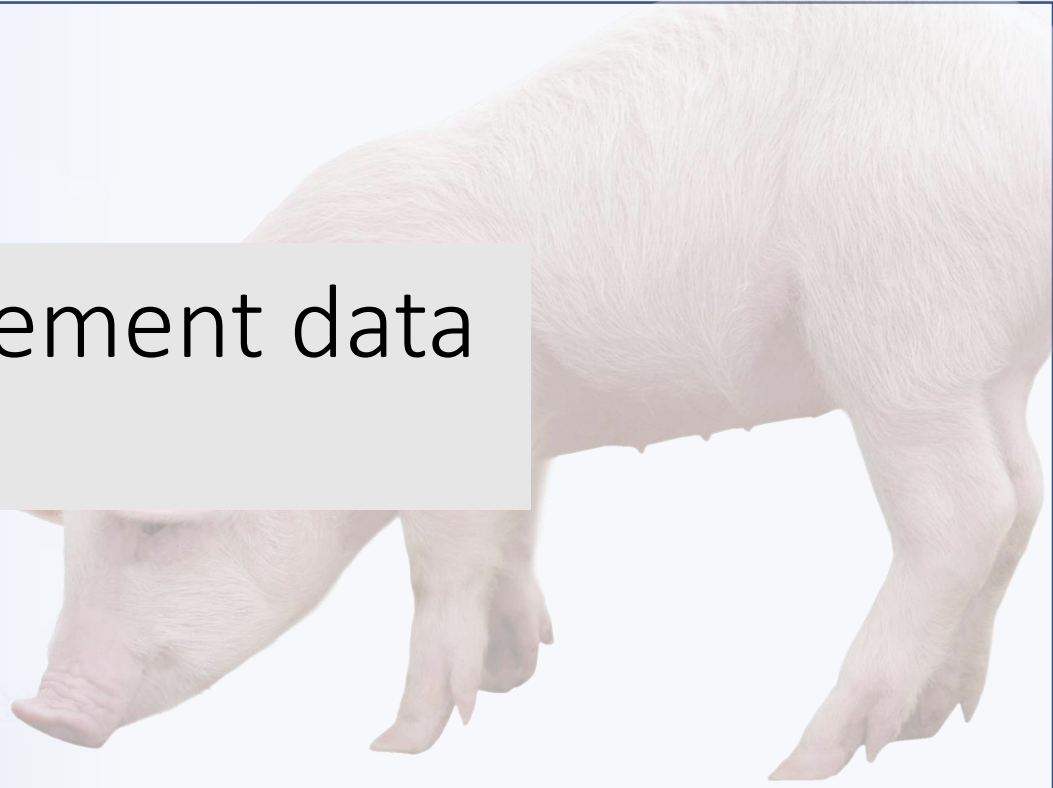
# Network analysis of animal movement data as an epidemiological tool

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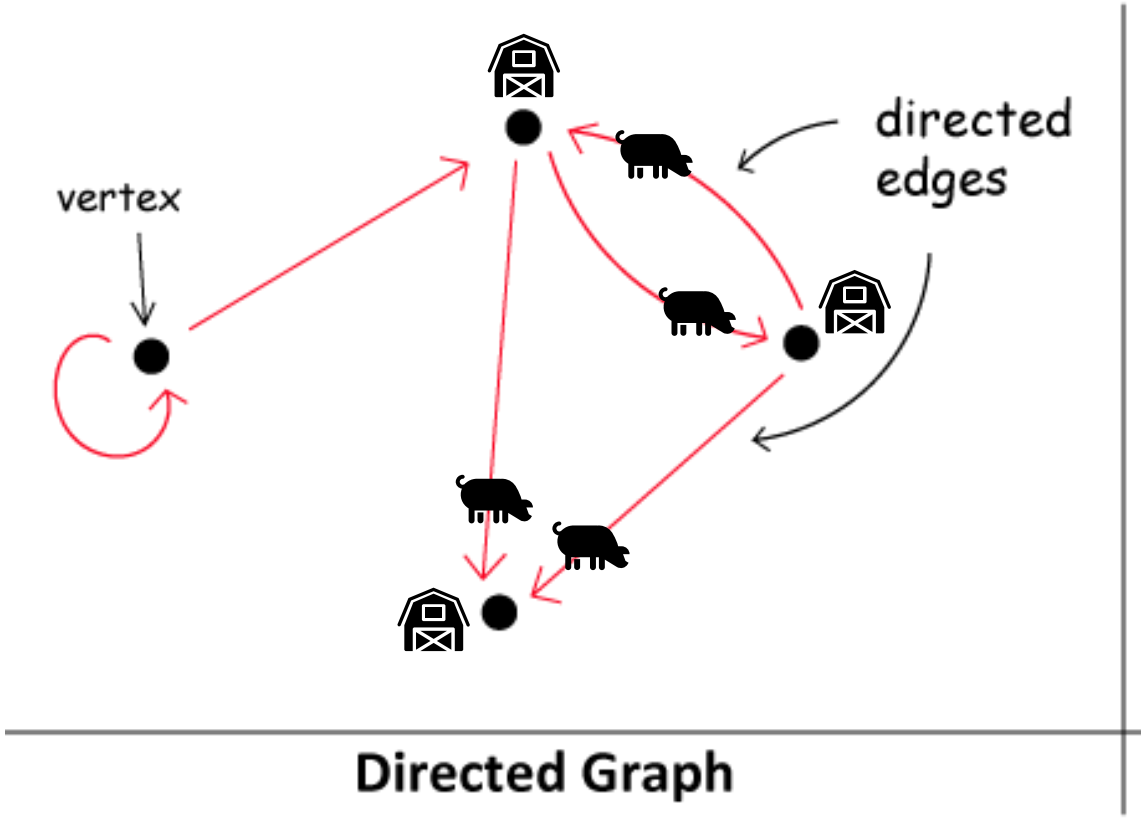
# What is network analysis?

- Livestock movement patterns can be studied through network-based approaches using **nodes** and **edges.**
  - **Nodes** represent the **holdings**, such as farms, markets, or slaughterhouses.
  - **Edges** represent **trades** between holdings. It can have weights (e.g. number of animals, frequency of exchanges).



# Objectives

Describe the pig trade network using social network analysis (SNA) methods.

Describe epidemiological relevance of the network description for disease surveillance and mitigation.

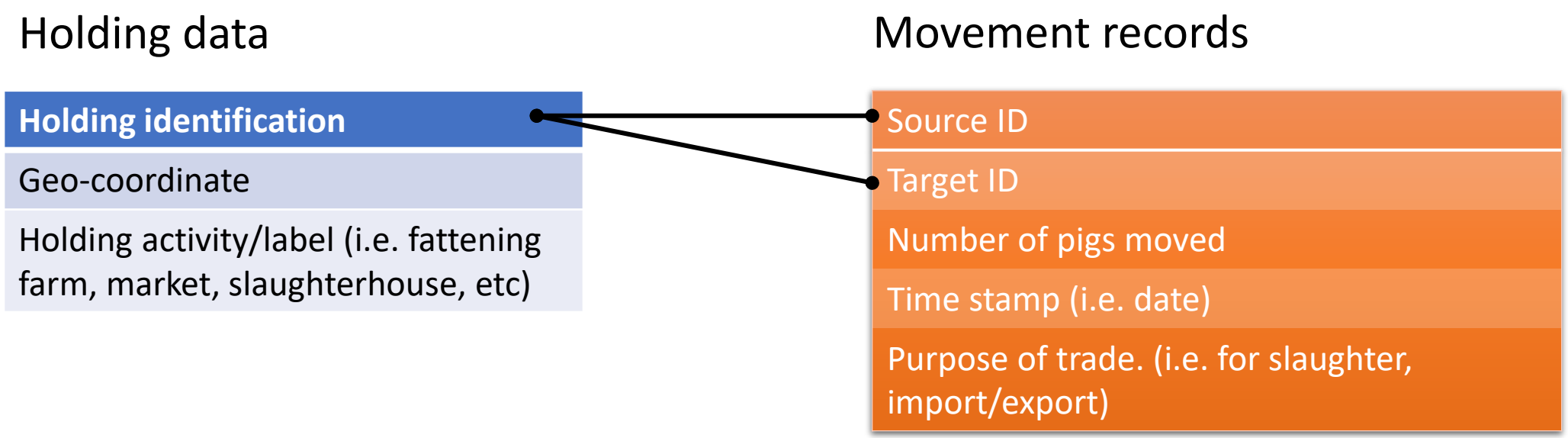
# Benefit of network analysis

**Valuable tool** in exploring trade patterns, quantifying network topology, and understanding disease transmission.

Example: Austrian pig value chain is threatened by major exotic diseases such as African swine fever and classical swine fever.

Network analysis can help in **understanding disease transmission** and **developing strategies** for **disease surveillance and mitigation**.

# Overview of data on pig movements




Movement data across country should be homogenized.
Ideally, record movements cover more than 1 year to observe any seasonality.

# Spatial distribution of holdings

**Structural vulnerability of the French swine industry trade network to the spread of infectious diseases**

S. Rautureau[1†], B. Dufour[2] and B. Durand[1]

*[1]Epidemiology unit (EPI), French Agency for Food, Environmental and Occupational Health & Safety (ANSES), 97 700 Maisons-Alfort, France; [2]Epidemiology Unit (EPIMAI), Alfort National Veterinary School (ENVA), 97 700 Maisons-Alfort, France*

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Swine farms were concentrated in the west of France in 2010:

- Brittany, the primary region of French pork production;
- and in the southwest, near the Pyrenees

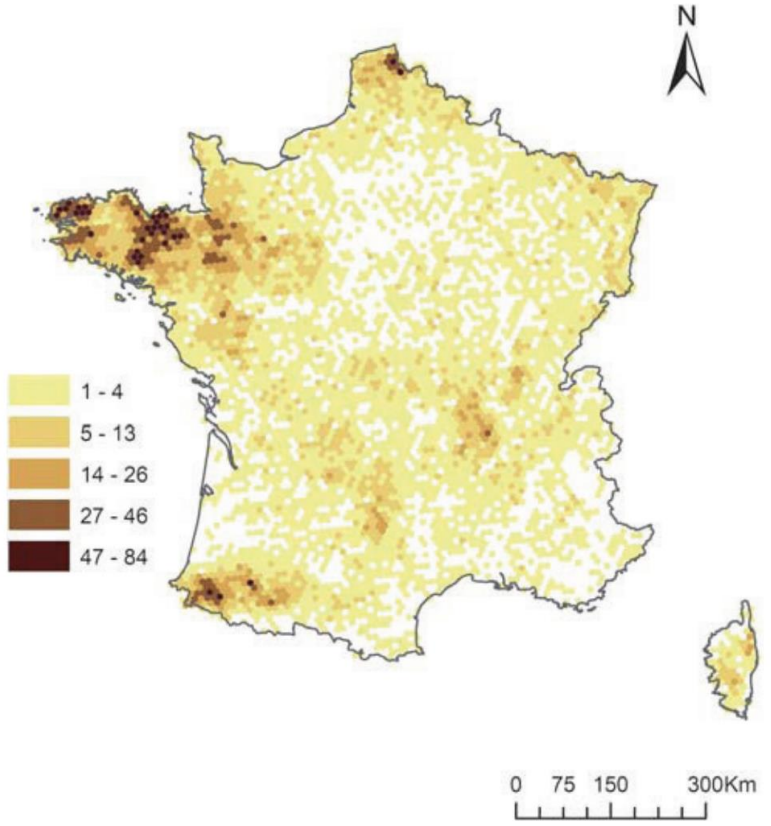



**Figure 2** Spatial density of swine farms, France, 2010. Density: number of holdings/10-km diameter hexagon.

# Contact structure between administrative boundaries

Germany pig trade network 2011 - 2014.

- Holdings are aggregated into its district and color coded by its federal states.
- The connection between districts correspond to the number of trade.
  - Trande includes live animals and intended for slaughter.
- Majority of trade take place within federal state (intra- trade).
  - Further analysis to observe the tendency of holding trade with other holding with similar attribute (i.e. federal state, district) can be assesed by its Assortativity.

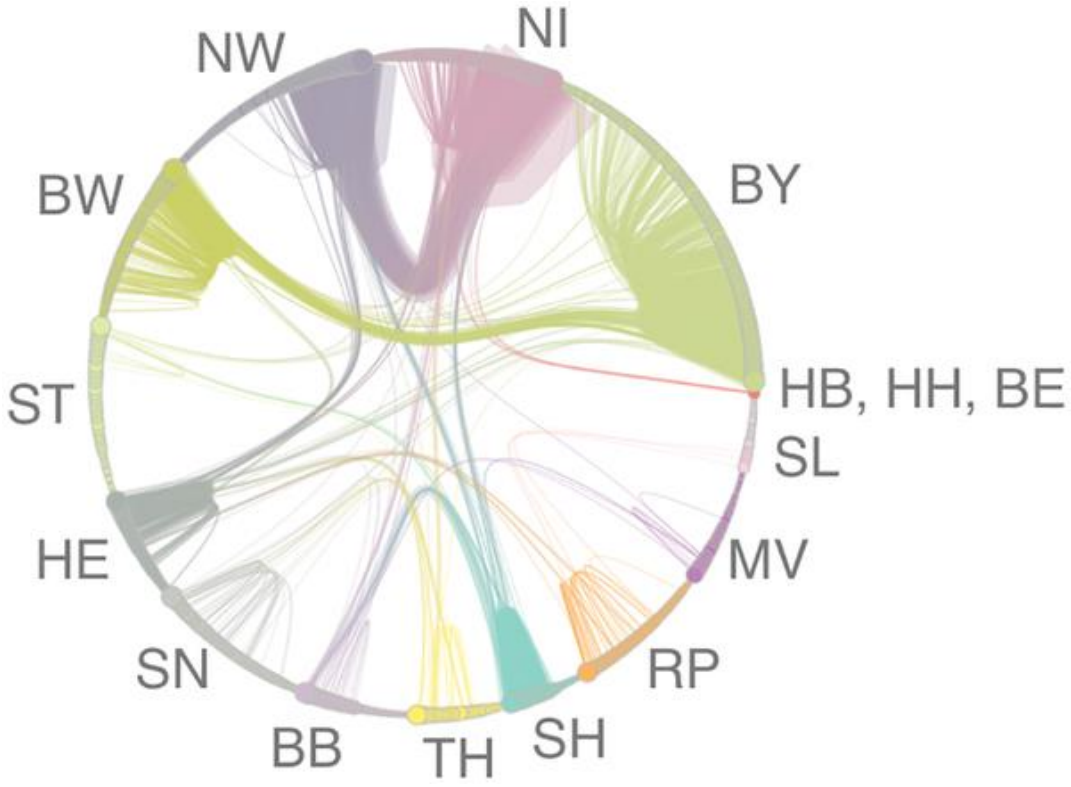
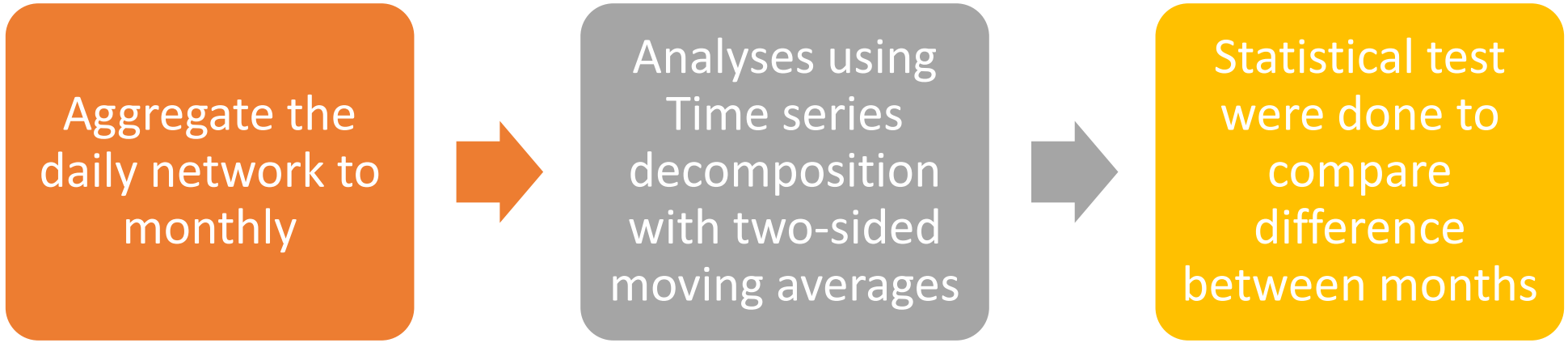



**Fig 5. Trade between districts in Germany.**

Lentz HHK, Koher A, Hövel P, Gethmann J, Sauter-Louis C, et al. (2016) Disease Spread through Animal Movements: A Static and Temporal Network Analysis of Pig Trade in Germany. PLOS ONE 11(5): e0155196. https://doi.org/10.1371/journal.pone.0155196
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0155196

# Trend analysis

- To analyze the trend of active holdings (nodes), its trade relation (edges), and volume of traded pigs in the Austrian pig trade network:



# Trend in other network

- North Macedonia
  - Farms and number of pigs (2016 – 2020) have been increasing
  - Farms increased by 31.6%
  - Number of pigs increased 17.7%

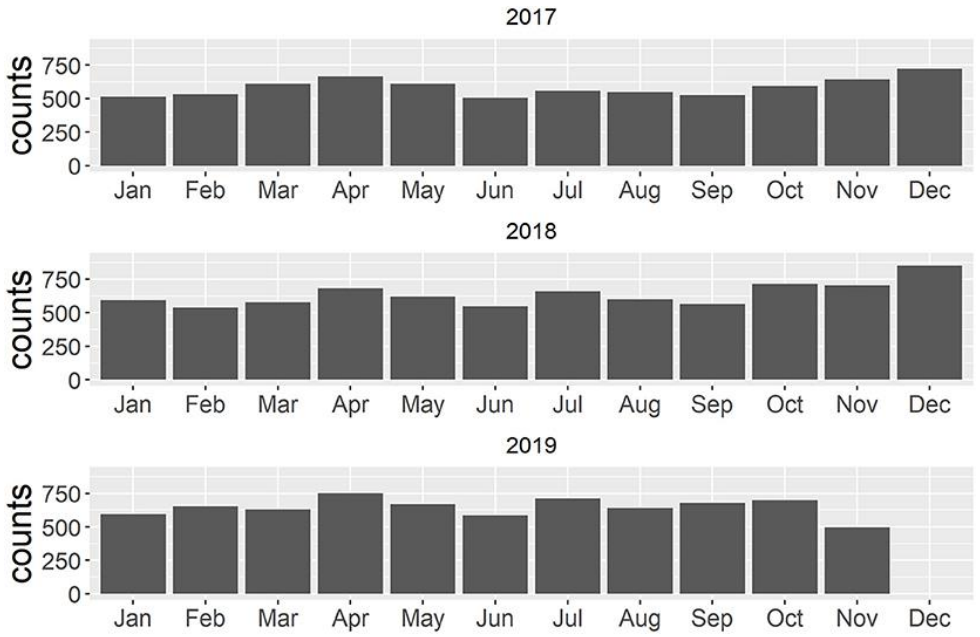
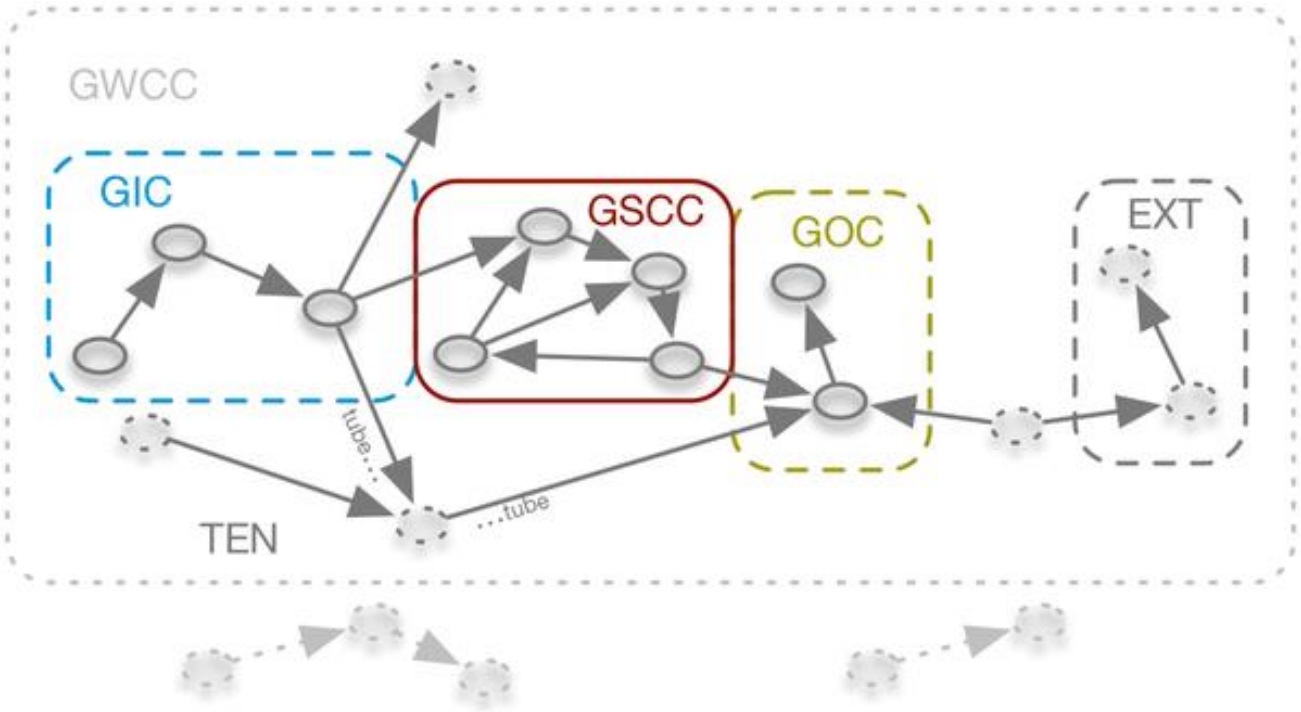



Figure 4. Number of live pig movements within North Macedonia by shipment month for 2017–2019. O'hara et.al. 2022

# Role of hubs

- Hubs are the holdings with high connection compared to other holding in the network
- Identification: top 1% of most connected active holding in the trade network.
- Implication: Enhancing biosecurity in highly connected holdings (hubs) that act as "gatekeepers" would greatly reduce the structural risk and  timely detection of pathogens (early warning).

# Identifying network component




Strongly connected component (SCC)

- Holdings can be reached from every other holdings **via directed path.**
- The size of the largest SCC can be used to **estimate the lower bound of the maximum epidemic size.**

Weakly connected component (WCC)

- Holdings can be reached from every other holding **ignoring the trade direction.**
- The size of the WCC can be used to **estimate the upper bound of the maximum epidemic size.**

**Fig 2. Component structure of directed networks.**

Lentz HHK, Koher A, Hövel P, Gethmann J, Sauter-Louis C, et al. (2016) Disease Spread through Animal Movements: A Static and Temporal Network Analysis of Pig Trade in Germany. PLOS ONE 11(5): e0155196. https://doi.org/10.1371/journal.pone.0155196
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# Network Largest Strongly Connected Component (LSCC)

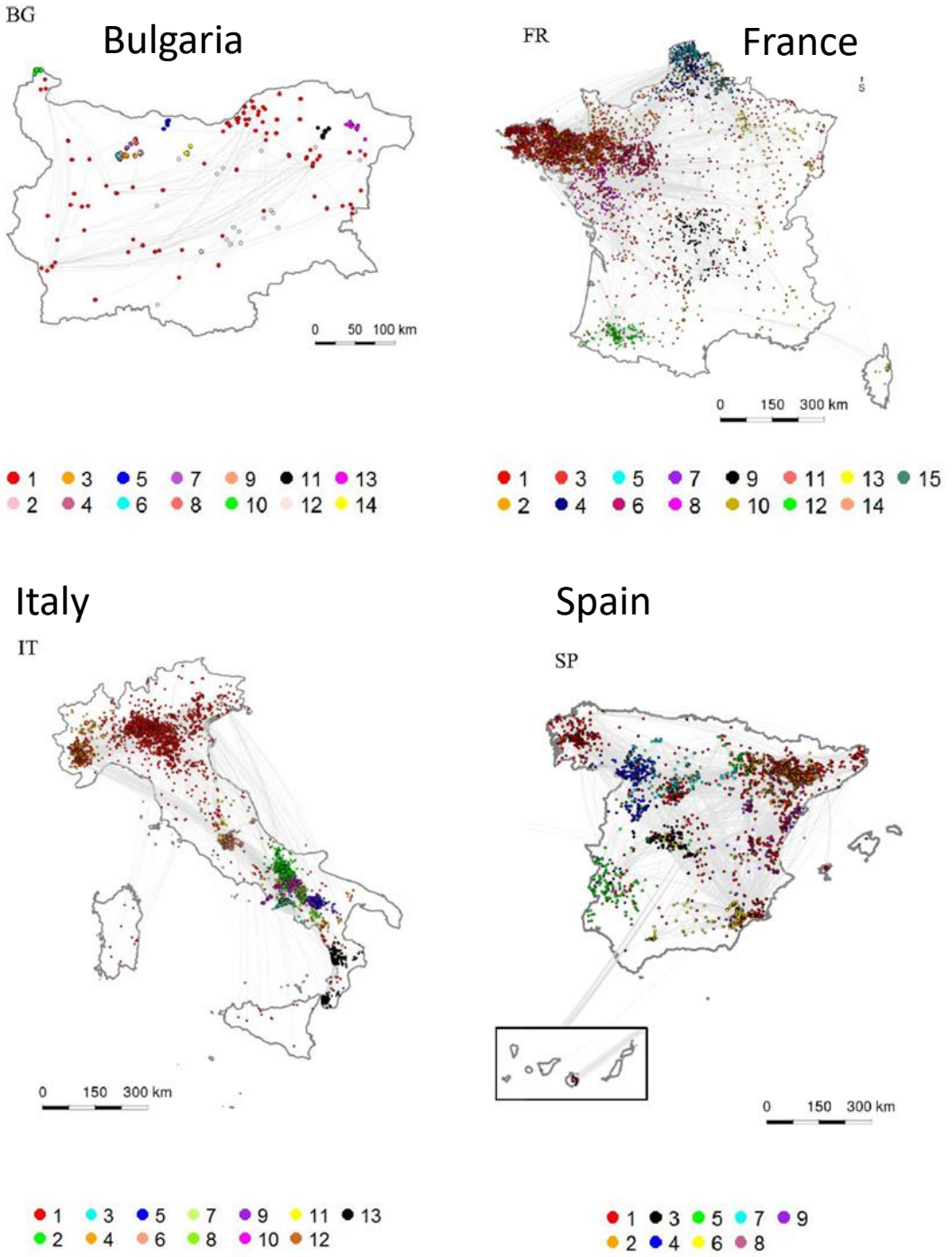
| Country | % of LSCC |
|---|---|
| Germany: static 2011-2014 | 28 |
| North Macedonia: yearly average 2017-2019 | 2.4 |
| Bulgaria: size in 2011 | 0.15 |
| France: size in 2011 | 0.60 |
| Italy: size in 2011 | 0.14 |
| Spain: size in 2011 | 0.18 |

# Detecting trade community

- Community: subset of holdings in which there are significantly more trade.
- A network can be divided into communities
  - i.e. holding level: subsets of holdings that are closely trade;
  - district level: subsets of districts that trade more with each other than with other districts.
- Community can be identified by implementing an algorithm
  - i.e. random walk, based on modularity
- Time respective community detection.
  - Observe the changing or stability of communities.

# Static community detection

- Network for domestic trade.
- Static community detection, computed for network in 2011.
- Links referred to the number of pig batches.
- Method using Walktrap algorithm.
  - Number of communityes were preidentified.
- In France and Spain, the largest communities were intensive (50% commercial pig farms and <10% raised outdoors)
- In Bulgaria, 2 of the largest community were intensive. Others were small-scale (50% small scale raising indoor or outdoor).
- Implication: alternative zoning approach to manage infectious diseases.




Relun, A., Grosbois, V., Sánchez-Vizcaíno, J. M., Alexandrov, T., Feliziani, F., Waret-Szkuta, A., Molia, S., Etter, E. M. C., & Martínez-López, B. (2016). Spatial and functional organization of pig trade in different european production systems: Implications for disease prevention and control. *Frontiers in Veterinary Science*, *3*(FEB), 4. https://doi.org/10.3389/FVETS.2016.00004/BIBTEX

# Limitation

- **Complex comparison**

Comparing networks between different countries is not straightforward task due to the use of different methods, i.e. period covered, algorithms employed, country size, and economic factors. A standardized dataset would significantly enhance the comparison process.

- **Presence of unknow connection**

e.g. truck movement data would advance understanding of disease spread risk through direct and indirect contacts between holdings.

# Future research

- **Modeling swine infectious disease spread in the network**

- **Describing the disease spread**

Looking at the risk in pigs production and quantify the economic impact of the disease

- **Further information needed**

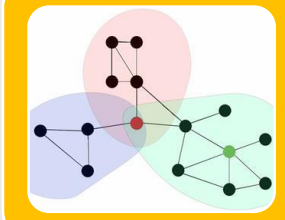
Assumption of birth and death rate of pigs in Austria is needed for better prediction.

- **Analyses of small scale and commercial scale farms.**

# Take home message:

The presence of high-density farms and high-connected pig holdings

The seasonality of the pig trade network



The presence of communities within the network

These should be considered when designing epidemiological surveillance activities and implementing disease control measures in the pig trade network.

Reference to the preprint paper:
https://doi.org/10.21203/rs.3.rs-2506122/v1

# Thank you for your attention!

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