Modeling foot-and-mouth disease dissemination in Brazil

Evaluating the effectiveness of control measures

Dr. Nicolas Cardenas[1], Dr. Gustavo Machado[1]

May 29, 2023

[1]College of Veterinary Medicine
Lab website: https://machado-lab.github.io

NC STATE UNIVERSITY

Background and introduction

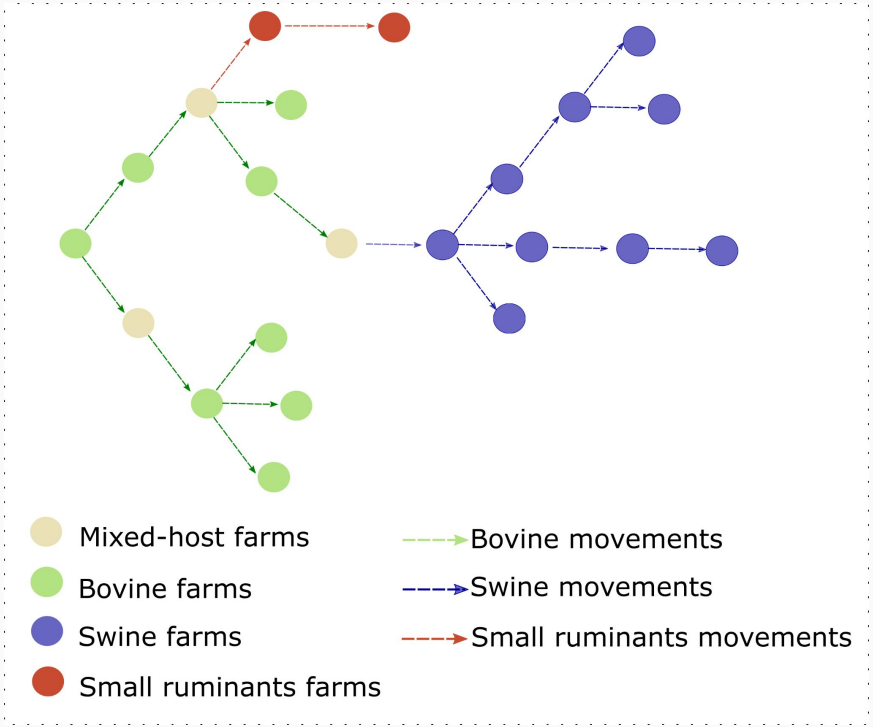
Free of FMD without vaccination since 2020.

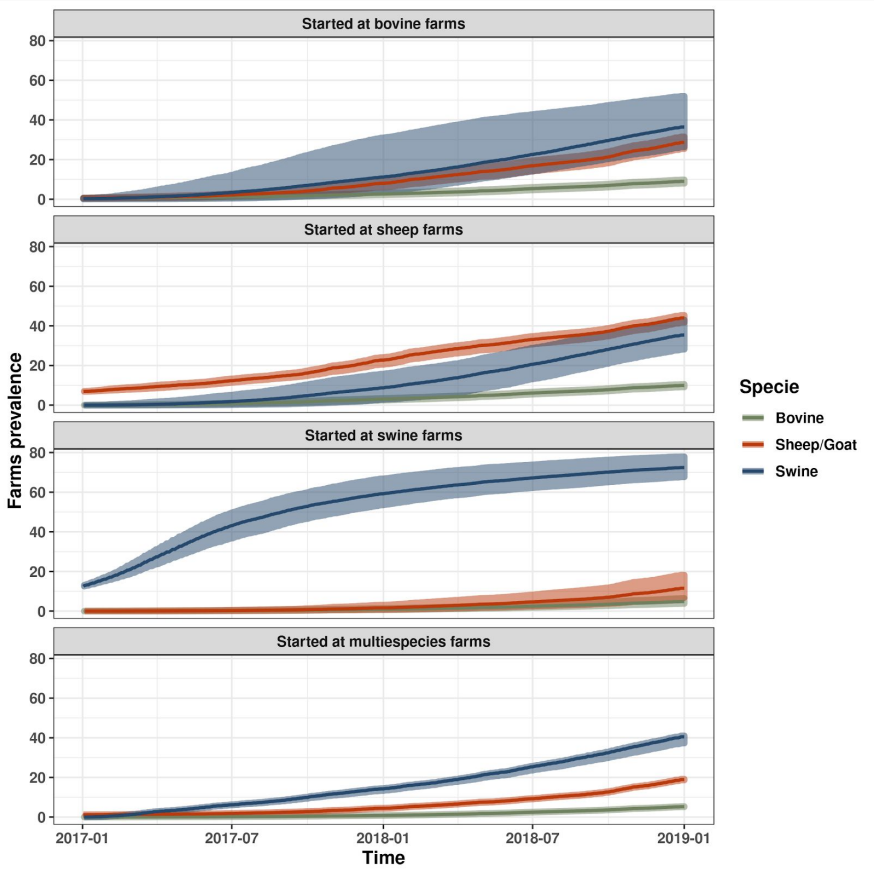
Need to be prepared for possible outbreaks:

- Know epidemic potential.
- Potential effect of control actions.

Material and Methods

Why more than one species is really essential ?



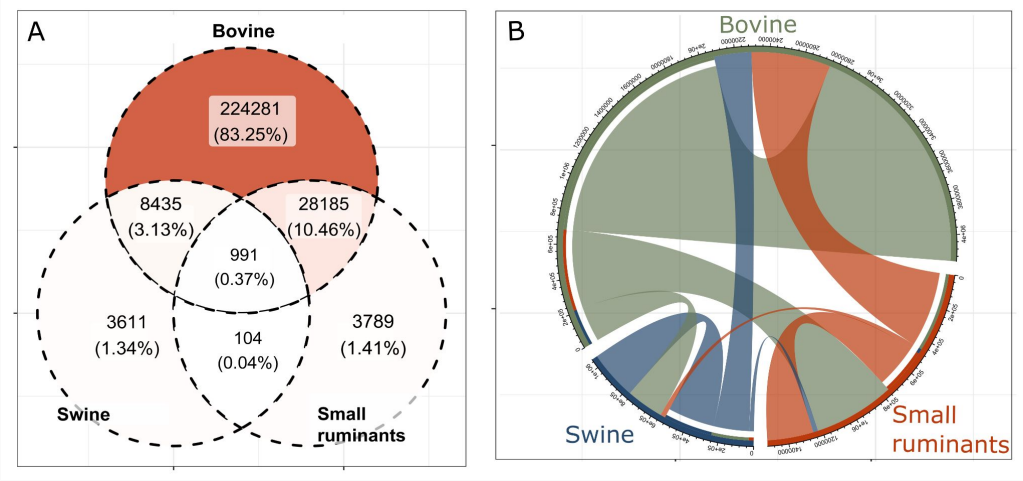


NC STATE UNIVERSITY

Cardenas, N.C., Sykes, A.L., Lopes, F.P.N. et al. Multiple species animal movements: network properties, disease dynamics and the impact of targeted control actions. V
https://doi.org/10.1186/s13567-022-01031-2

Background

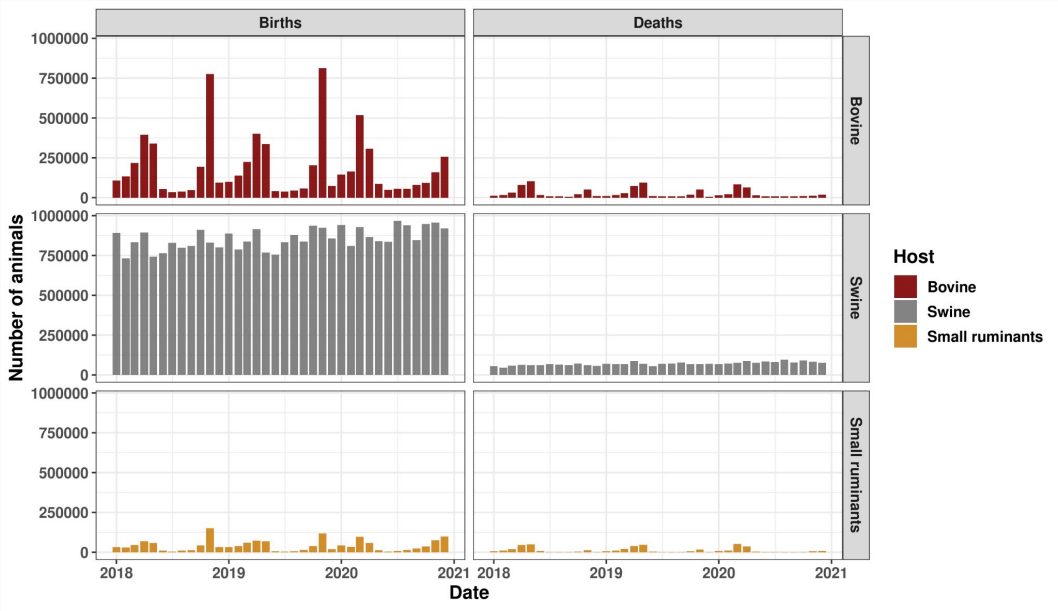
1. Livestock movements included the daily between-farm movements of farms containing:
   a. Bovine.
   b. Swine.
   c. Small ruminants.
2. Birth and death records
3. Data covering three years (2018-2020).



Cardenas, N.C., Sykes, A.L., Lopes, F.P.N. et al. Multiple species animal movements: network properties, disease dynamics and the impact of targeted control actions. Vet Res 53, 14 (2022)

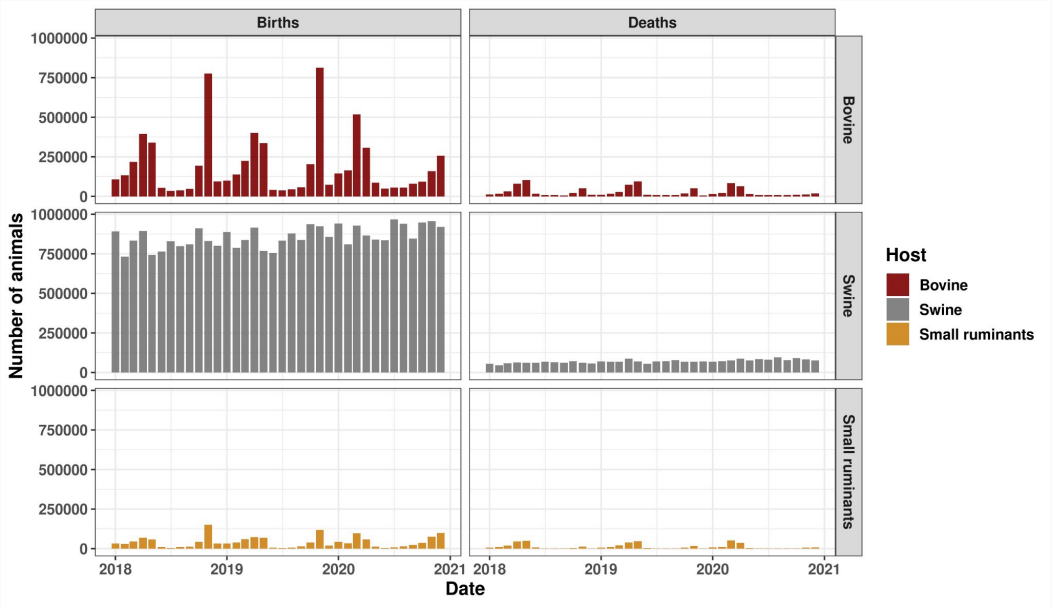
Background

1. Livestock movements included the daily between-farm movements of farms containing:
   a. Bovine.
   b. Swine.
   c. Small ruminants.
2. Birth and death records
3. Data covering three years (2018-2020).



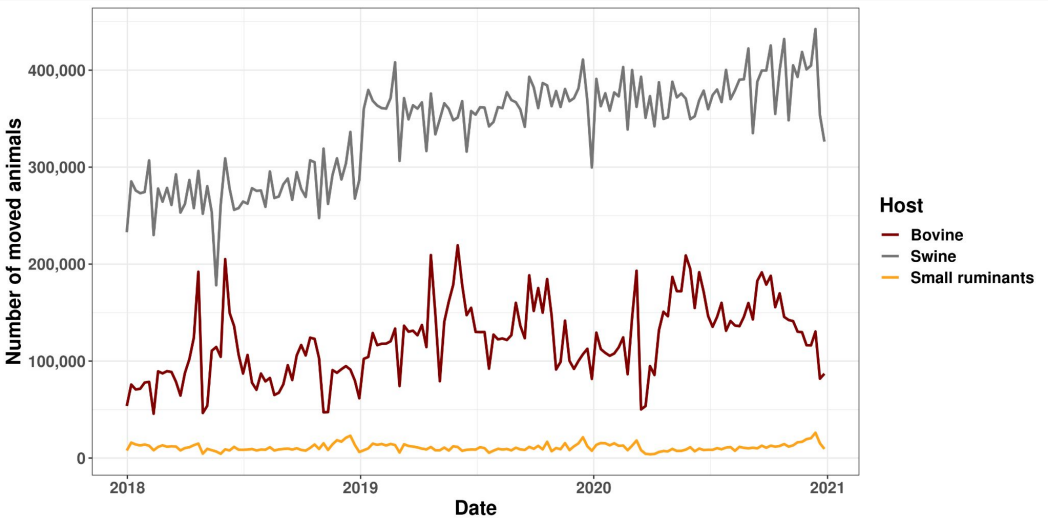
Background

1. Livestock movements included the daily between-farm movements of farms containing:
   a. Bovine.
   b. Swine.
   c. Small ruminants.
2. Birth and death records
3. Data covering three years (2018-2020).

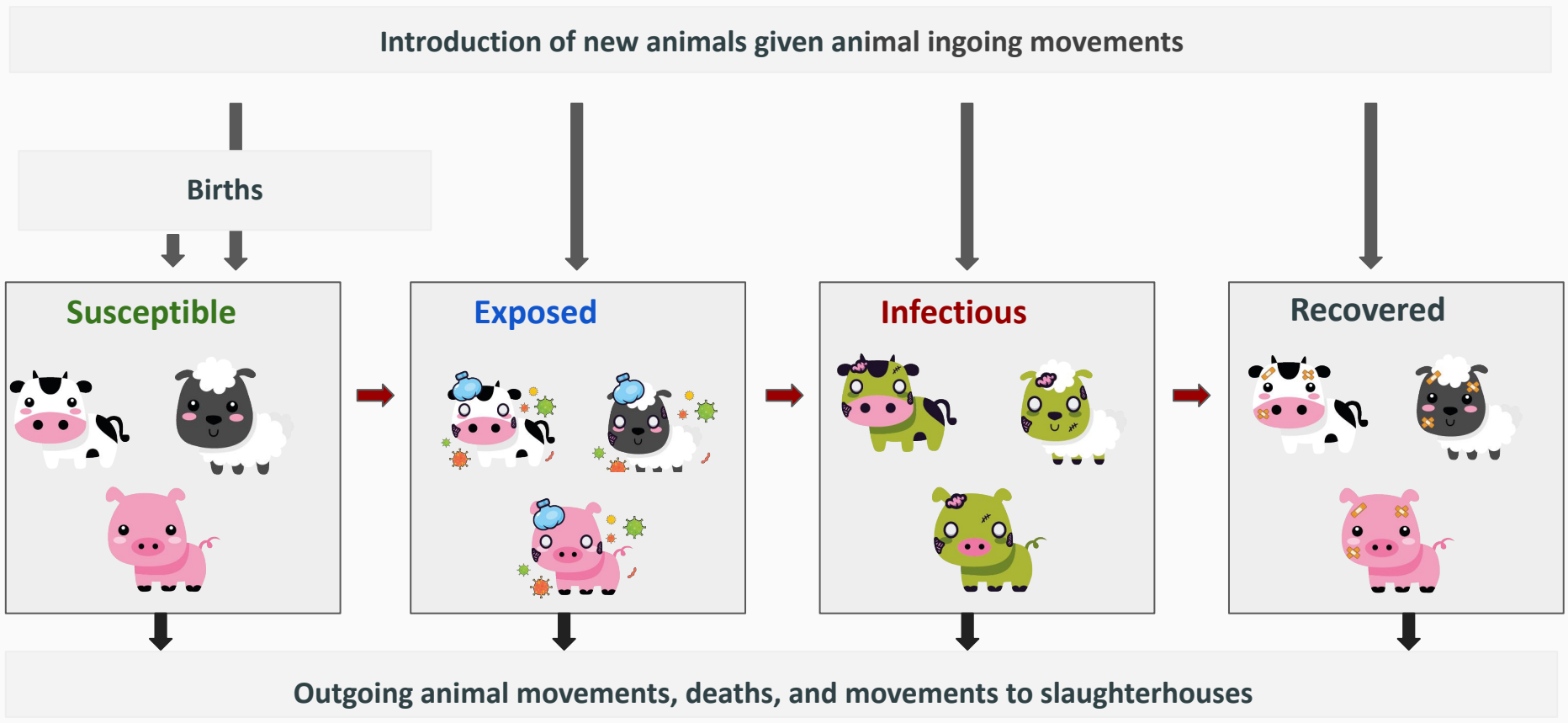


Background

1. Livestock movements included the daily between-farm movements of farms containing:
   a. Bovine.
   b. Swine.
   c. Small ruminants.
2. Birth and death records
3. Data covering three years (2018-2020).



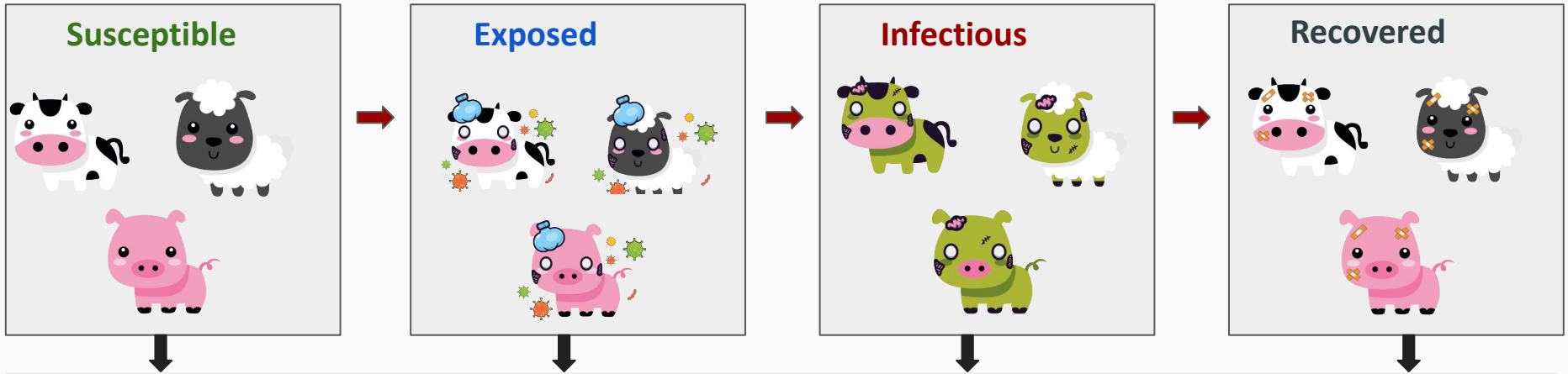
Methods


Introduction of new animals given animal ingoing movements
Births
Susceptible
Exposed
Infectious
Recovered
Outgoing animal movements, deaths, and movements to slaughterhouses

Methods

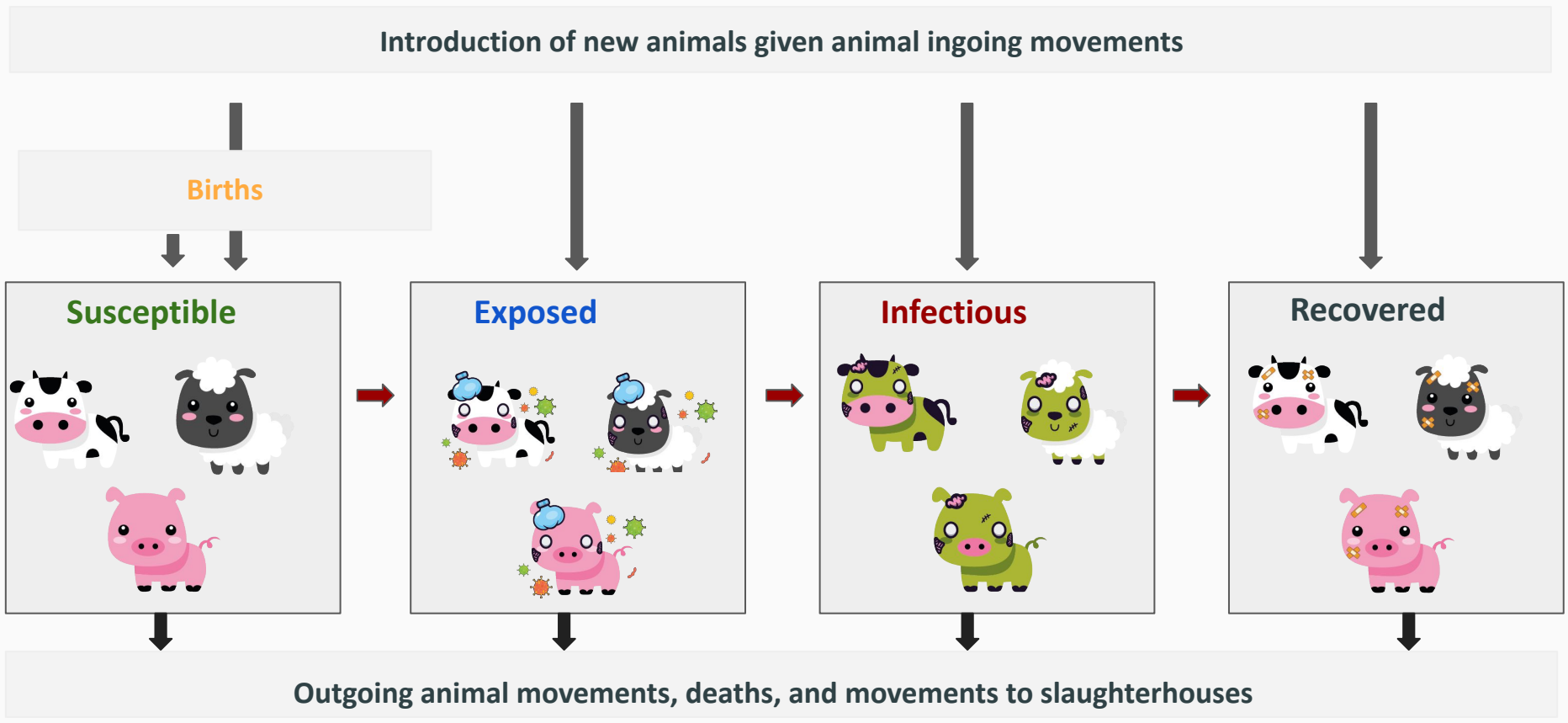
Introduction of new animals given animal ingoing movements

Births



Outgoing animal movements, deaths, and movements to slaughterhouses

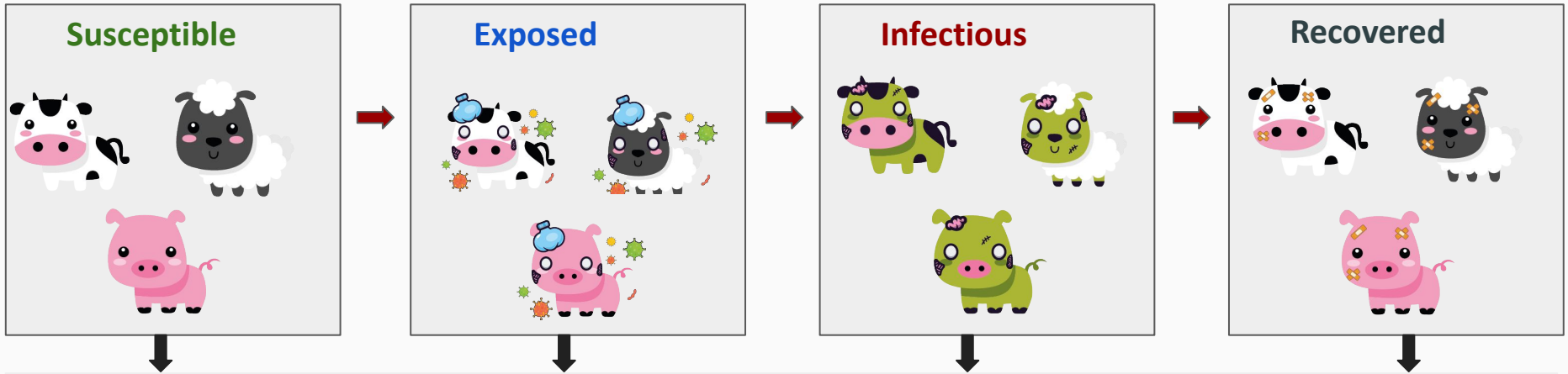
Methods


Introduction of new animals given animal ingoing movements
Births
Susceptible
Exposed
Infectious
Recovered
Outgoing animal movements, deaths, and movements to slaughterhouses

Methods

Introduction of new animals given animal ingoing movements

Births

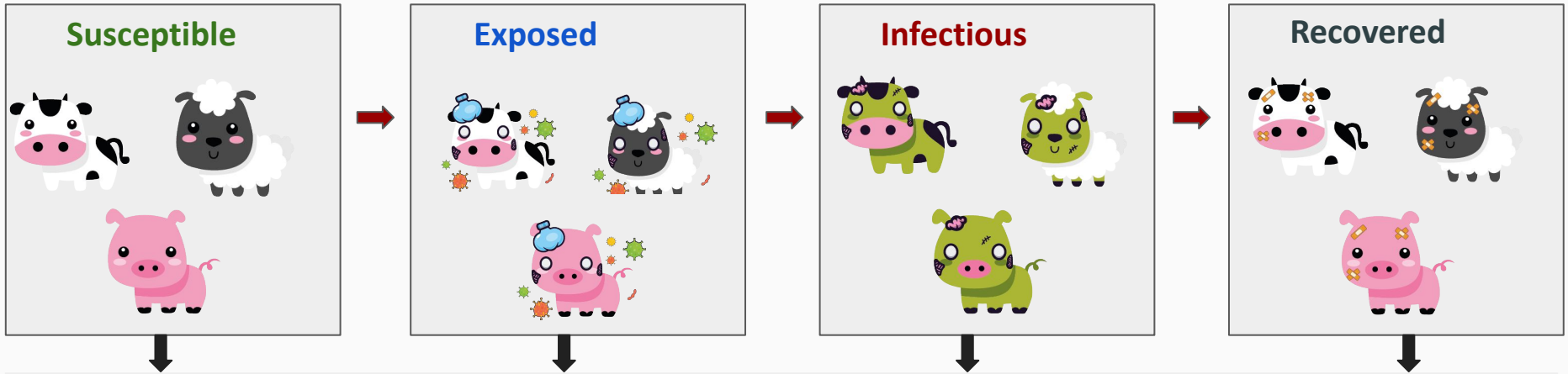


Outgoing animal movements, deaths, and movements to slaughterhouses

Methods

Introduction of new animals given animal ingoing movements

Births

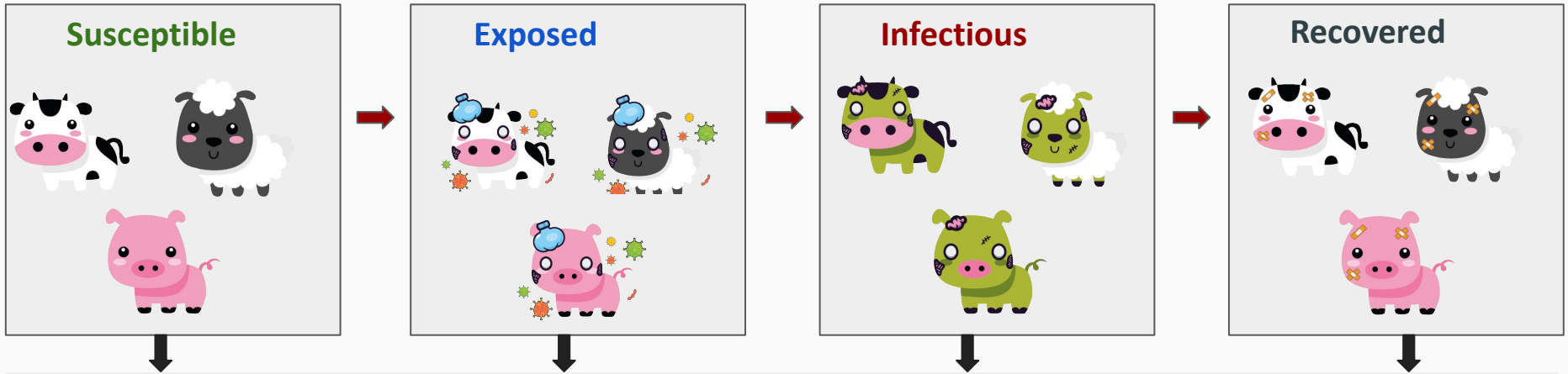


Outgoing animal movements, deaths, and movements to slaughterhouses

Methods

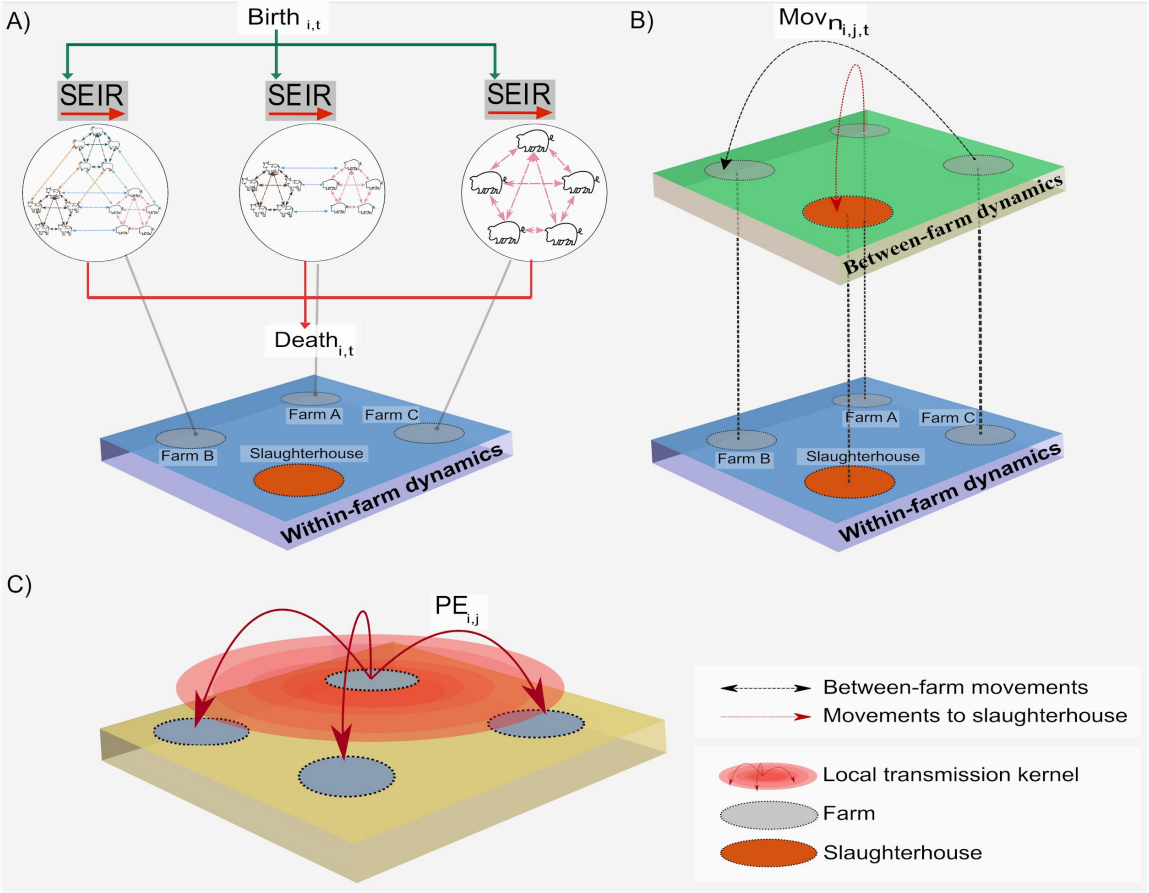
Introduction of new animals given animal ingoing movements

Births



Outgoing animal movements, deaths, and movements to slaughterhouses

Methods


A)
Birth i,t
SEIR
SEIR
SEIR
Death i,t
Farm A
Farm C
Farm B
Slaughterhouse
Within-farm dynamics
B)
Mov n i,j,t
Between-farm dynamics
Farm A
Farm C
Farm B
Slaughterhouse
Within-farm dynamics
C)
PE i,j
Between-farm movements
Movements to slaughterhouse
Local transmission kernel
Farm
Slaughterhouse

Material and methods: Initial Conditions

Initial infections in **15,721** farms:

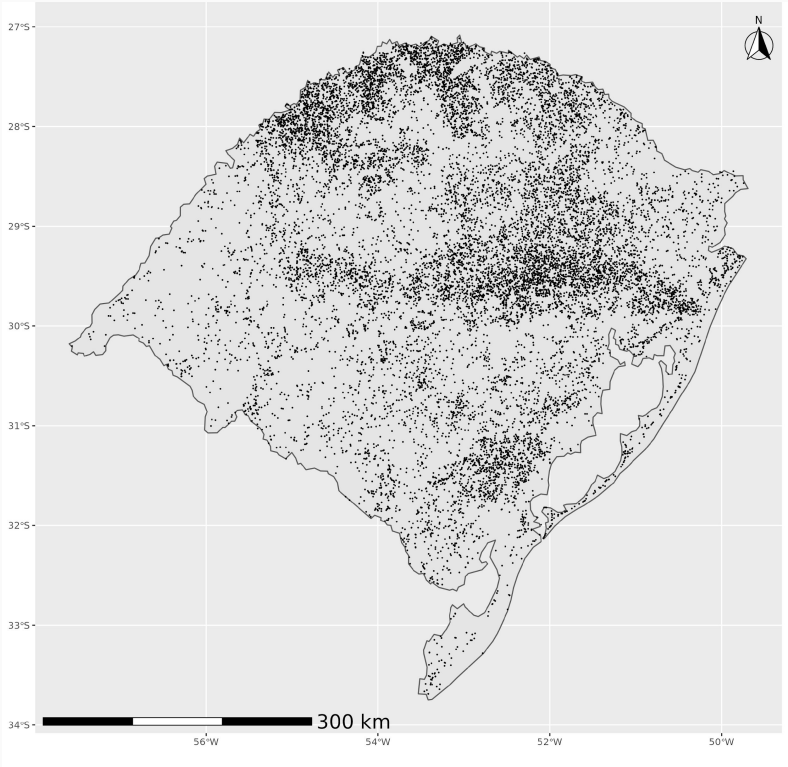
- **10,473** (cattle and/or buffalo)
- **5,179** (swine)
- **69** (small ruminants).

All animals considered fully susceptible.

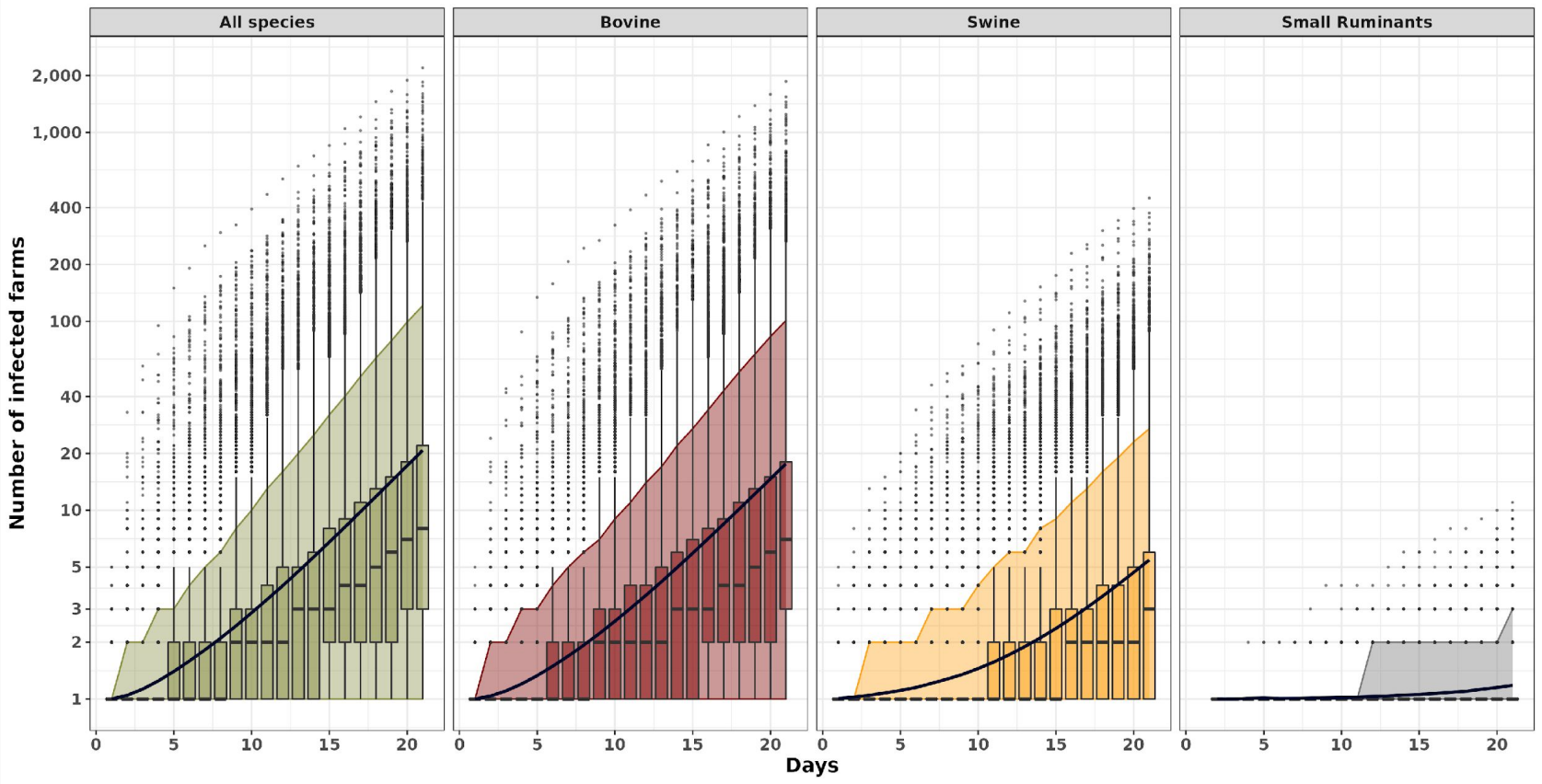
Initial infection of **one** animal.

10 repetitions per farm (seeded randomly at any day between 2018-2020).

20 days of silent spread.

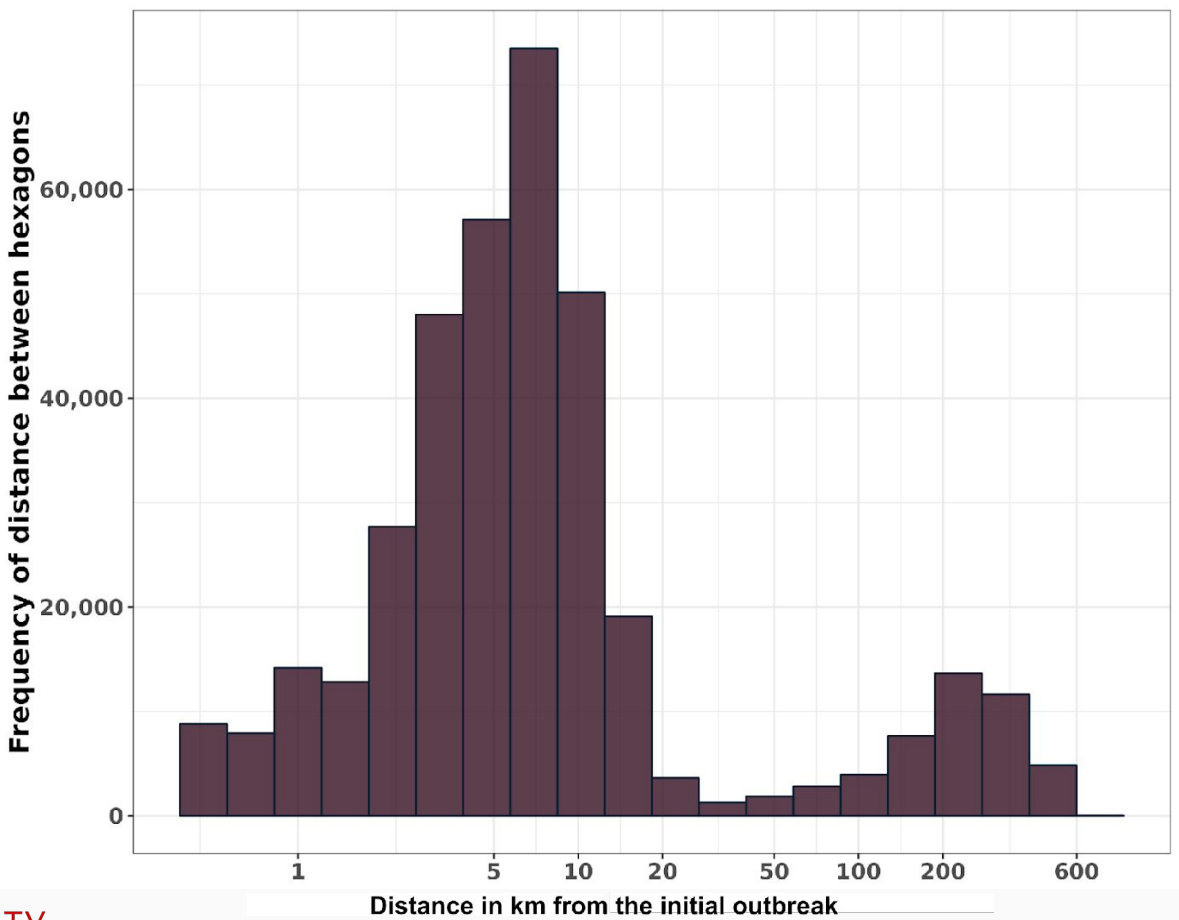


Results: Epidemic trajectories

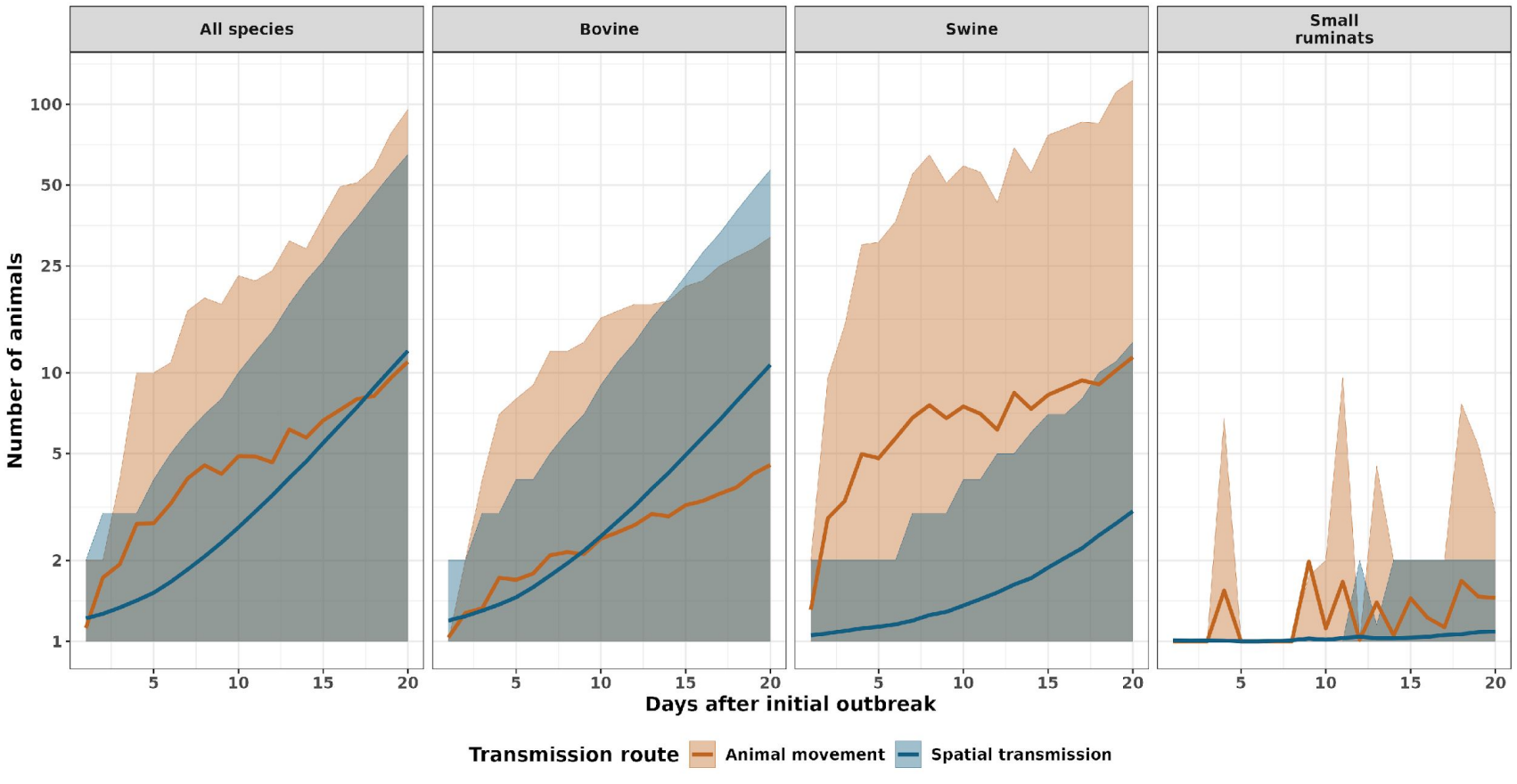


Transmission routes

Results: Distance in km from the initial infected farm



Results: Transmission routes



Control action modelling

Control and eradication simulations

Intervention strategy	Infected zone (3 km)	Buffer zone (7 km)	Surveillance zone (15 km)
Clinical sings	Every three days	Every three days	Every three days
Depopulation	**Four infected farms per day**	-	-
Animal movements	30 days standstill	30 days standstill	30 days standstill
Trace back	In/Outgoing one step from infected farms	No trace back	No trace back
Vaccine	**5,000 uninfected animals per day**	5,000 uninfected animals per day	No vaccination

- Scenario 1: Stamp out of **8** infected farms and vaccination of **10,000** uninfected animals per day.
- Scenario 2: Stamp out of **8** infected farms per day.
- Scenario 3: Stamp out of **12** infected farms & ii) vaccination of **15,000** uninfected animals per day.

Control and eradication simulations

Intervention strategy	Infected zone (3 km)	Buffer zone (7 km)	Surveillance zone (15 km)
Clinical sings	Every three days	Every three days	Every three days
Depopulation	**Four infected farms per day**	-	-
Animal movements	30 days standstill	30 days standstill	30 days standstill
Trace back	In/Outgoing one step from infected farms	No trace back	No trace back
Vaccine	**5,000 uninfected animals per day**	5,000 uninfected animals per day	No vaccination

- Scenario 1: Stamp out of 8 infected farms and vaccination of 10,000 uninfected animals per day.
- Scenario 2: Stamp out of 8 infected farms per day.
- Scenario 3: Stamp out of 12 infected farms & ii) vaccination of 15,000 uninfected animals per day.

Control and eradication simulations

Intervention strategy	Infected zone (3 km)	Buffer zone (7 km)	Surveillance zone (15 km)
Clinical sings	Every three days	Every three days	Every three days
Depopulation	Four infected farms per day	-	-
Animal movements	30 days standstill	30 days standstill	30 days standstill
Trace back	In/Outgoing one step from infected farms	No trace back	No trace back
Vaccine	5,000 uninfected animals per day	5,000 uninfected animals per day	No vaccination

- Scenario 1: Stamp out of 8 infected farms and vaccination of 10,000 uninfected animals per day.
- Scenario 2: Stamp out of 8 infected farms per day.
- Scenario 3: Stamp out of 12 infected farms & ii) vaccination of 15,000 uninfected animals per day.

Control and eradication simulations

Intervention strategy	Infected zone (3 km)	Buffer zone (7 km)	Surveillance zone (15 km)
Clinical sings	Every three days	Every three days	Every three days
Depopulation	Four infected farms per day	-	-
Animal movements	30 days standstill	30 days standstill	30 days standstill
Trace back	In/Outgoing one step from infected farms	No trace back	No trace back
Vaccine	5,000 uninfected animals per day	5,000 uninfected animals per day	No vaccination

- Scenario 1: Stamp out of 8 infected farms and vaccination of 10,000 uninfected animals per day.
- Scenario 2: Stamp out of 8 infected farms per day.
- Scenario 3: Stamp out of 12 infected farms & ii) vaccination of 15,000 uninfected animals per day.

Control and eradication simulations

Intervention strategy	Infected zone (3 km)	Buffer zone (7 km)	Surveillance zone (15 km)
Clinical sings	Every three days	Every three days	Every three days
Depopulation	Four infected farms per day	-	-
Animal movements	30 days standstill	30 days standstill	30 days standstill
Trace back	In/Outgoing one step from infected farms	No trace back	No trace back
Vaccine	5,000 uninfected animals per day	5,000 uninfected animals per day	No vaccination

- Scenario 1: Stamp out of 8 infected farms and vaccination of 10,000 uninfected animals per day.
- Scenario 2: Stamp out of 8 infected farms per day.
- Scenario 3: Stamp out of 12 infected farms & ii) vaccination of 15,000 uninfected animals per day.

Control and eradication simulations: control definition

We defined **400** farms as the maximum number of farms that the Official Veterinary Service could manage.

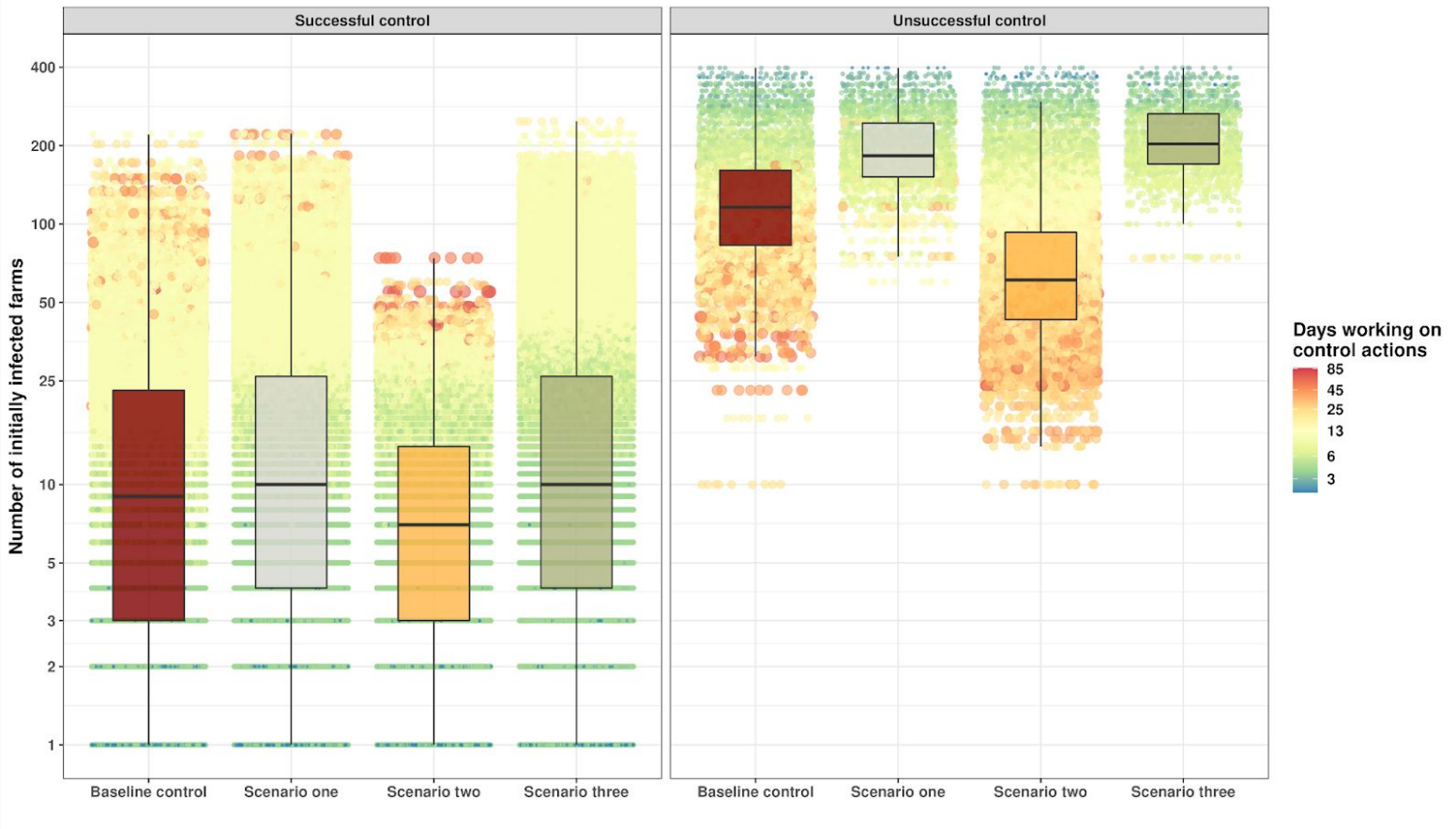
Successful

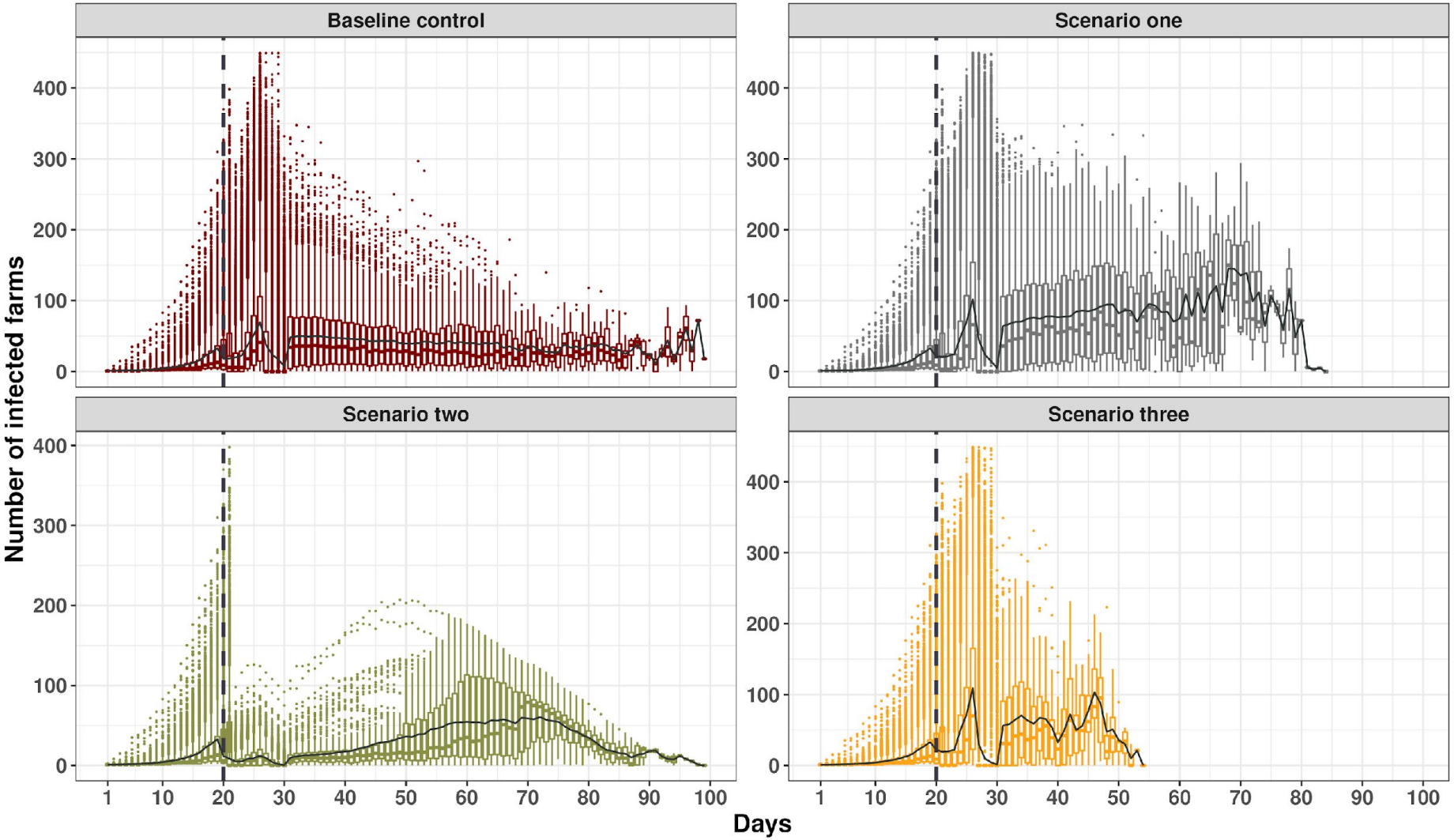
- When no more infected farms were present.

Unsuccessful

- When infected farms were present after **100 days** of control action.
- And/or more than **400 farms** were infected.

Control and eradication simulations




Baseline control
Scenario one
Scenario two
Scenario three
Number of infected farms
Days
0
100
200
300
400
1
10
20
30
40
50
60
70
80
90
100

Further remarks

Further remarks

- ***<u>This package includes:</u>***

1. SEIR stochastic compartment model.

2. Multilevel model.
   - Farm level (meta-population).
   - Between farm.
     - Spatial.
     - Movement.
3. Multiple species.

4. Front end dashboard.

5. MHASpread can be used with large datasets.

Nicolas Cardenas ncesped@ncsu.edu

Gustavo Machado gmachad@ncsu.edu

Lab website:https://machado-lab.github.io