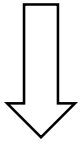
A movement rewiring algorithm applied to epidemic spread among bovines

Thibaut Morel-Journel

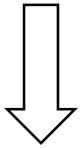
ModStatSAP meeting – 12/03/2019

Context and objectives

Hypothesis: cattle movement through commercial exchanges is a major factor of disease transmissions between farms



Question: How can we change the movements to reduce infection risks without reducing cattle exchange ?



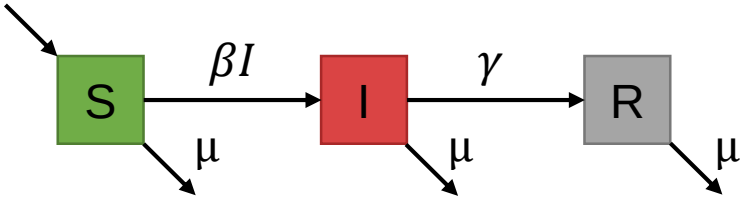
Movement rewiring algorithm

Tested on data-based movements +

mechanistic epidemic model

The computational model

Intra-herd dynamics without variation in herd size



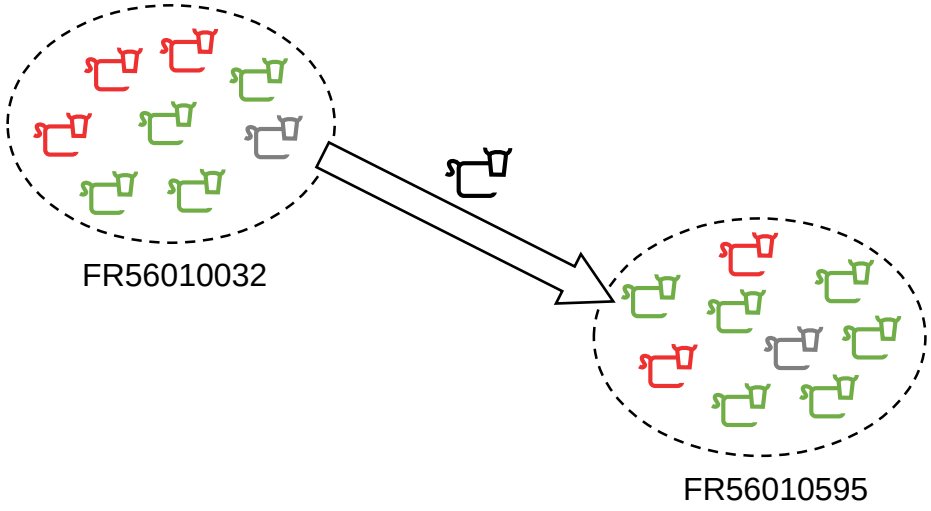
SIR model with **3 parameters**:

- The infection rate β
- The mean infection duration $1/\gamma$
- The death rate μ

Inter-herd dynamics based on real data

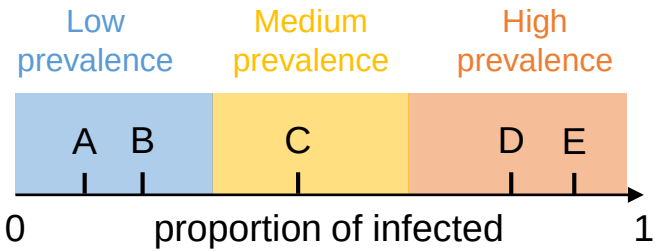
From the BDNI

# movement	Date	Origin	Destination
00001	2005-04-01	FR56010032	FR56010595
00002	2005-04-01	FR56236171	FR56236297
00003	2005-04-02	FR56102021	FR56051028

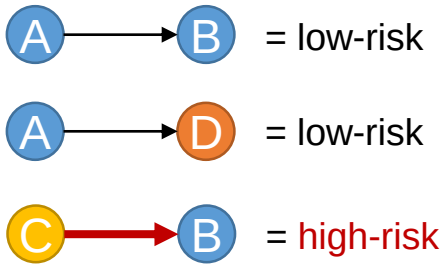


The rewiring algorithm

Each herd is assigned a **prevalence class**:



Movements are **high risk** if the prevalence class of the source is **higher** than the prevalence of the destination



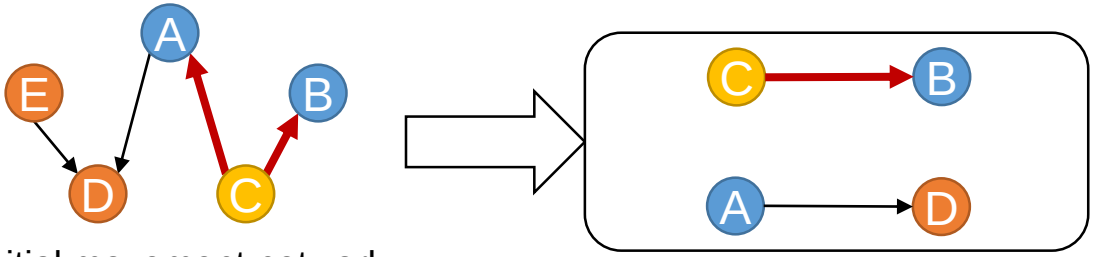
The objective: **change the source of high-risk movements to create low-risk movements**

under **4 constrains**:

- The algorithm works on the movements occurring on a given day only
- The (in- and out-) degrees of each herd must not change
- No loops
- The prevalence class of the new source is always lower for high-risk movements

The rewiring algorithm: an example

- Step 1: swap the origins of two movements



Initial movement network:
2 high-risk movements

The rewiring algorithm: an example

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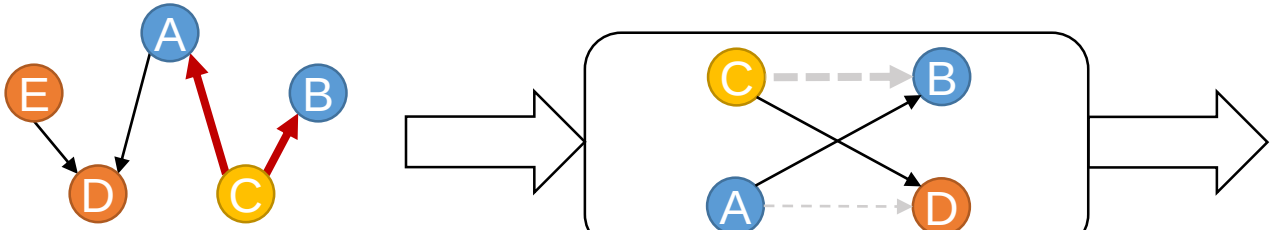
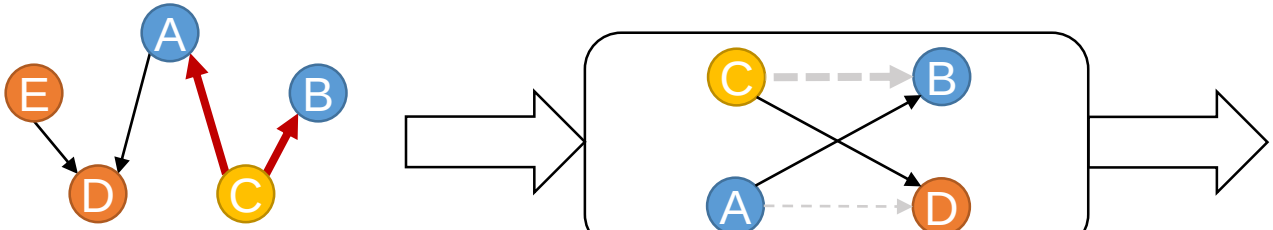


Initial movement network:
2 high-risk movements

Final movement network:
1 high-risk movement

The rewiring algorithm: an example

- Step 1: swap the origins of two movements



Initial movement network:
2 high-risk movements

Final movement network:
1 high-risk movement

- Step 2: push back the remaining high-risk movements to the next day

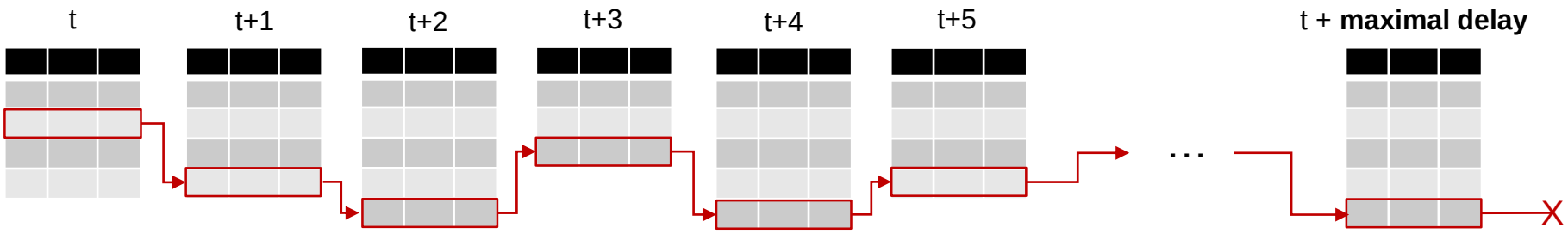
Movements of day 1

Date	Origin	Destination
1	A	B
1	C	A
1	C	D
1	E	D

Movements of day 2

Date	Origin	Destination
2	B	C
2	A	E
2	D	B
2	C	A

The rewiring algorithm: an example



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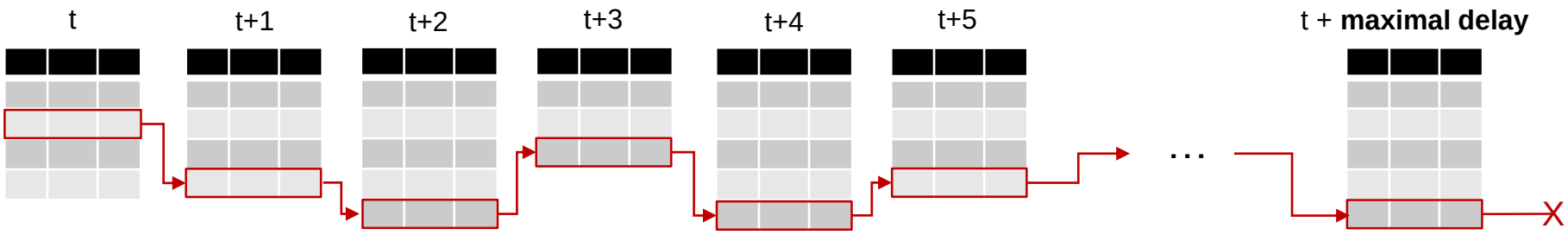
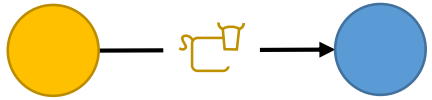


- Step 3: managing the high-risk movements reaching the maximal delay

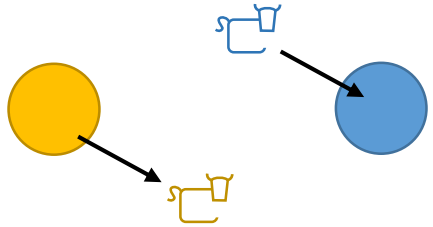
One of these methods

3a: perform the high-risk movement as such



3b: not perform the high-risk movement

3c: simulate movements from/to other herds outside of the network



Testing the algorithm

BDNI →

What ?

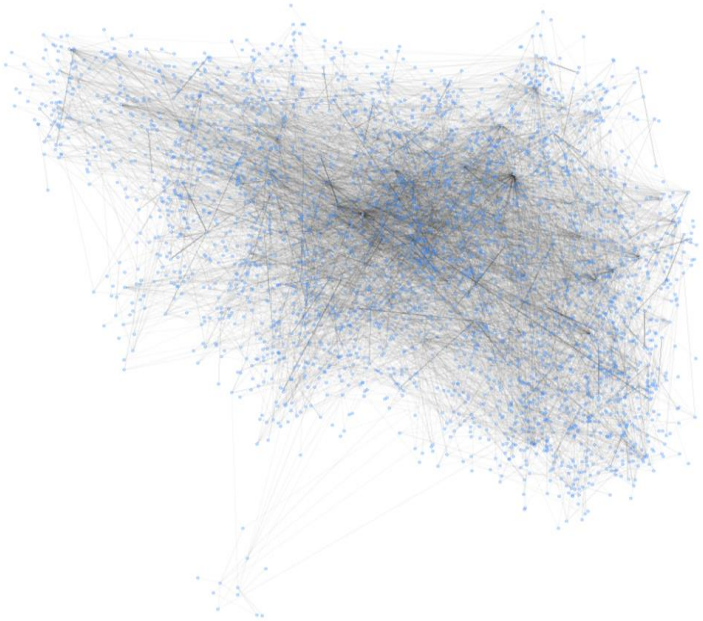
Prim'Holstein

Where?

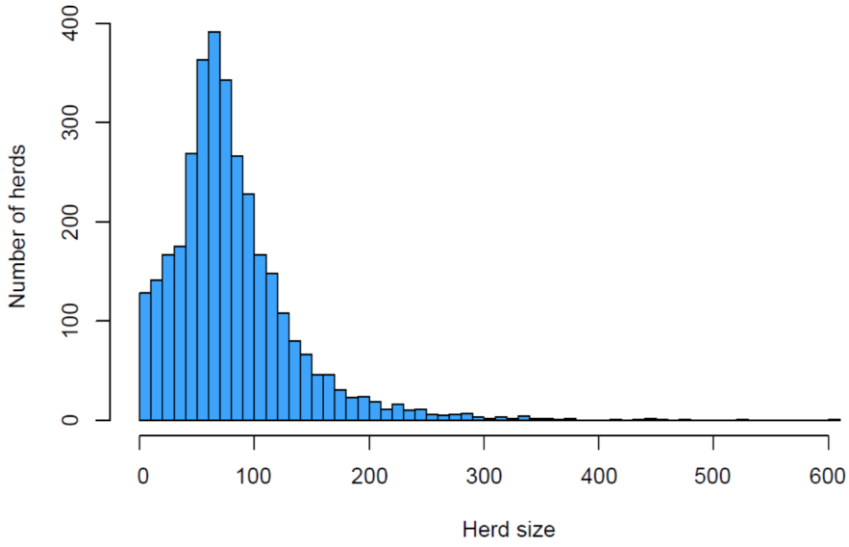
Morbihan

When ?

15429 movements between 3300 herds



Herd sizes from 1 to 605 animals



Parameters of the simulation

3 sets of parameters considered:

	Simulations #1	Simulations #2	Simulations #3
• Number of classes of prevalence	**2 ⟶ 4 classes**	4 classes	4 classes
• Maximal delay in step 2	7 days	**0 ⟶ 28 days**	7 days
• Method used in step 3	Method 3a	Method 3a	**Method 3a, 3b or 3c**

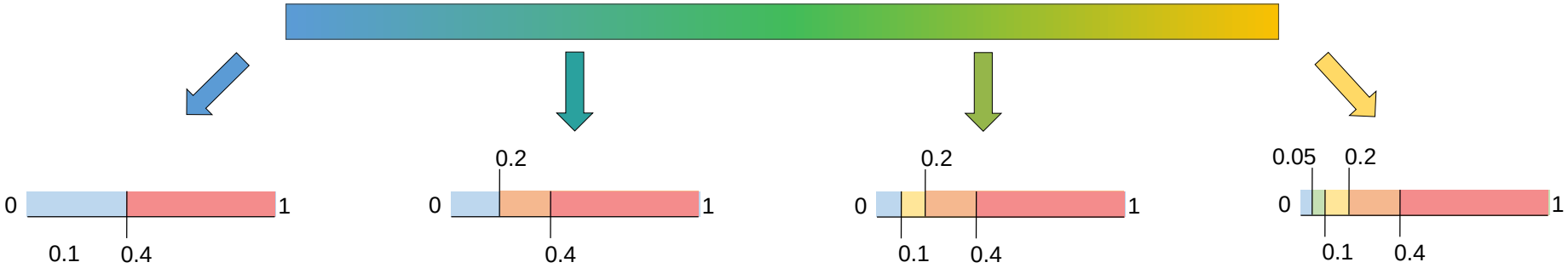
Other parameters:

- Epidemiological parameters: $\beta = 0.005$, $^1/_\gamma = 50$, $\mu = 0.02$

  ⟶ R varies between 0.05 (N = 1) and 30.25 (N = 605)

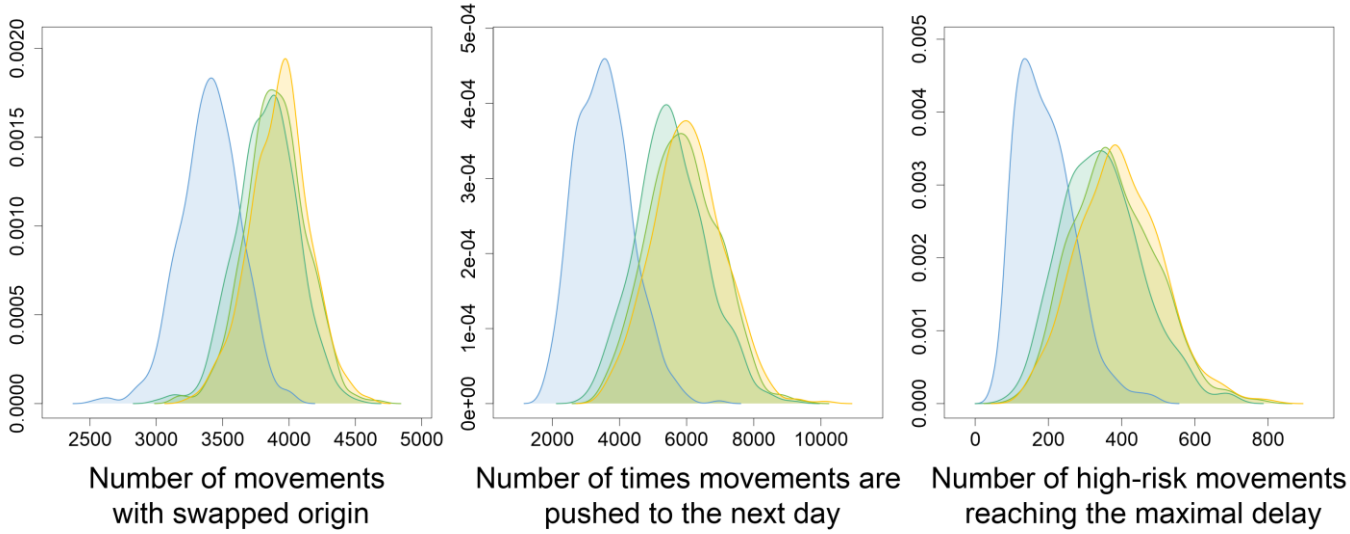
- 660 herds (20%) infected initially (chosen at random)
- 25% of status *I* in the herds infected initially
- 500 repetitions per scenario

2 to 5 classes of prevalence



(+ Maximal delay = 7 days + Method = 3a: high-risk movements performed)

Algorithm functionning



2 to 5 classes of prevalence

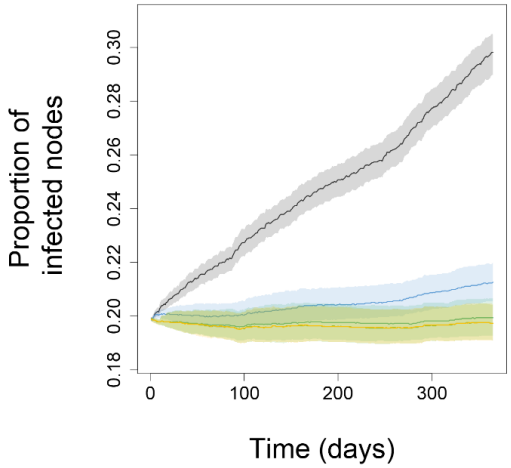
2 classes

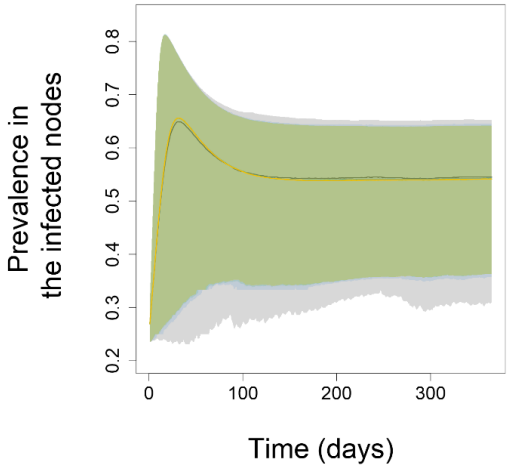
3 classes

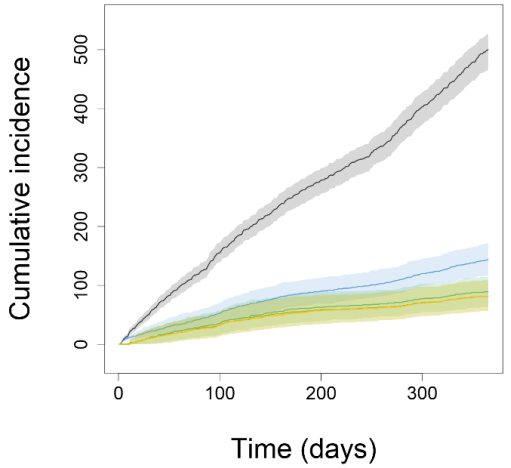
4 classes

5 classes

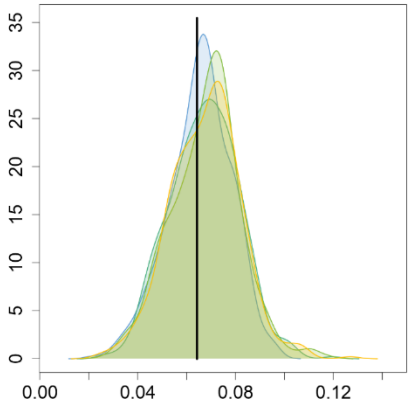
Epidemics

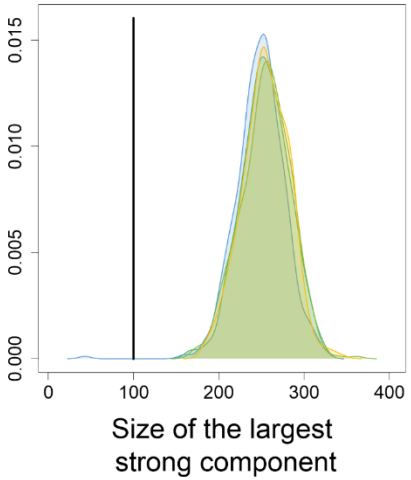


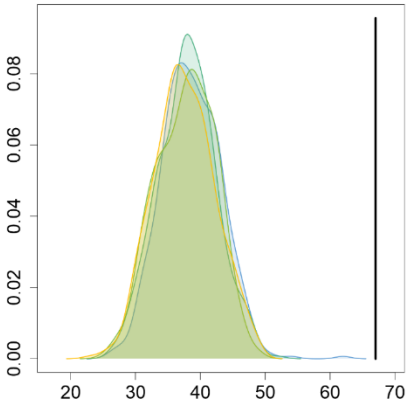




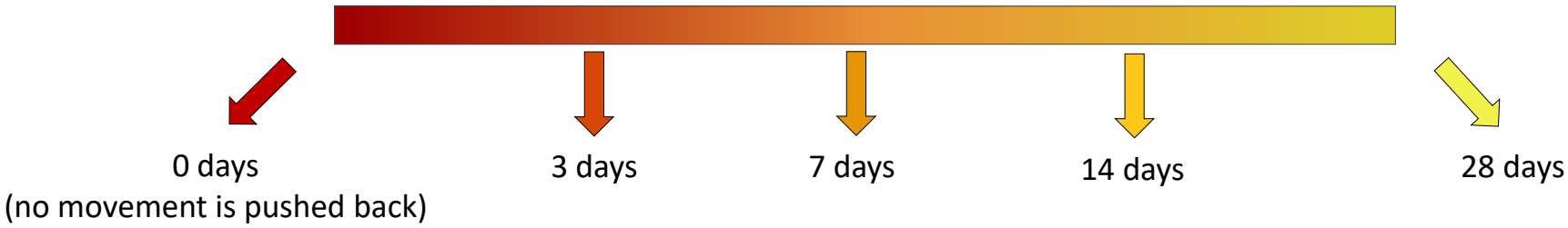
Structure of the movement network





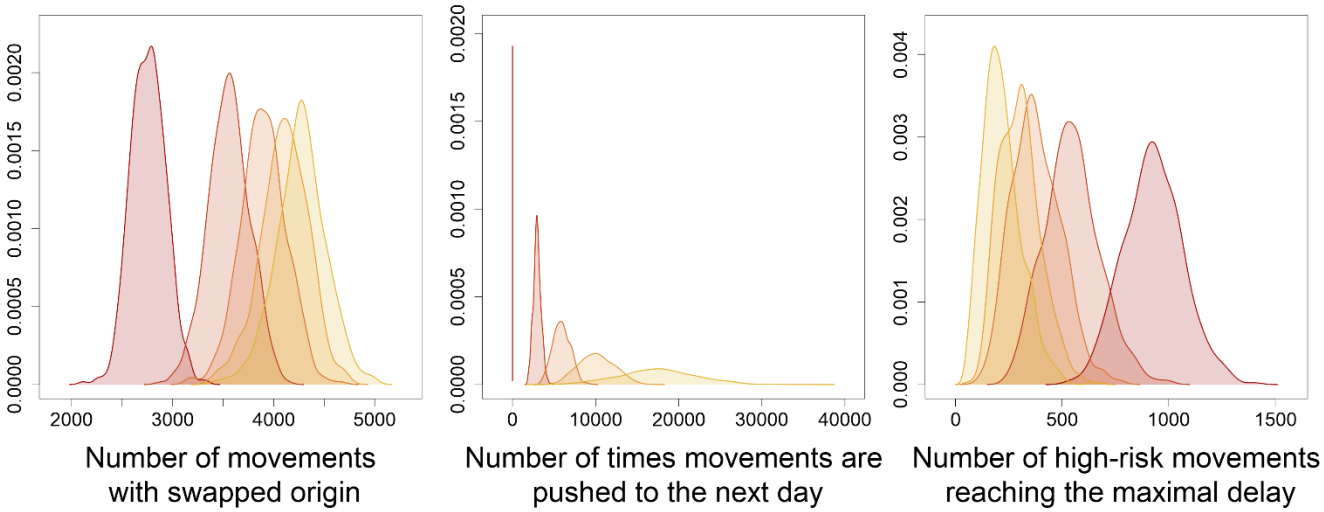


0 to 28 days of maximal delay



(+ 4 classes of prevalence + Method = 3a: high-risk movements performed)

Algorithm functionning



0 to 28 days of maximal delay

0 days

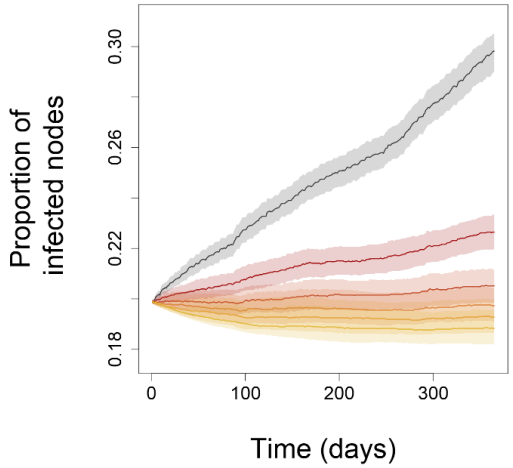
3 days

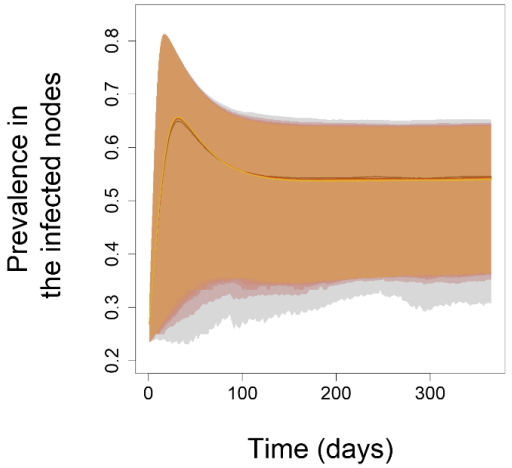
7 days

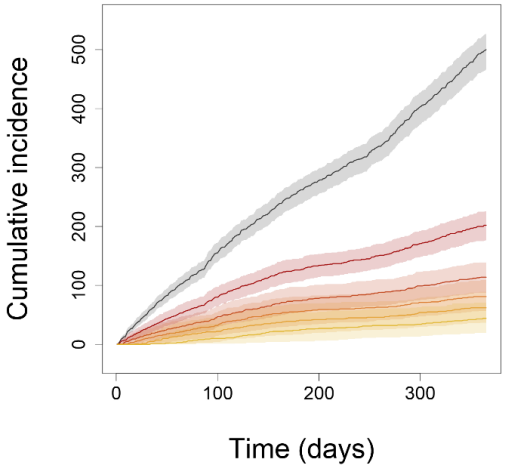
14 days

28 days

Epidemics







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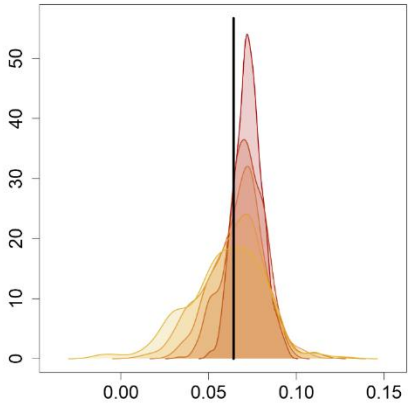
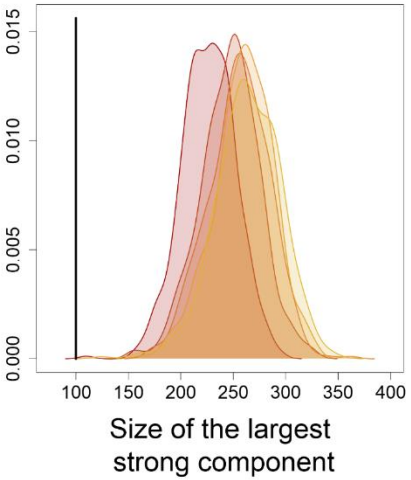
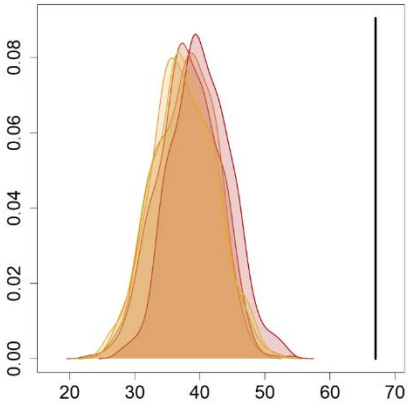






3 methods for the last high-risk movements

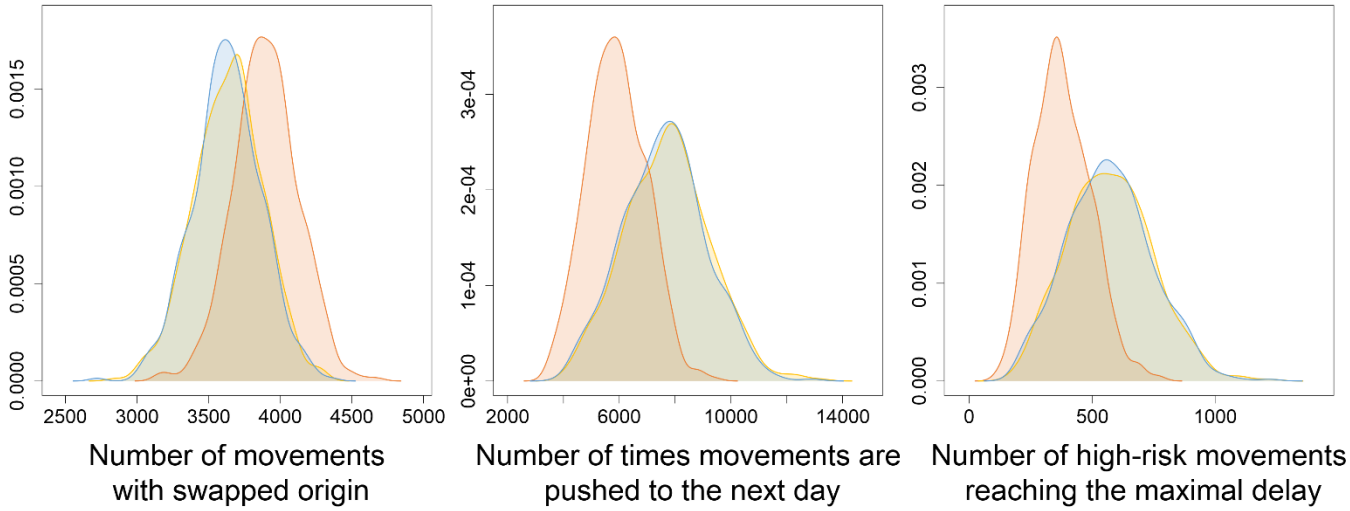
3a: perform the movements

3b: remove the movements

3c: move to the outside

(+ 4 classes of prevalence + Maximal delay = 7 days)

Algorithm functionning



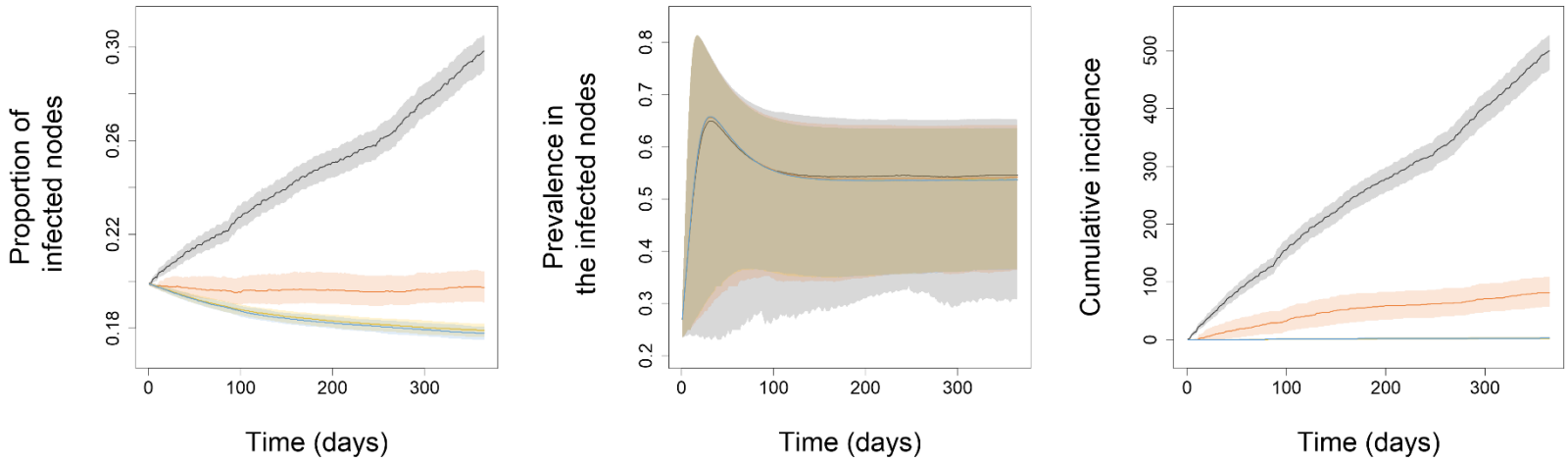
3 methods for the last high-risk movements

Method 3a

Method 3b

Method 3c

Epidemics



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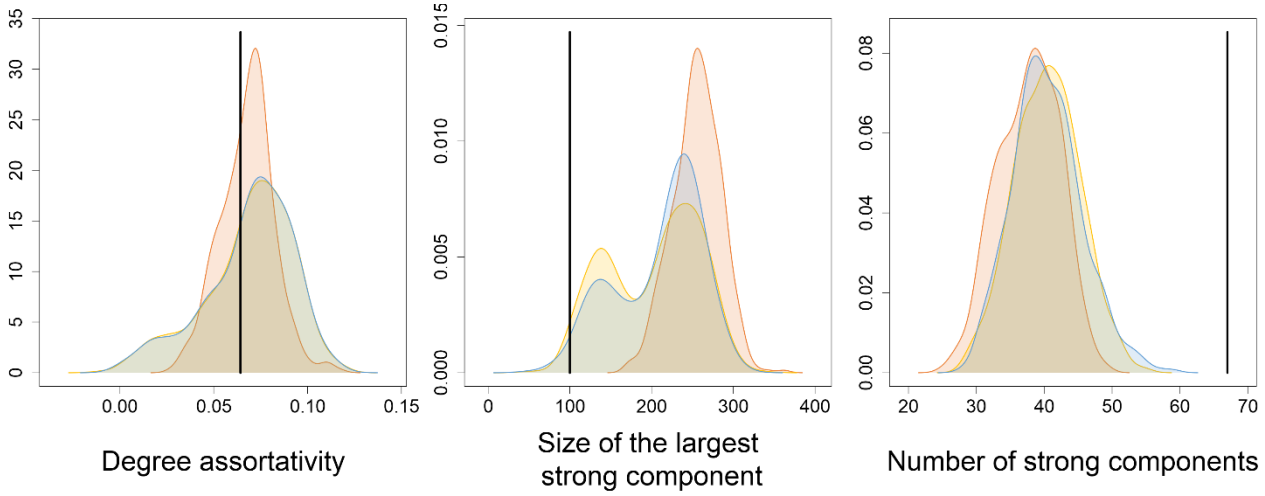

Perspectives

Sensitivity analyses

- to the three epidemiological parameters (β ,γ and μ)
- to the rewiring parameters

Mimic real bovine diseases

- which parameters result in a « realistic » infection without rewiring?

Different ways to handle the prevalence classes

- how often are they updated? (*daily in the current model*)
- which error on the estimation of prevalences (*no error in the current model*)

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THANK YOU

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