Catch me if you can:
control disease in 40 days

G.A. Puspitarani[1,2], H. Schuster[3], E. Coleman[4], R. Fuchs[5], A. Desvars-Larrive[1,2]

[1]University of Veterinary Medicine Vienna, Vienna, Austria; [2]Complexity Science Hub, Vienna, Austria ;
[3]Vienna University of Economic and Business, Vienna, Austria; [4]Bristol Medical School, University of Bristol, Bristol, United Kingdom; [5]Department for Data, Statistic and Risk Assessment, Austrian Agency for Health and Food Safety (AGES), Graz, Austria; [6]Institute of System Science, University of Graz, Graz, Austria.

Background

The Austrian swine industry plays a crucial role in the national economy, with an average pork consumption of 43.6 kg per capita annually. With a self-sufficiency level of 103%, the industry may face critical losses in the event of an exotic disease introduction. Using pig movement data from 2021, this study investigates the potential spread of an African swine fever-like disease within Austria following its introduction.

Objectives

- **Explore pig mobility flows and identify key hubs**.
- **Model the spread of an introduced ASF-like disease** within the pig movement network to simulate outbreak scenarios and assess potential transmission pathways.
- **Inform targeted mitigation strategies.**

Methods

Data

Daily pig movements in Austria (2021), consisting of 23,722 holdings with 250,136 movements.

source	target	date	n	types
Holding of origin	Receiving holding	Daily record	Number of pigs	Purpose of movement: domestic, slaughter, import/export, import/export for slaughter

Tab 1. Overview of pig movements records of between pairs of holdings in Austria.

1. Identify municipality with high import

We aggregated nodes by municipality and analyzed trade flows, identifying the highest-import municipality (m^*). Trade distribution from m^* was examined, with Euclidean distance. We defined for long-distance trade as mean +2SD.

2. Simulate the spread of ASF-like seeded from m^*

2.1: Within holding transmission:
We seeded infections in a randomly selected holdings within m^*. Using ASF-like parameters, we developed SEIR model.

2.2. Between holdings:
We considered two transmission paths:

- **Direct transmission** via time-respective trade network edges
- **Localized spread within 5-km** radius using spatial kernel

We defined holding status as infected if at least one pig in E or I compartments was present:

We introduced the disease at two different times: January (low trade activity) and April (heightened trade activity).

3. Evaluate the impact

1. **Estimate epidemic size.**
   Count the number infected pigs, infected holdings, and municipalities.
1. **Analyzed long-distance transmission.**
   Identified infection jumps, including timing and contributing municipalities.

Results

We identified Straß in Steiermark as the highest-import municipality (m^*), a key node for disease introduction. Trade network analysis revealed that 89% of Austrian municipalities could be reached within six trade steps from m^*. The mean trade distance was 46.8 km (SD:57.3 km), with long-distance trades defined as those exceeding 161.4 km.

The SEIR model estimated a peak of 3,183 infectious pigs and 477 infected holdings (Fig 1), reaching 10.2% of municipalities. On average, 5.6 long-distance infection jumps occurred per simulation, with high-risk municipalities clustered in Styria and Carinthia (Fig 2). The first infection jump occurred within 40 days (days 42-48, P: 0.7%). When seeded during high-trade period reduced to 20 days (P: 11.7%) (Fig 3). Infection jump entered their first peak phase within 100 days post-introduction.

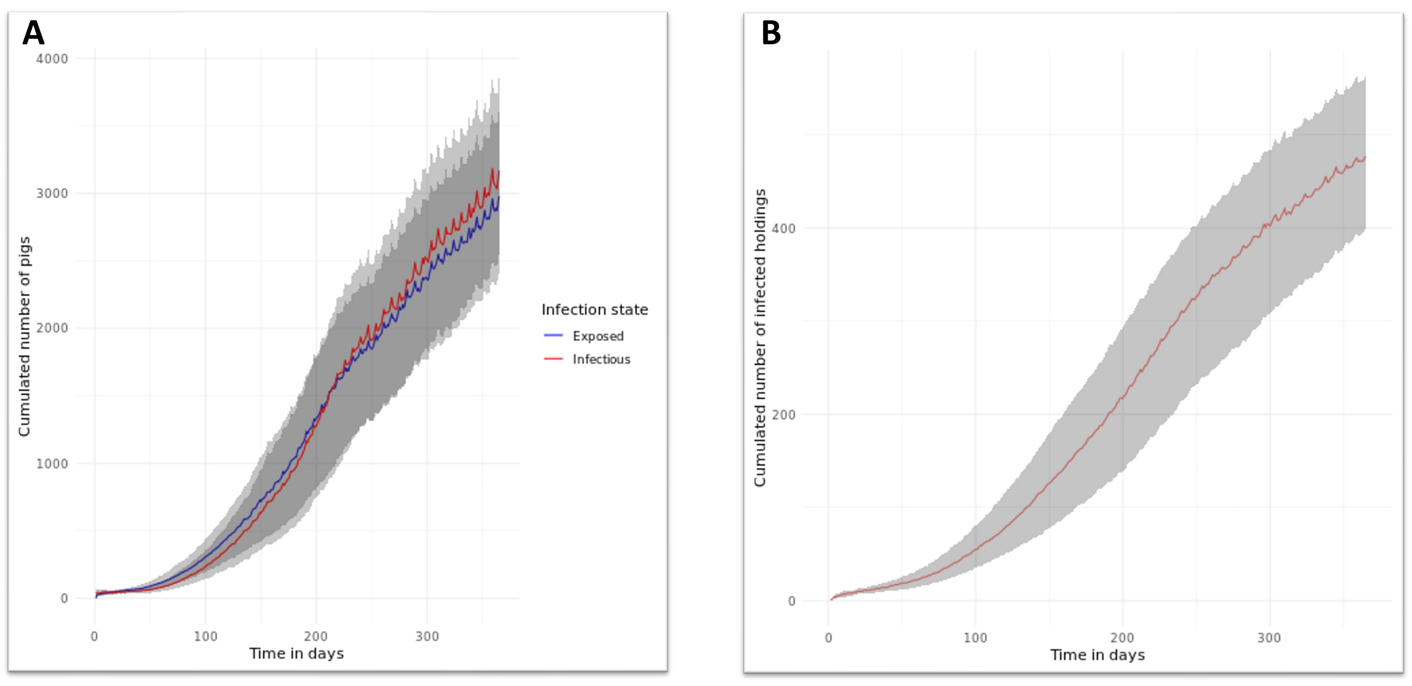

Fig 1.Temporal dynamic of an ASF-like disease in Austria over a 365-day simulation. One holding, located in the municipality of Straß in Steiermark (the highest-import municipality), was randomly selected as the origin of the outbreak.
A shows the temporal dynamic of Exposed (E) and Infectious (I) pigs following the disease introduction, with the blue and red line represent the median count of E and I pigs, respectively.
B illustrate the progression of infected holdings. A holding was considered infected if it contained at least one pig in either E or I compartment, and it reminded infected for the duration of the simulation. The red line represent the cumulative median counts of infected holdings at each time point.
The shaded gray area indicates the 95\% confidence interval (CI), reflecting variability across 1,000 simulations.

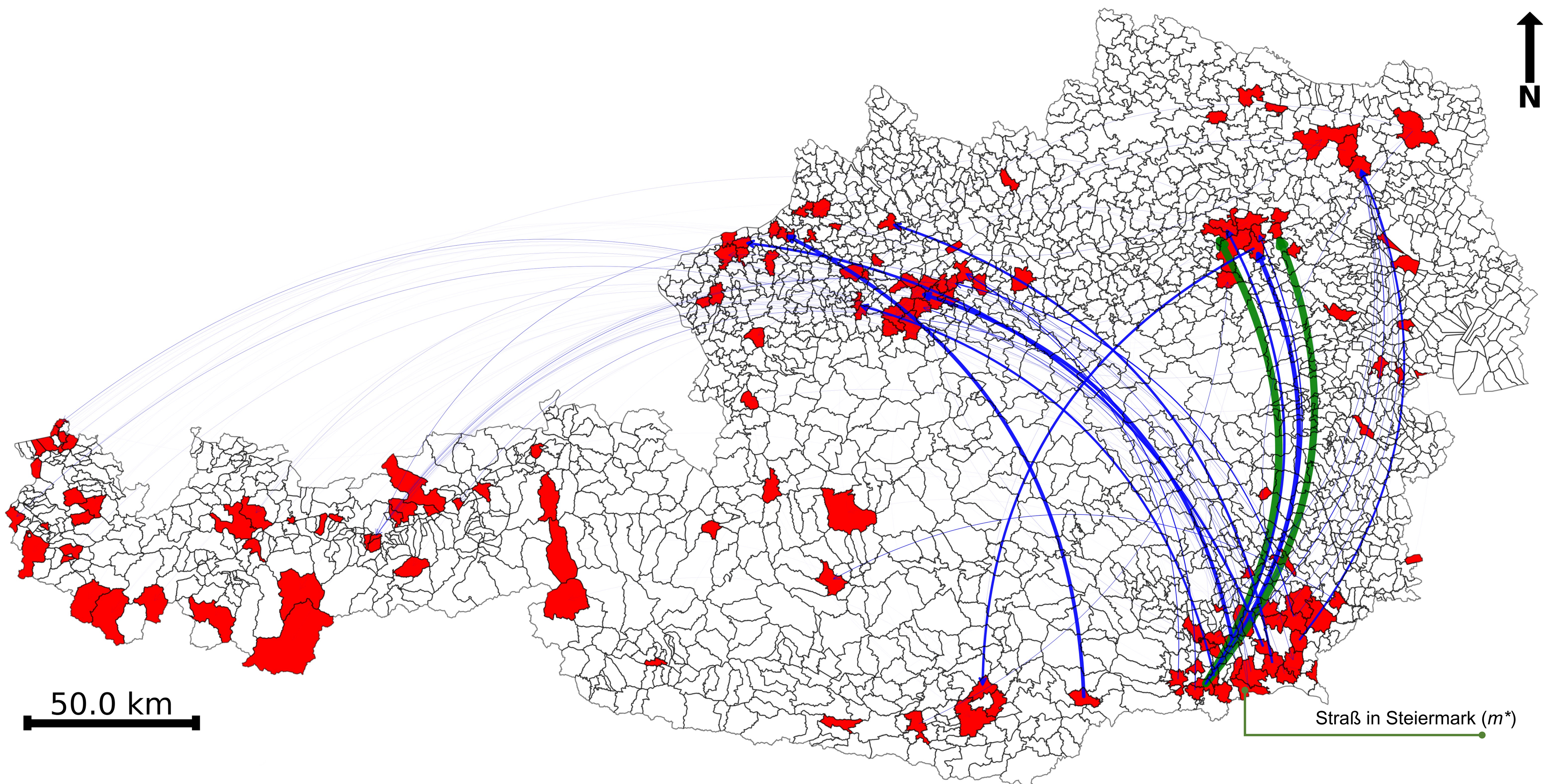

Fig 2. Likelihood of long-distance infection jumps. Municipalities colored in red participated in at least one infection jump via long-distance trade (as source or recipient). Directed blue arcs indicate long-distance infection jumps, with arrows pointing from the source municipality to the recipient. The thickness of each arc is proportional to the likelihood of the corresponding infection pathway, with thicker arcs representing higher probabilities of transmission. Green arcs shows the highest-likelihood pathways from Großklein to Karlstetten(P: 0.73) and Großklein to Würmla(P: 0.72).

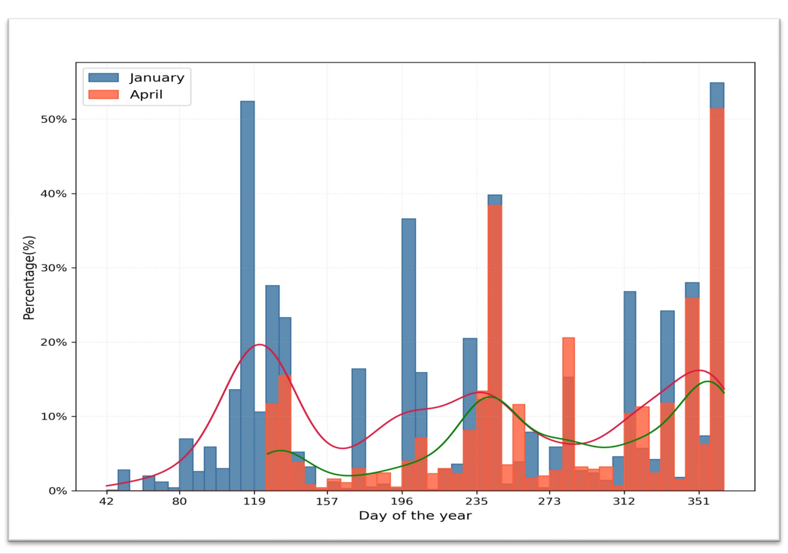

Fig 3. Temporal distribution of successful infection jump via long-distance trade. Distribution of the percentage of successful infection jumps facilitated by long-distance trade with an overlaid red KDE (Kernel Density Estimate) curve. The histogram represents the percentage of simulations in which an infection jump occurred within a given time bin, with blue bars corresponding to January seeding and orange bar to April seeding.

Conclusion

High-import regions act as potential entry points for exotic disease introduction. In Austria, control measures within the first 40 days after introduction are crucial for limiting large scale outbreak. However, when introduced during a period of increased trade activity this window shortens. If the outbreak circulates more than 100 days, effective containment requires intervention both locally, in the region of introduction, and distant regions.

vetmeduni
University of Veterinary Medicine, Vienna

Complexity Science Hub

Contact:
Gavrila A. Puspitarani: gavrila.puspitarani@vetmeduni.ac.at
Amélie Desvars-Larrive: amelie.desvars@vetmeduni.ac.at