Faculty of Agricultural and Nutritional Science

Christian-Albrechts-University Kiel
Institute of Animal Breeding and Husbandry

Efficient fragmentation of animal trade networks by targeted removal of central farms

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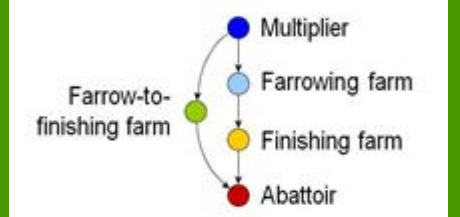
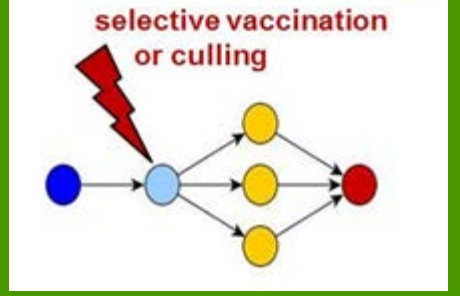
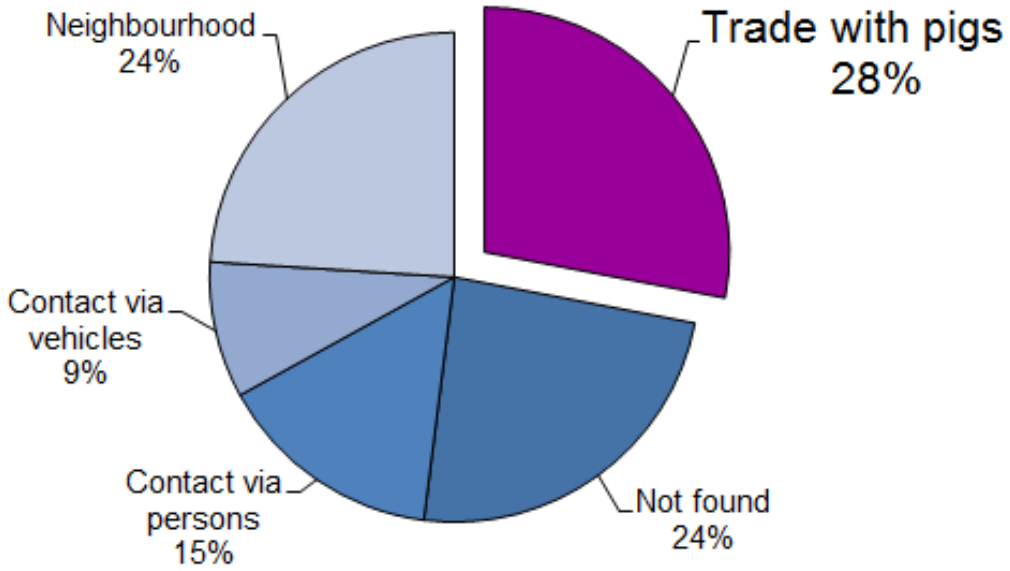




Introduction

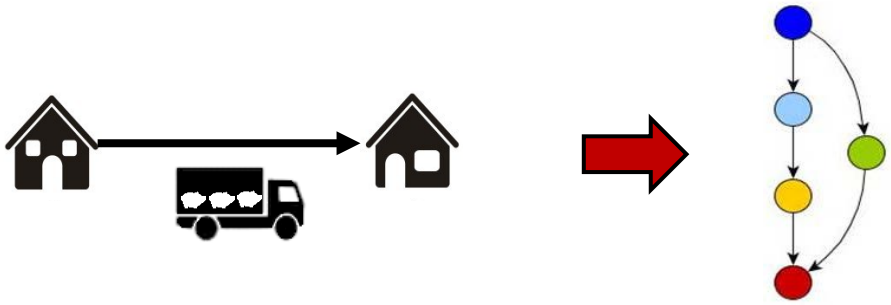
- Extensive economic losses in the livestock industry by **animal diseases**
- **Transport of live animals:** Major risk factor for the spread of infectious diseases
- Source of classical swine fever virus infection in German domestic pig herds from 1993 – 1998 (Fritzemeier et al., 2000)

→ **Secondary and follow-up outbreaks**



Introduction

- **Network view of animal movements**
  - → Farms: nodes
  - → Trade contacts: edges



- **Network analysis**
  - → Detection of central or important farms in the network
  - → Characterisation of network topology

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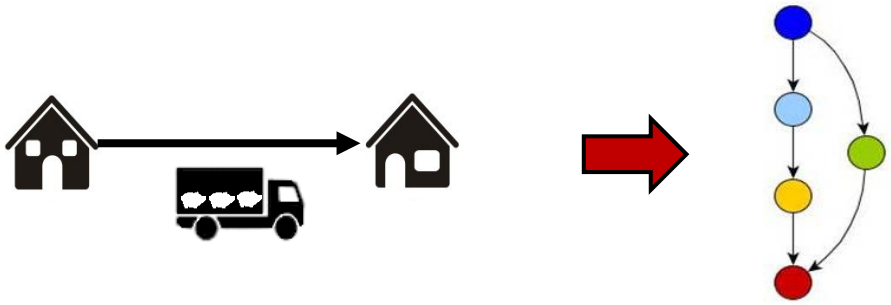


- **Network analysis**
  - → Detection of central or important farms in the network
  - → Characterisation of network topology

- **Aim of the study**
  - → To characterize the changes in the network topology by successive removal of the most central farms in the trade network
  - → To evaluate which centrality parameter is the most suitable measure for a rapid fragmentation of the trade network
  - → **Interruption of the chain of infection**

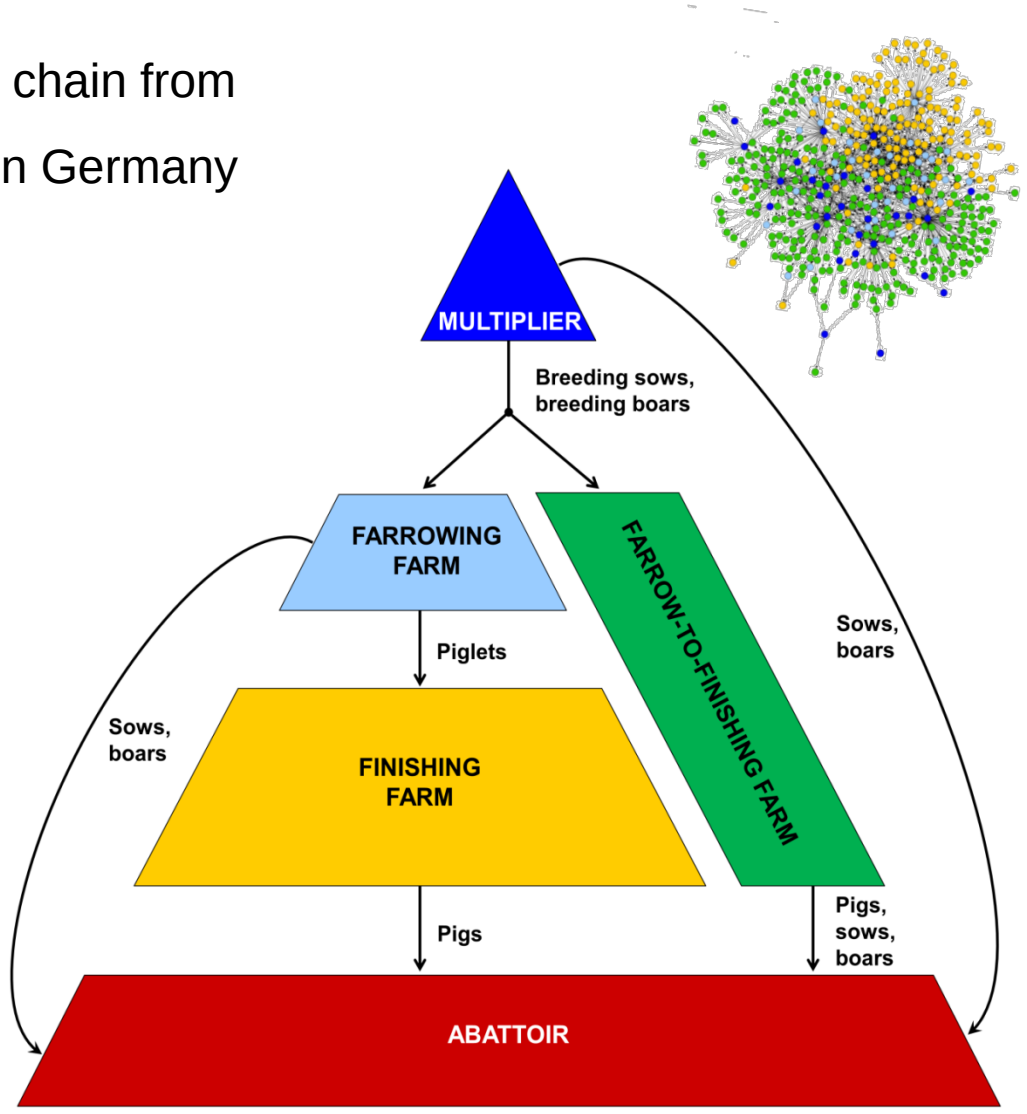
Materials and methods – Data basis

- Trade network of the pork supply chain from a producer community in Northern Germany
- **Observation period:**

  June 2006 to May 2009
- **Transported livestock:**

  Piglets, pigs, sows and boars
- **Three time intervals**
  - → 1 Three-year network
  - → 3 Yearly networks
  - → 36 Monthly networks
- **Network properties:**

  Directed & static



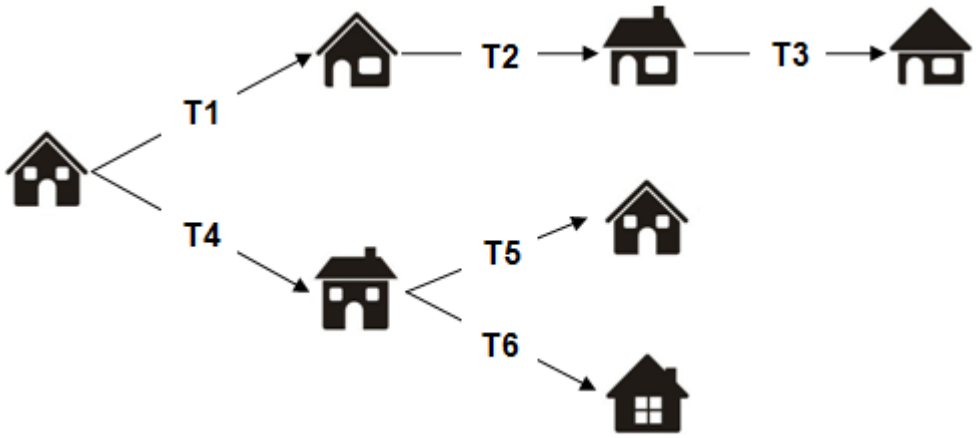
Materials and methods – Data basis

Number of farms and trade contacts in the different time intervals

	Three-year network	Yearly networks			Monthly networks		
		Mean	Min	Max	Mean	Min	Max
Number of farms	483	322	319	323	129	107	148
Number of trade contacts							
Dynamic	4635	1545	1522	1571	427	359	479
Static	926	449	431	468	114	93	134

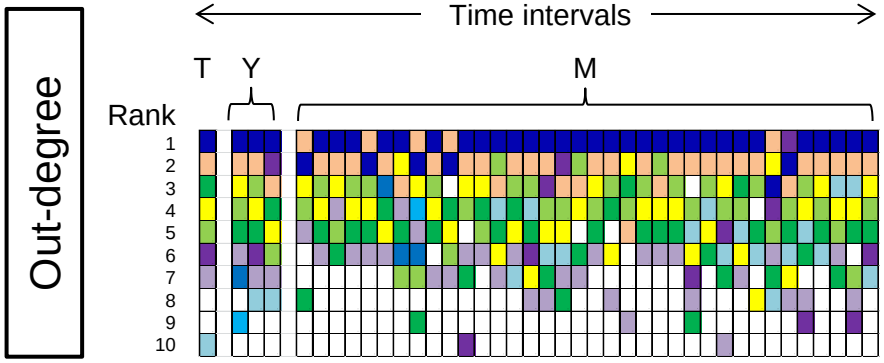
Materials and methods – Centrality parameters

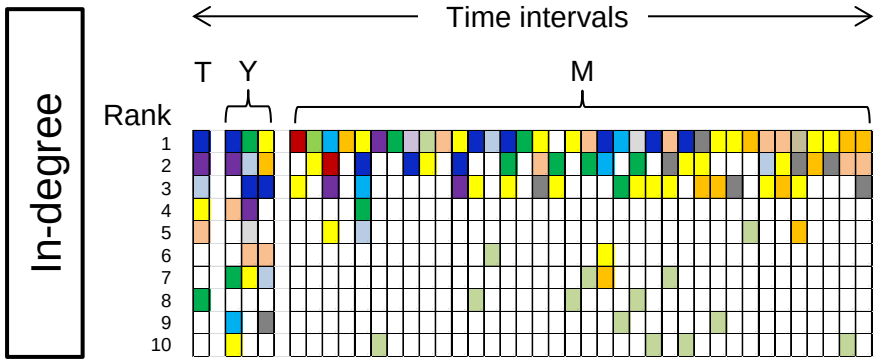
- **Degree:** Number of **direct** trade contacts
  - → Ingoing trade contacts: **In-degree**
  - → Outgoing trade contacts: **Out-degree**
- **Infection chain:** Number of **direct and indirect** trade contacts regarding the chronological order of the trade contacts
  - → Ingoing trade contacts: **Ingoing infection chain**
  - → Outgoing trade contacts: **Outgoing infection chain**



Results – Temporal properties

- **Centrality parameters based on the outgoing trade contacts (Out-degree & outgoing infection chain)**
  - → Stable characteristics within time
  - → In all time intervals the same farms are the most central
- **Centrality parameters based on the ingoing trade contacts (In-degree & ingoing infection chain)**
  - → Strong fluctuations in the ranking of the farms
  - → Small range of the centrality parameters



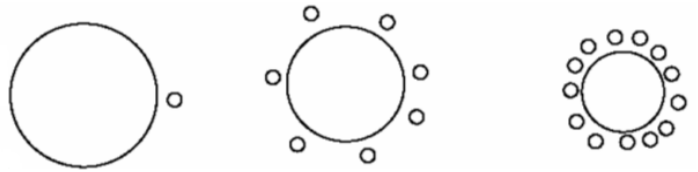


Materials and methods – Network resilience

- **Properties of networks with a right-skewed distribution of the centrality parameters**

→ **Random removal**

Highly resistant



→ **Targeted removal**

Highly vulnerable

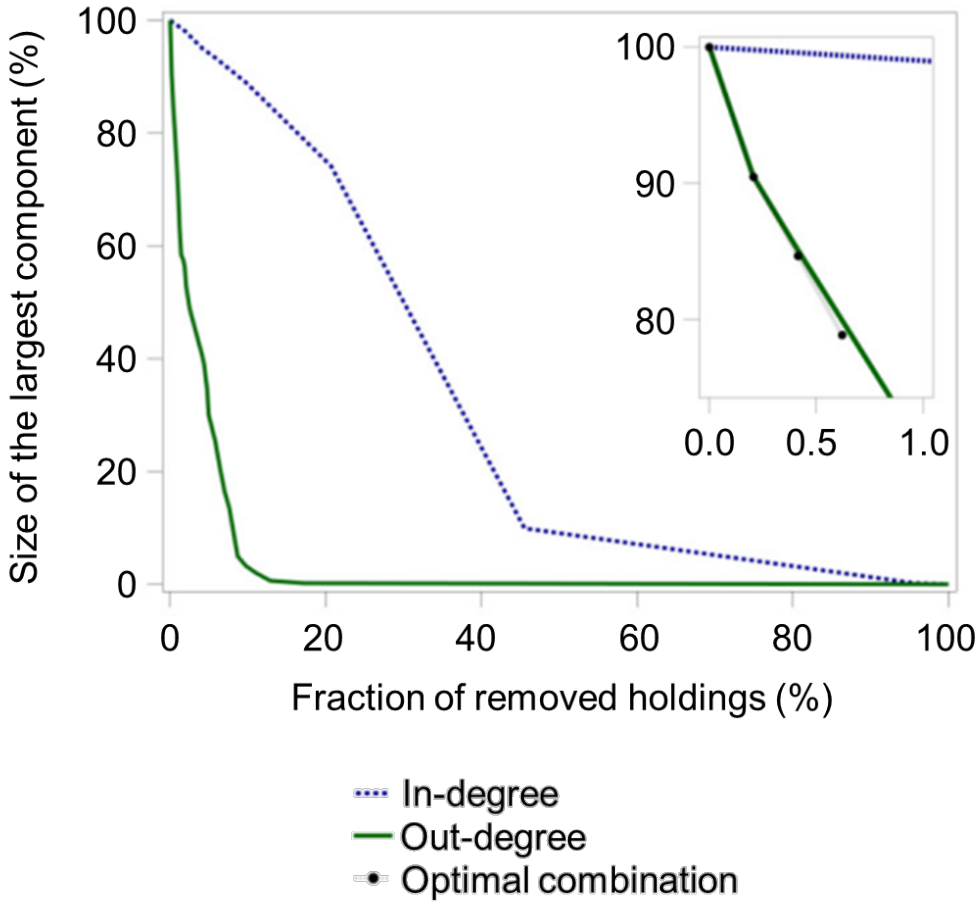
→ **PERCOLATION**

- **Evaluation criteria for the percolation process**

→ Number of holdings in the largest network component depending on the number of removed holdings

Results – Targeted removal

Three-year network: In-degree & out-degree



Reduction of the size of the largest component by more than 75%:

Number (Proportion) of removed farms

→ **In-degree:**

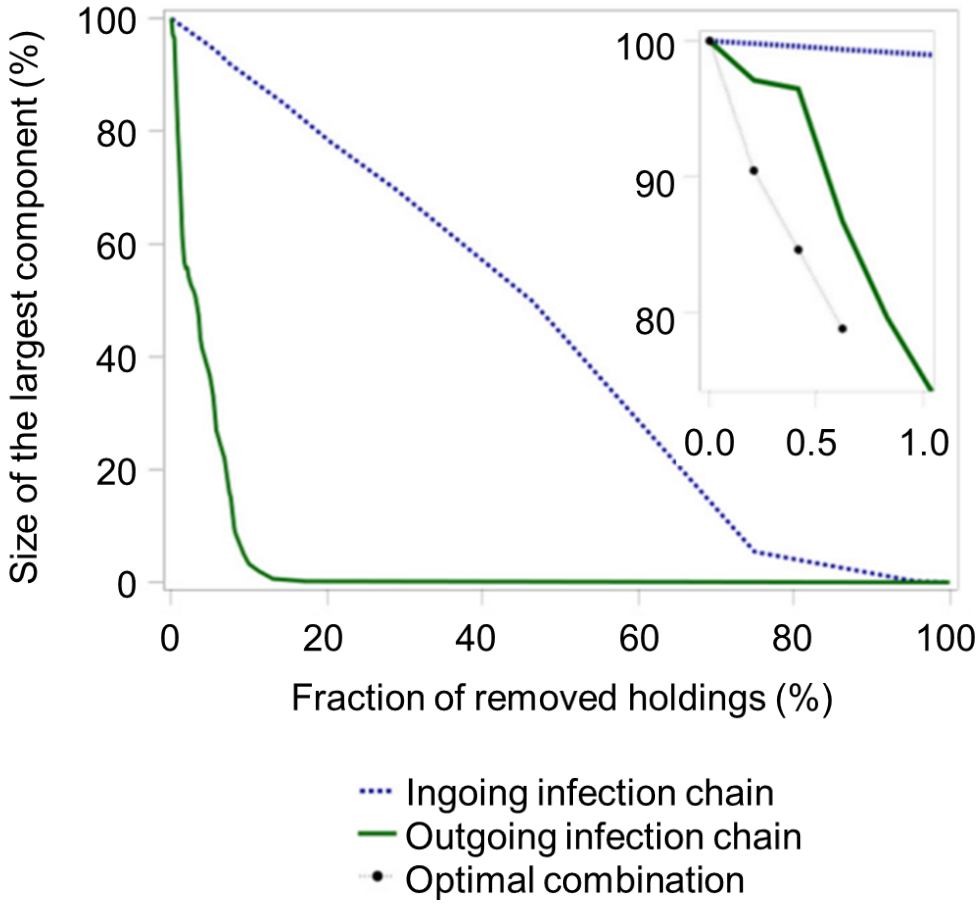
220 (46 %)

→ **Out-degree:**

31 (6 %)

Results – Targeted removal

Three-year network: Ingoing infection chain & outgoing infection chain



Reduction of the size of the largest component by more than 75%:

Number (Proportion) of removed farms

→ **Ingoing infection chain:**

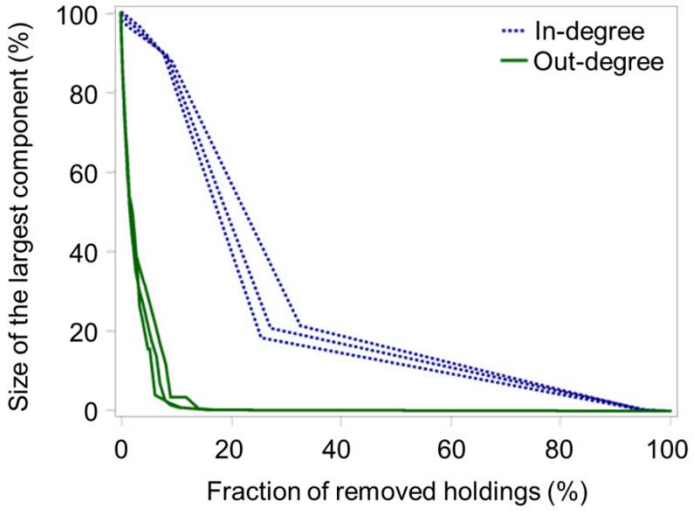
362 (75 %)

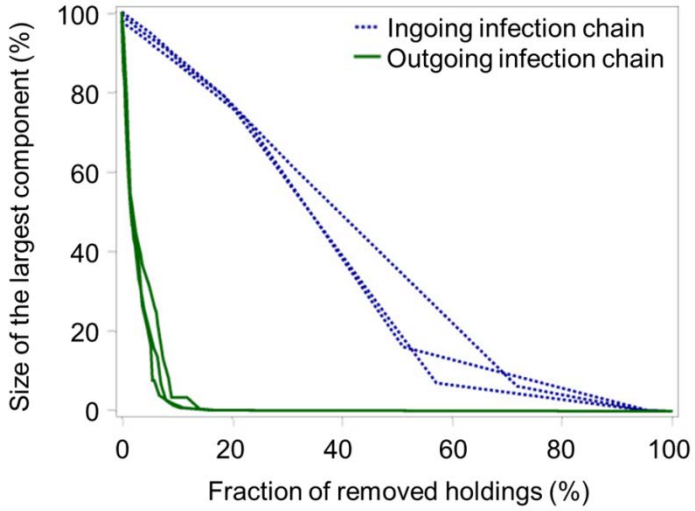
→ **Outgoing infection chain:**

32 (7 %)

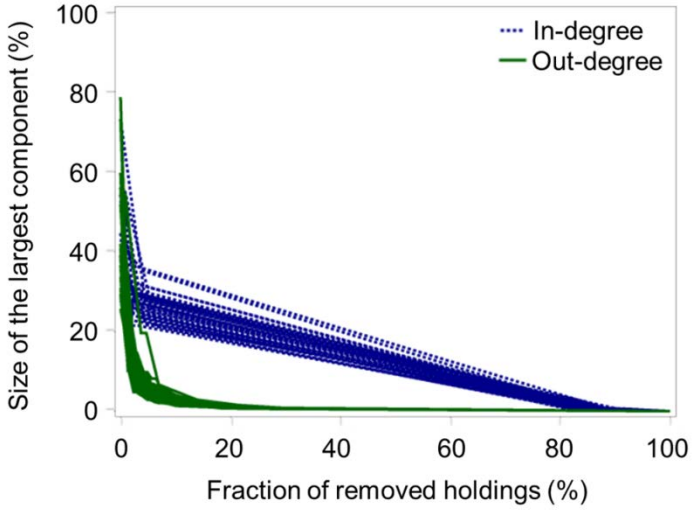
Results – Targeted removal

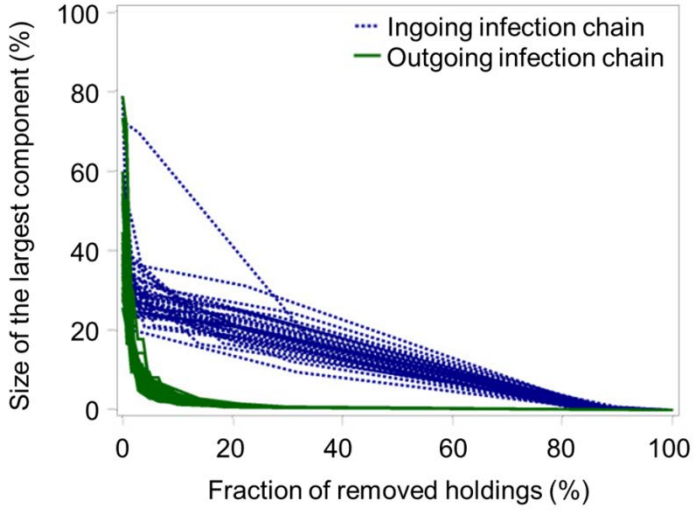
Yearly networks





Monthly networks





Results – Optimal combination

Targeted removal in comparison to the optimal combination

Improvement in % of network decomposition by removal of the optimal combination of the first three farms in comparison to the targeted removal of farms regarding the calculated centrality parameters

Parameter	Three-year network	Yearly networks	Monthly networks
In-degree	20.5	30.7	19.2
Out-degree	1.0	1.7	1.4
Ingoing infection chain	20.5	30.6	19.9
Outgoing infection chain	7.9	5.6	1.5

Conclusion

- **Stable characteristics** for all observed time periods

  → Centrality parameters based on outgoing trade contacts

- **Right-skewed distribution** for all calculated centrality parameters

- **Appropriate method to interrupt the chain of infection:**

  Successive removal of the most central farms regarding the parameters

  → **Out-degree**

  → **Outgoing infection chain**

- The targeted removal by out-degree was closest to the removal of the optimal combination

Preventive and control measures should consider

the parameters based on the outgoing trade contacts

Thank you for your attention!

Deutsche Forschungsgemeinschaft

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