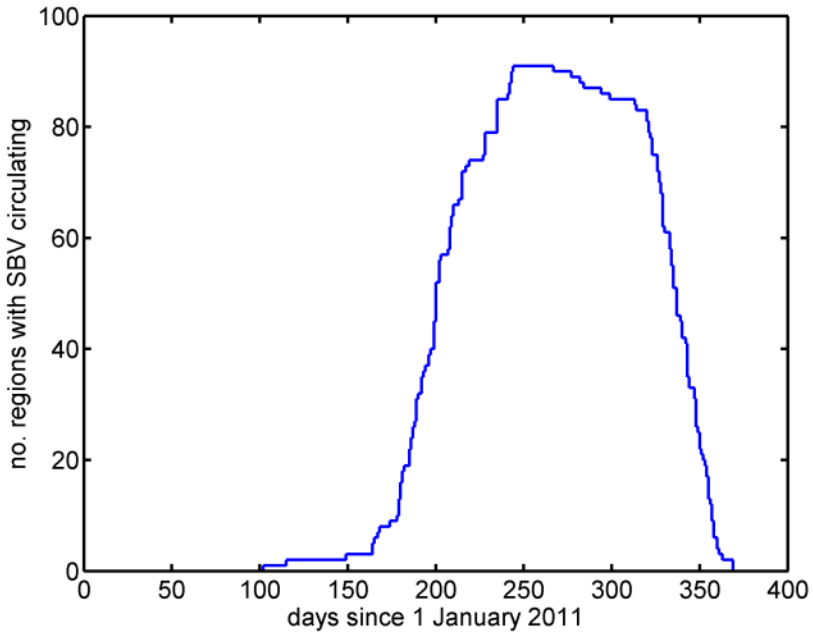
- Apply this to each farm reporting AHS cases in a region



The reconstructed epidemic

- Assuming same risk period as for Akabane virus
  - cattle: days 64-96; sheep: days 30-50





Part II

Modelling approach

Modelling the spread of SBV

- Simple model for the transmission of SBV in Europe
  - scenarios for 2012

- Model applied at level of NUTS2 regions
  - i.e. same as the data
  - includes EU28, Norway, Switzerland

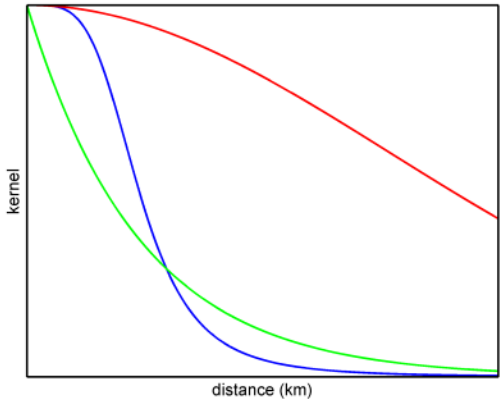
- The model has three components:
  - transmission between regions
  - duration of transmission period
  - within-region transmission (but no dynamics)

Transmission between regions

- Force of infection depends on:
  - distance between region centroids
  - number of cattle and sheep farms
  - seasonal vector activity

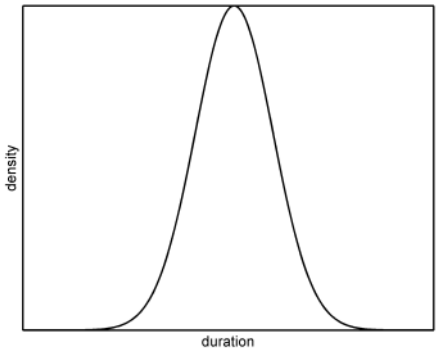
- Cattle and sheep holdings assumed to be equally infectious/susceptible

- Different kernels considered:
  - fat-tailed, Gaussian, exponential
  - density-dependent vs -independent



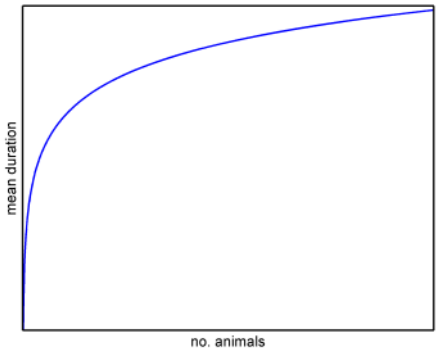
Duration of transmission period

- This is the period during which SBV circulates within a region



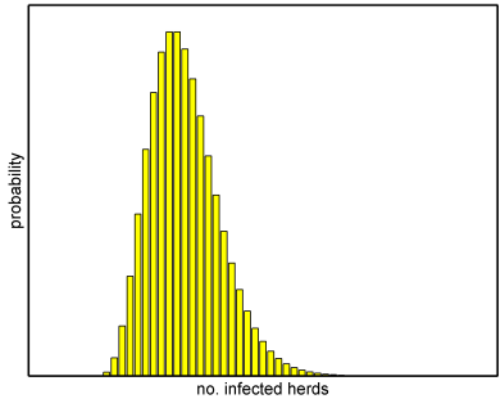
- It was assumed to follow a (truncated) Normal distribution

- Mean depends on region demography:
  - no dependency (i.e. constant)
  - log no. animals
  - log no. farms
  - log mean farm size



Within-region transmission

- Number of infected cattle and sheep farms assumed to follow a Poisson distribution



- Expected number of infected farms (e.g. cattle):

$$\mu_C = \text{force of infection} \times$$
$$\text{no. cattle farms} \times$$
$$\text{seasonal vector activity}$$

Parameter estimation

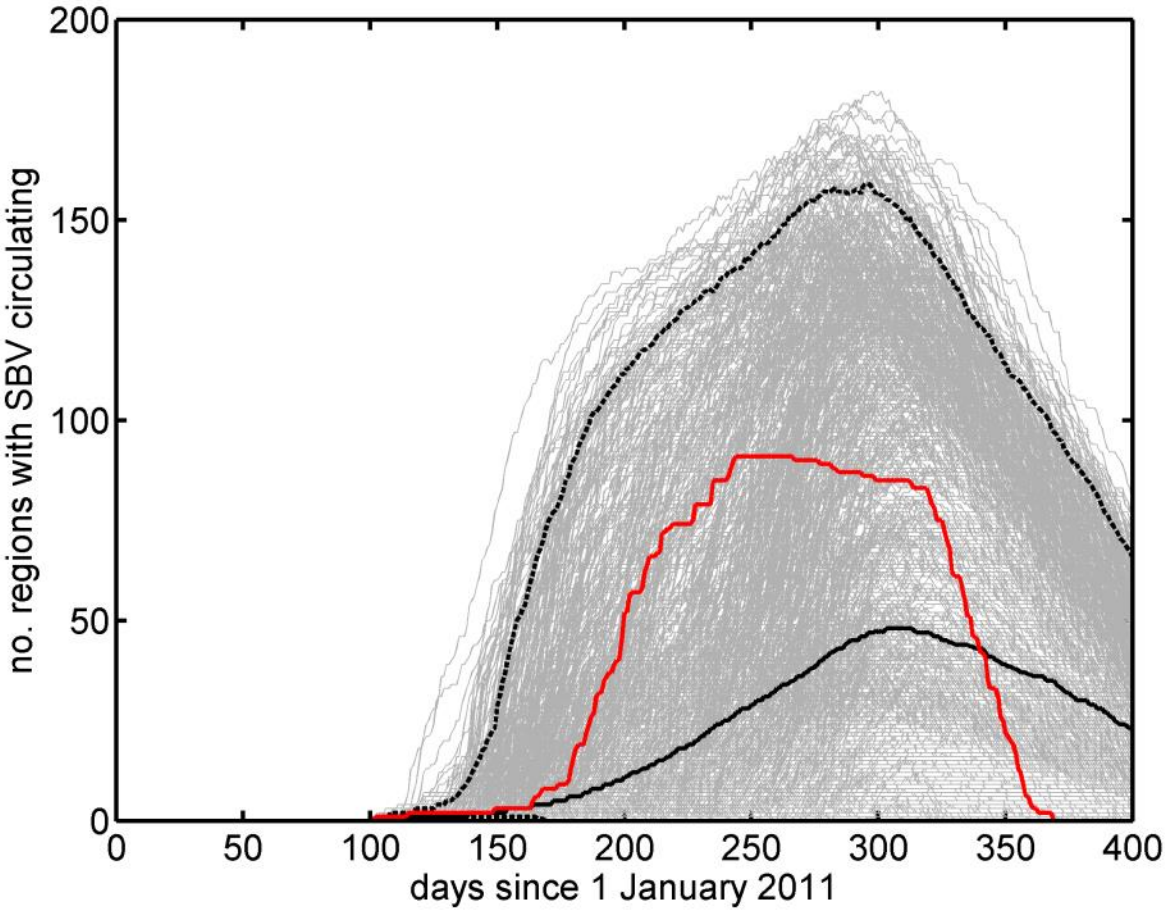
- Bayesian methods used to estimate parameters for each component of the model:
  - facilitates incorporating uncertainty in model predictions
  - adaptive Metropolis algorithm with non-informative priors
- Compare different models
  - only present results for best-fit model
- Assess impact of underascertainment
  - requires additional data (e.g. serological surveys)

Part III

Geographical spread in 2011 and scenarios for 2012

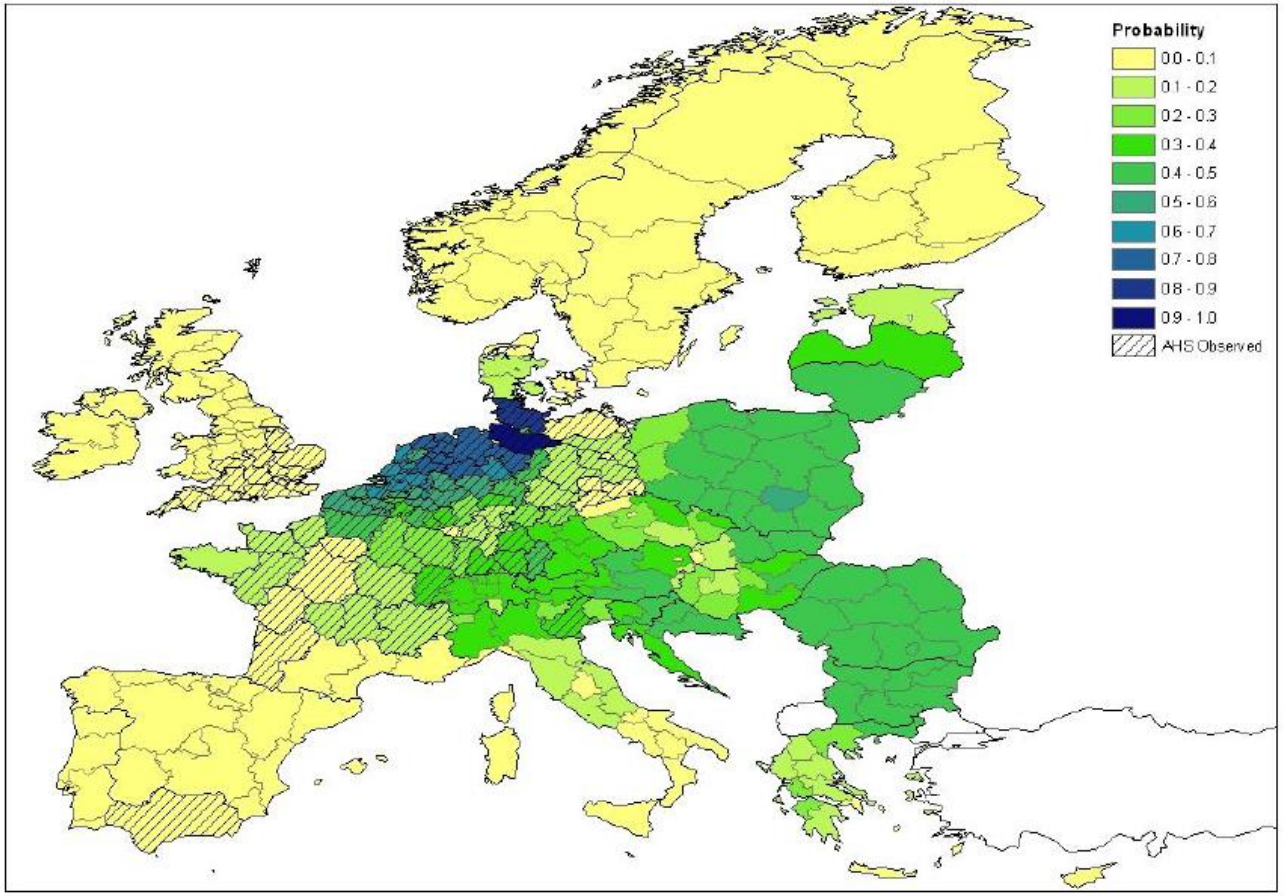
Time-course for 2011

- Fat-tailed density-dependent kernel



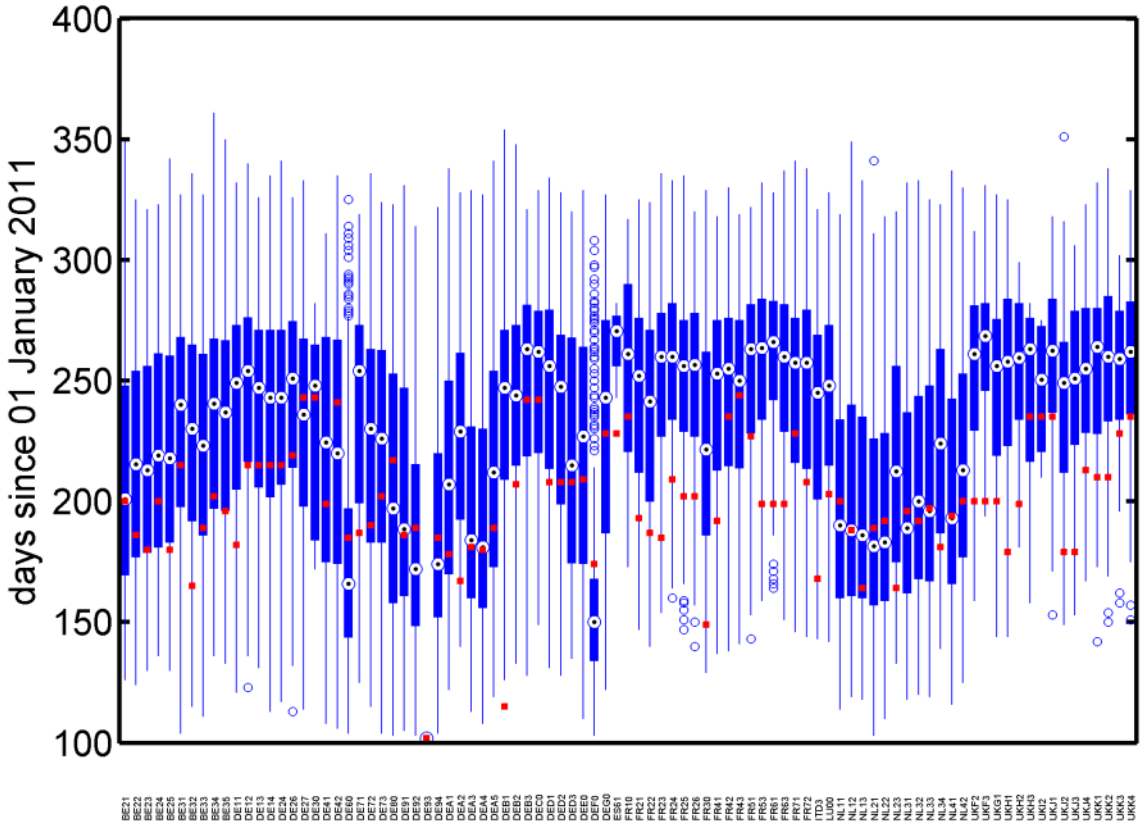
Geographical spread in 2011

- Fat-tailed density-dependent kernel



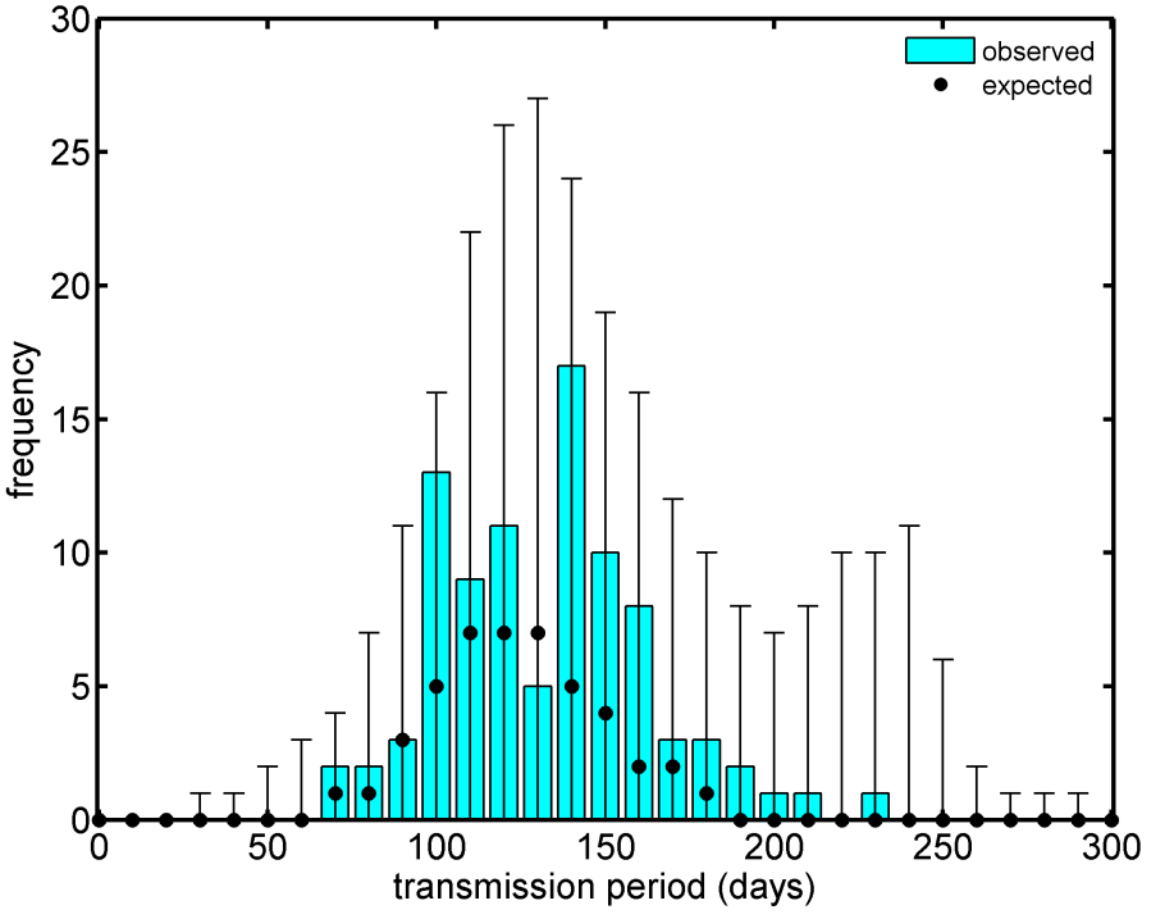
Timing of infection in 2011

- Fat-tailed density-dependent kernel



Duration of transmission period

- Mean depends on log no. animals



Scenarios for SBV in 2012

Model assumptions

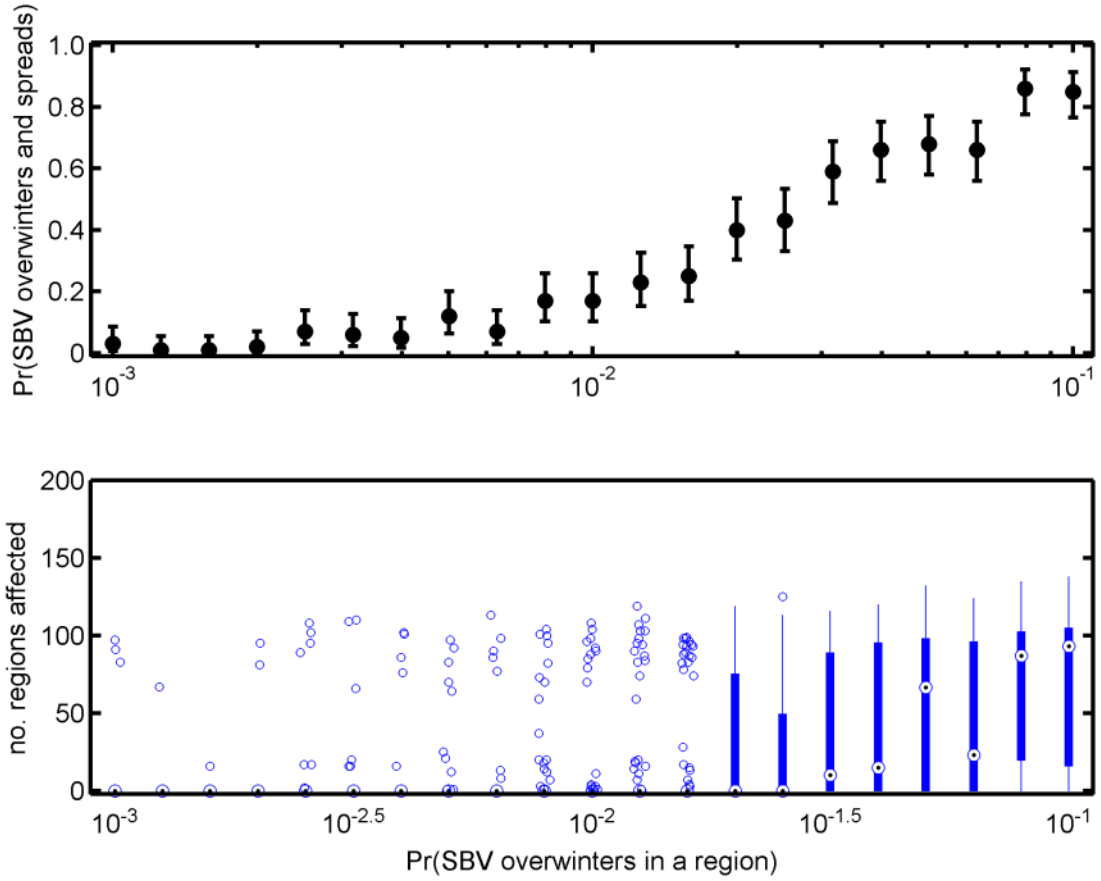
1. Regions infected during 2011 have experienced a complete outbreak (i.e. no additional spread)

2. However, they act as a source of infection for seeding outbreaks in 2012, with a given probability of overwintering

3. If SBV overwinters in a region, it remains a risk until the end of June

Scenarios: overwintering

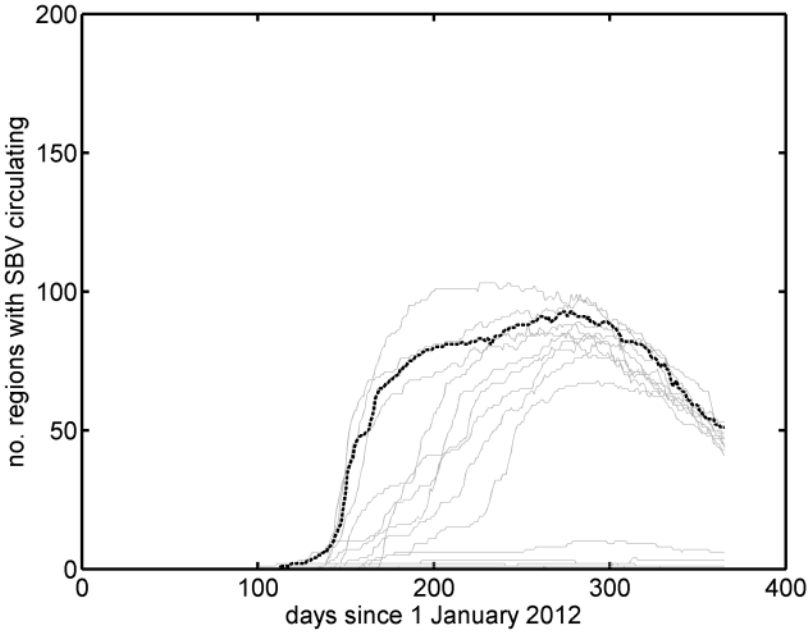
- Outcome in 2012 depends critically on probability of overwintering



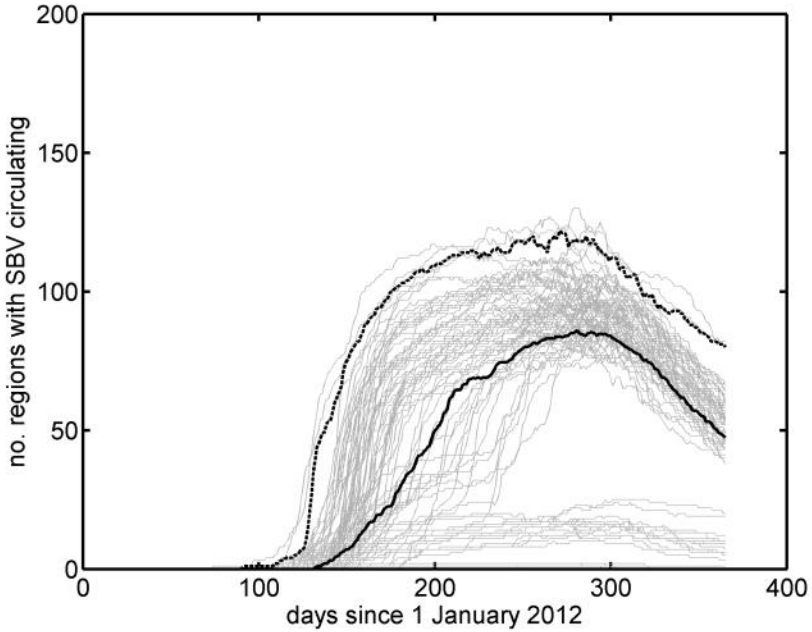
Scenarios: time-course

- Predicted time-course in 2012

Pr(overwintering in region)=0.01



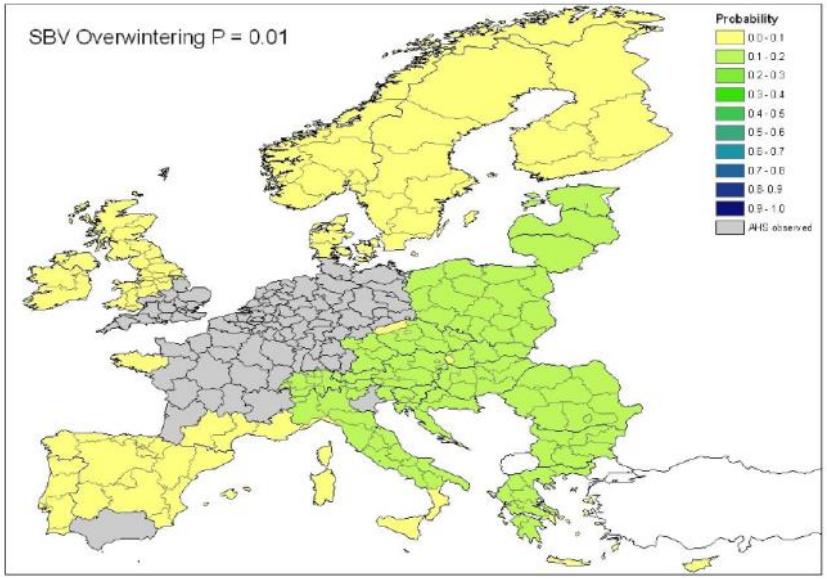
Pr(overwintering in region)=0.1



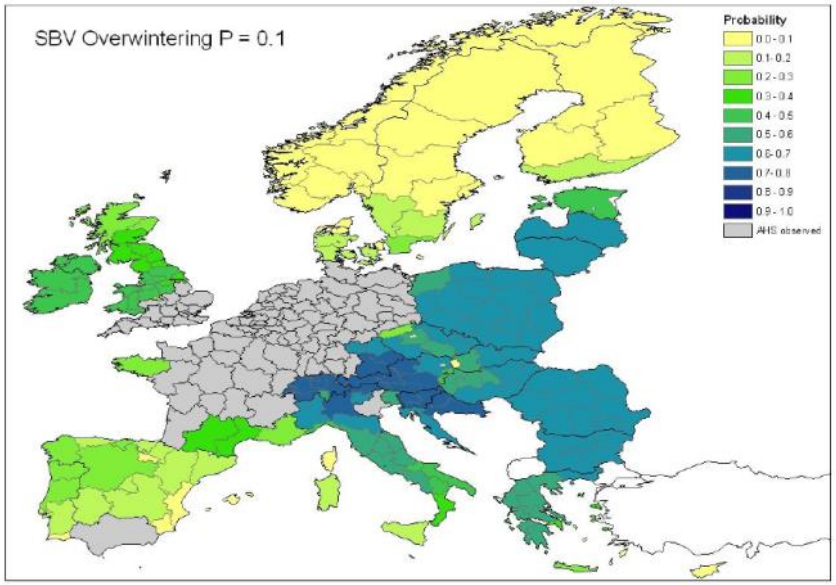
Scenarios: geographic spread

- Predicted geographic spread in 2012

Pr(overwintering in region)=0.01



Pr(overwintering in region)=0.1



Scenarios: conclusions

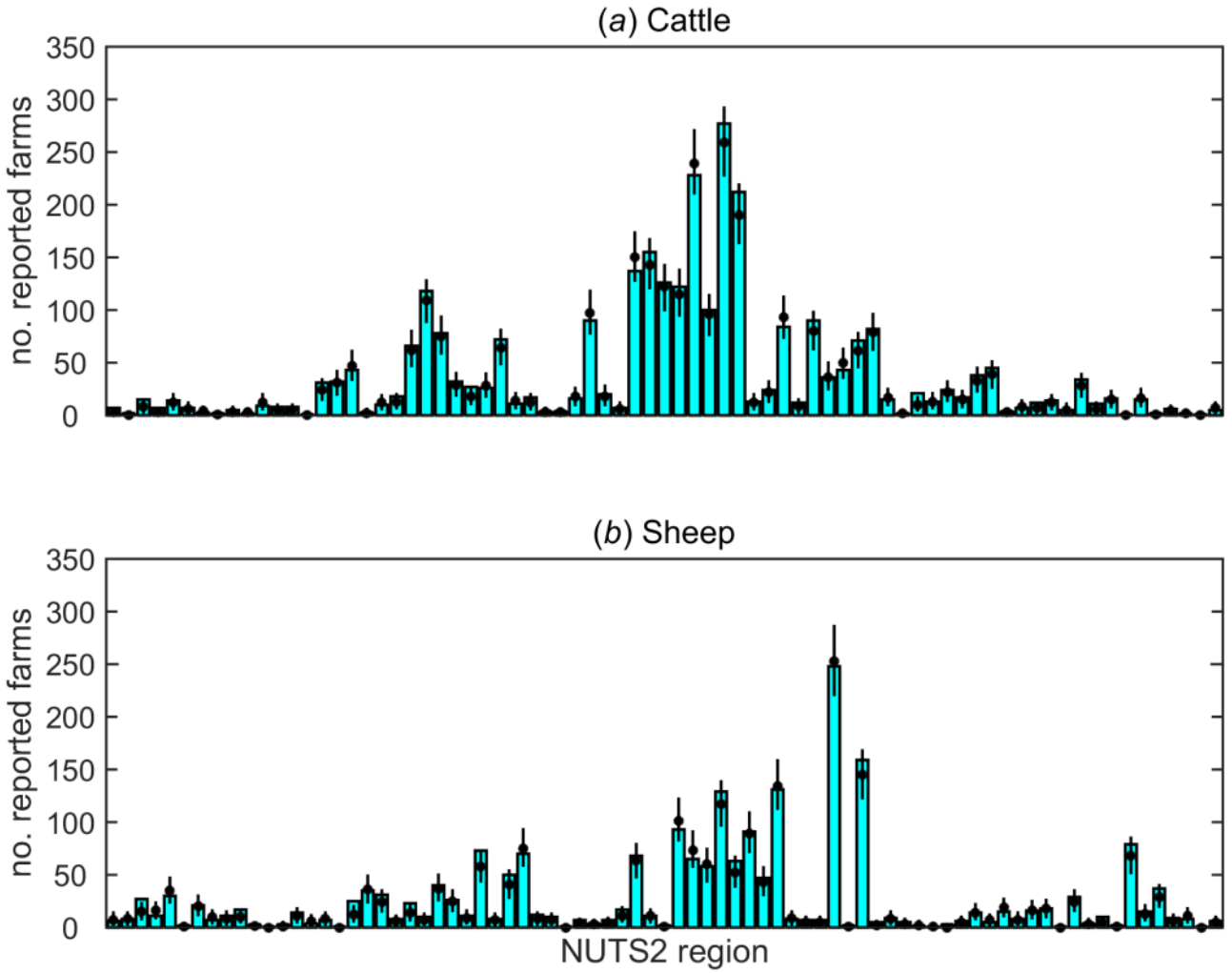
If SBV overwinters, the model predicts:

- it is likely to re-emerge between mid-April and the end of May in 2012
- the outbreak is likely to be of a similar size to the one occurred in 2011, though in regions previously unaffected

Part IV

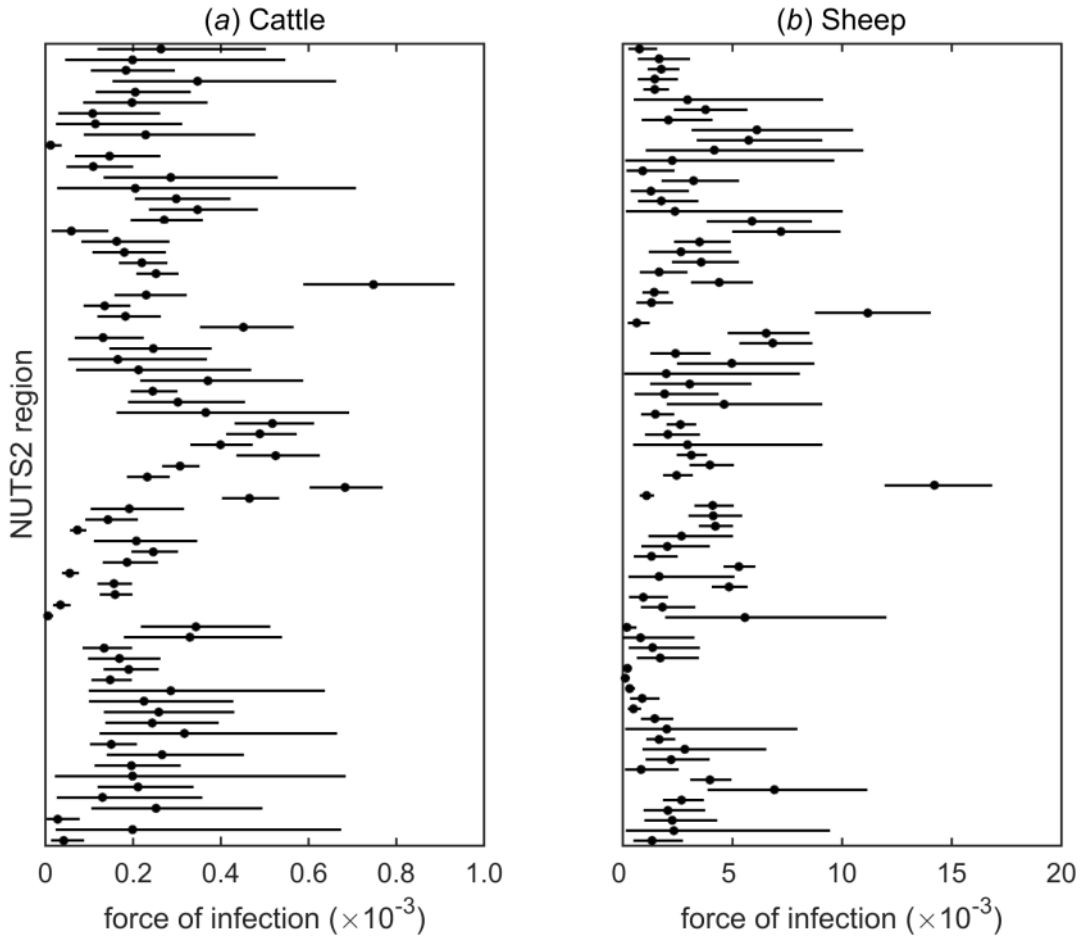
Within-region transmission

Affected farms in a region



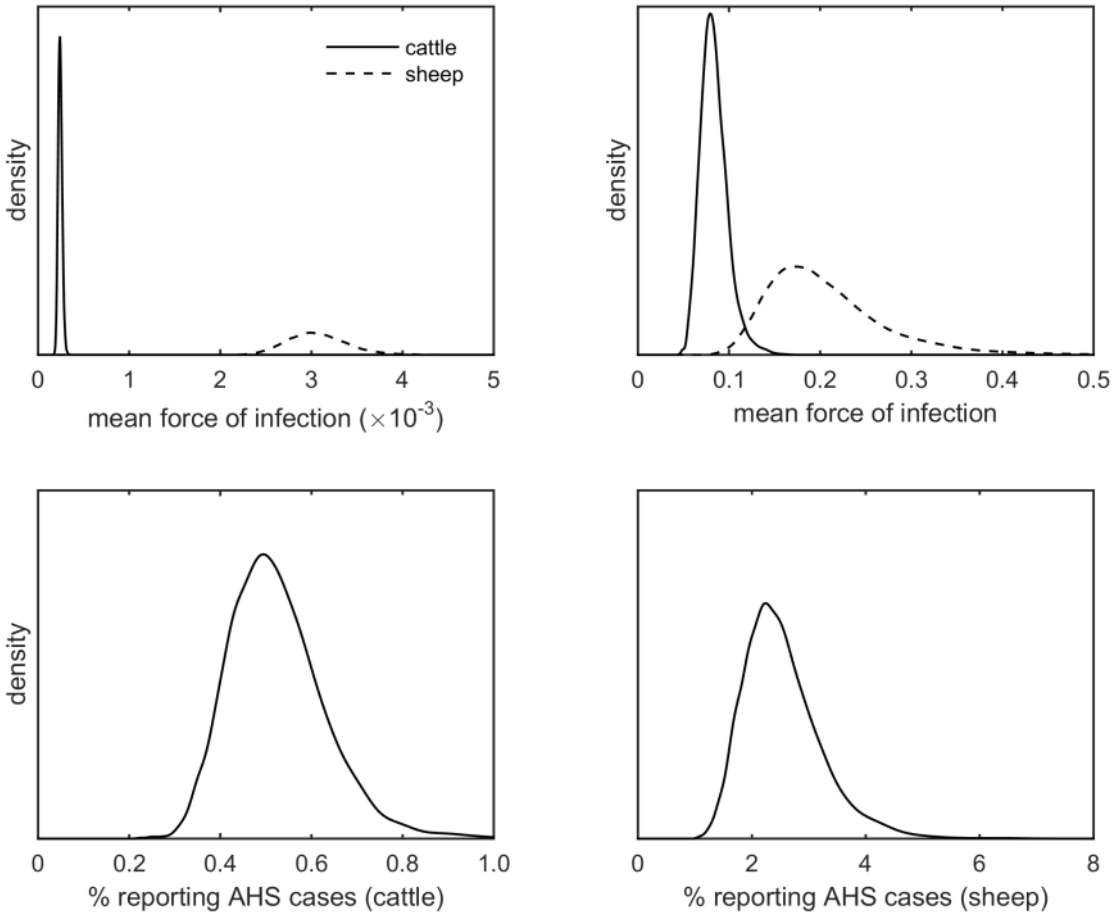
Within-region force of infection

- Regional heterogeneity in transmission



Impact of underascertainment

- Using sero-survey data for Belgium and The Netherlands



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The Pirbright campus is being redeveloped

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