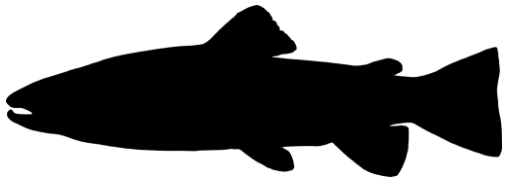
# Could ship movements transmit Infectious Salmon Anemia Virus between Norwegian fish farms ?

Hélène Duault, Maximilien Bailly, Mingli Zhao,
Sarah C. Hill and Guillaume Fournié



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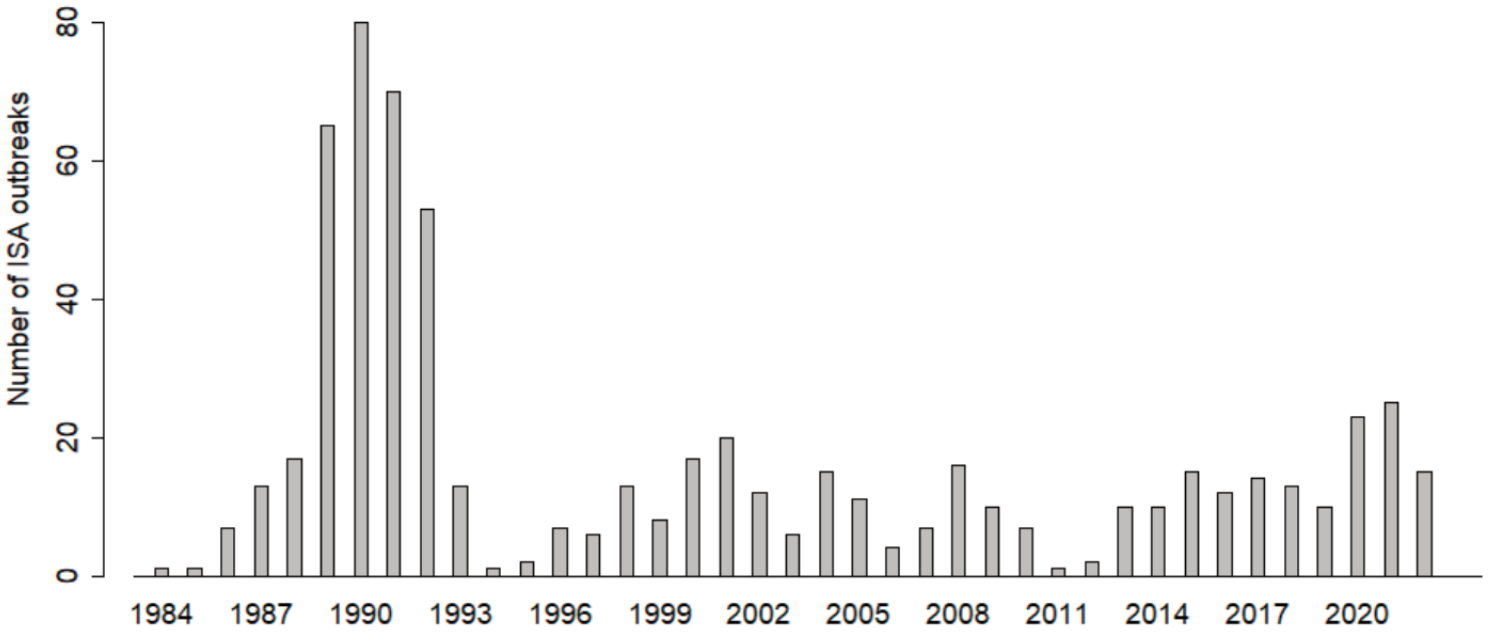
# Context

Infectious Salmon Anemia (ISA)
=
Notifiable & economically important disease

Two main phenotypic variants:
- ✓ virulent ISAV-HPRΔ (severe disease)
- ✓ non-virulent ISAV-HPR0 (not routinely tested)




I. Sommerset *et al.*, 2023

# Context

- ✓ Human activities can contribute to (long-distance) transmission:
  - Transport of infected fish
  - Release of contaminated ballast water from supply boats
  - Movements of contaminated equipment
  - Transfer of smolts
  - Treatments against sea lice
  - Harvesting

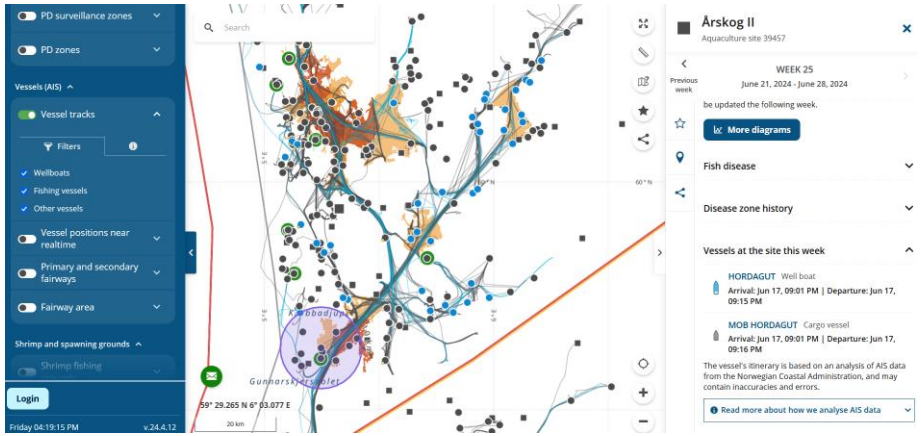
- ✓ Role of ship movements, in between-farm transmission?

OBJECTIVES:

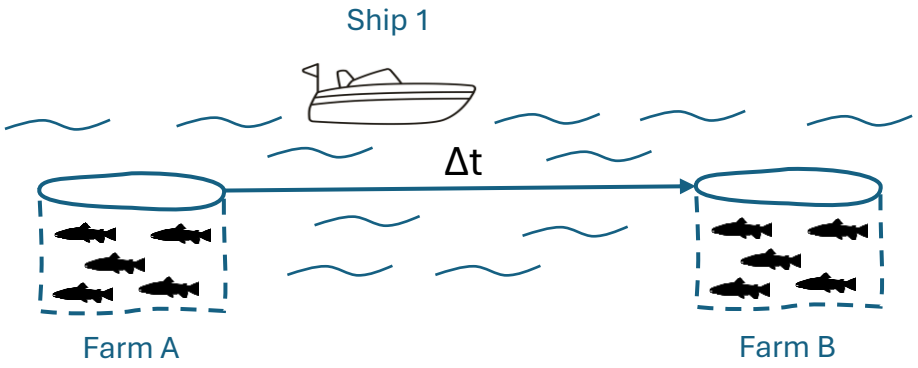
1. Describe the ship movement network.
2. Assess the possible contribution of ship movements to ISA virus (ISAV) transmission between farms.

# Material and Methods

- ✓ Open-access database on ships visiting aquaculture farms in Norway.
- ✓ Time period: 1st Jan 2021 – 31st Dec 2023
- ✓ Information on ship type NOT purpose of visit.




- ✓ Uncertain ISA virus survival times (Vike *et al.*, 2014, Tapia *et al.*, 2013).

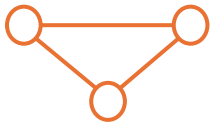



| Type of ships | Δt (days) |
|---|---|
| All ships | 1 |
| | 8 |
| | 15 |
| Only well boats | 1 |
| | 8 |
| | 15 |

STRATEGY:

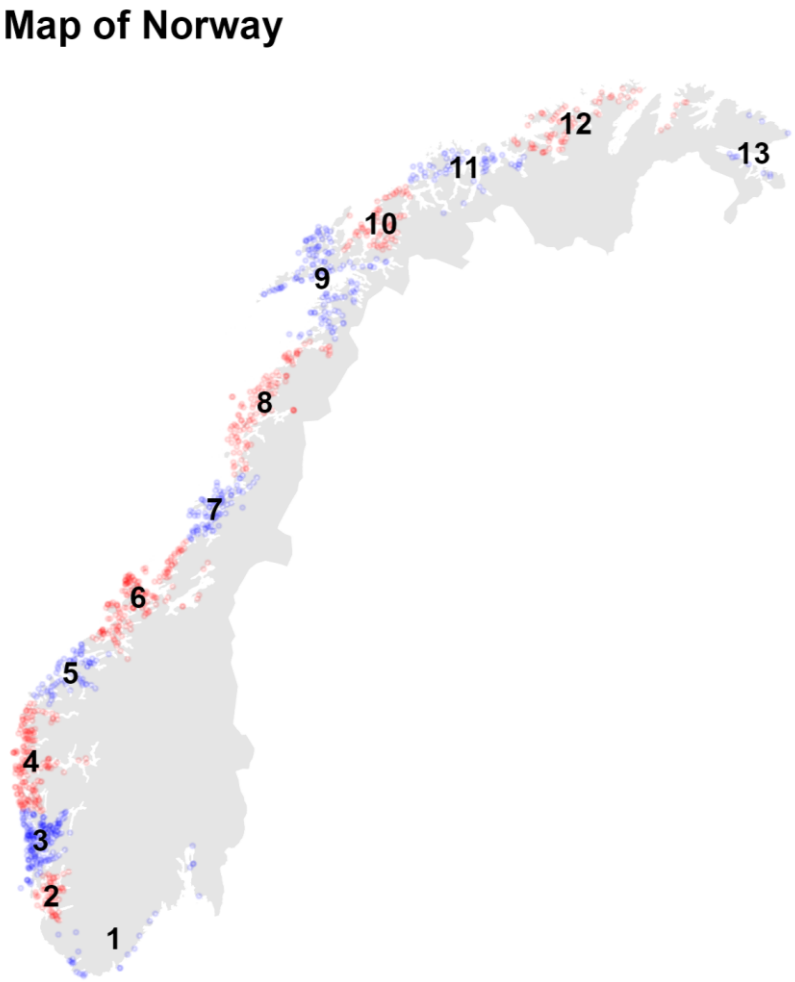
1. Describe the static network.

| Parameter | Definition |
|---|---|
| **Largest strongly connected component (LSCC)** | Largest subset of farms, expressed as the percentage of active farms, in which any farm can reach any other through at least one directed path. |
| **Average (un)weighted path length** | Mean of the shortest (un)weighted paths between all pairs of farms in the LSCC. |
| **Clustering coefficient** | [Number of triangles] x 3 / [Number of connected triples]<br>Proportion of closed triplets of nodes within the LSCC, ignoring direction and weight of edges. |



## STRATEGY:

1. Describe the static network.
2. Assess the relevance of production areas as subdivisions of the network.



## STRATEGY:

1. Describe the static network.
2. Assess the relevance of production areas as subdivisions of the network.

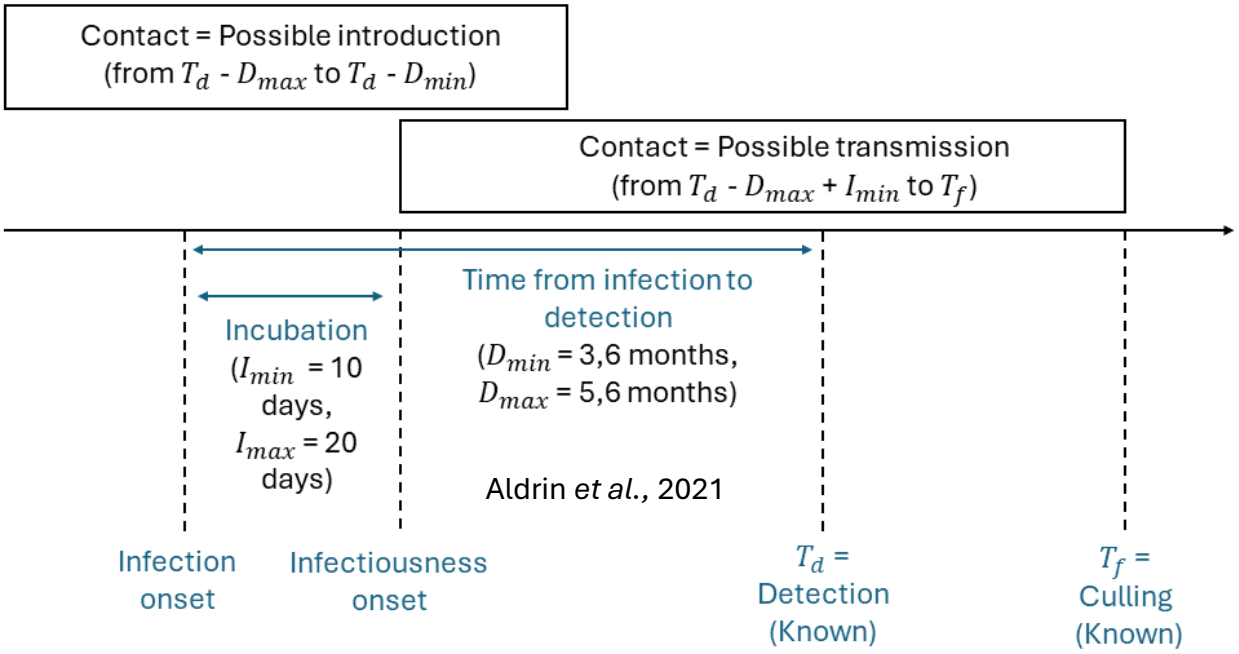
- ✓ Density: ratio between the number of actual and possible edges.
- ✓ Modularity: high density within groups and low density between groups. (Louvain algorithm *vs.* production areas).
- ✓ Shannon diversity index: comparing community mapping and production areas.

Shannon diversity index of production area j:

$$H'_j = -\sum_i p_{i,j} \log p_{i,j}$$

## STRATEGY:

1. Describe the static network.
2. Assess the relevance of production areas as subdivisions of the network.
3. Identify possible transmission events and compare results from three indicators to those computed on 1,000 permuted networks.




Rimstad and Mjaaland, 2002

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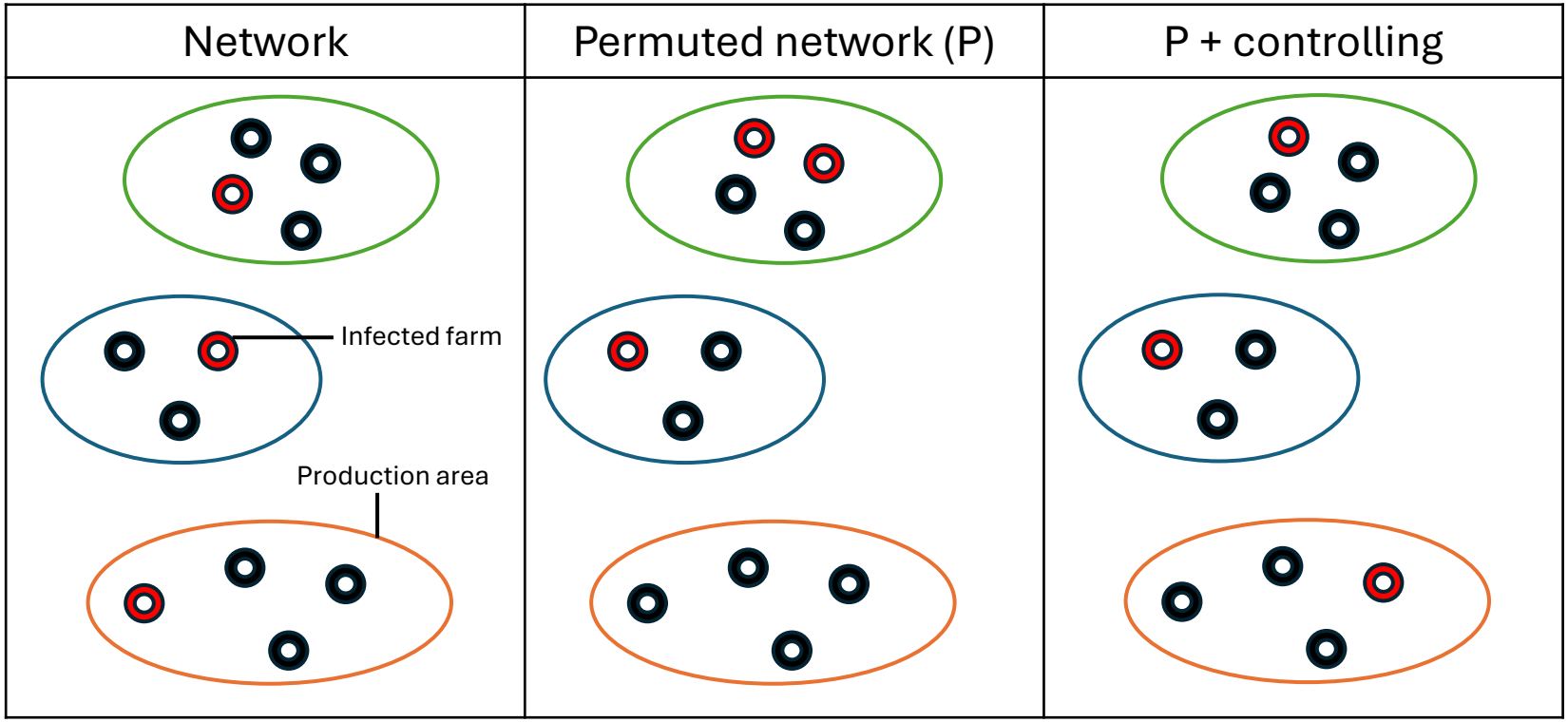
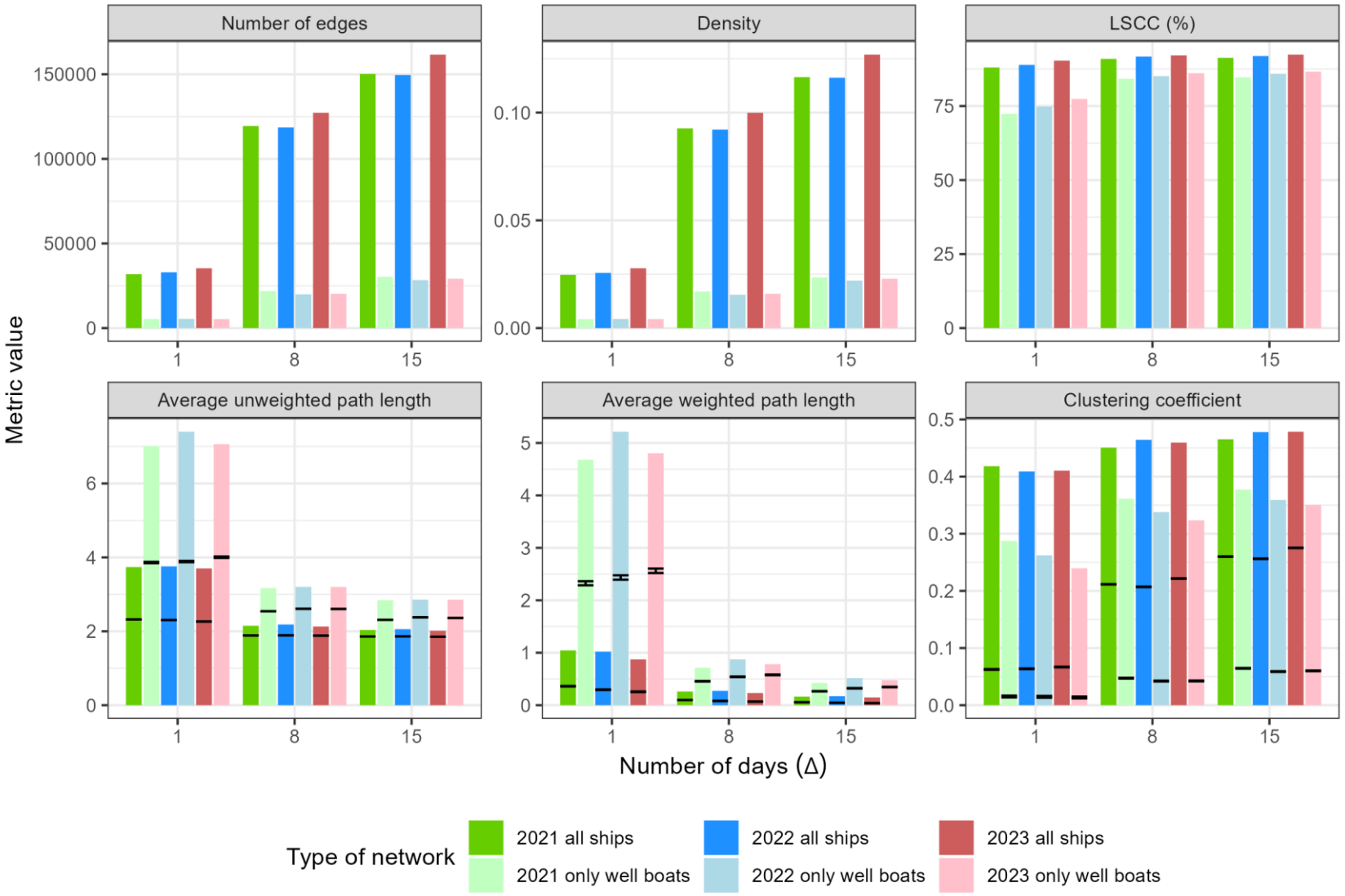


# Results: Static network



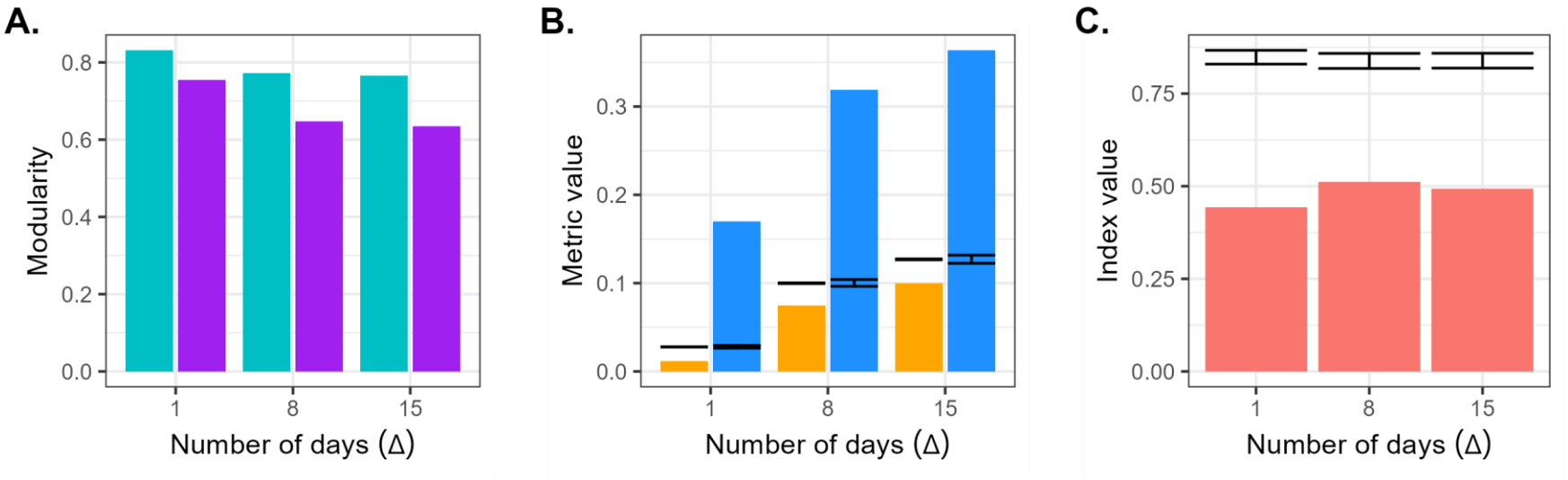
# Results: Production areas

Production areas in the 2023 “all ships” network.

A. Modularity estimated from communities and production areas.

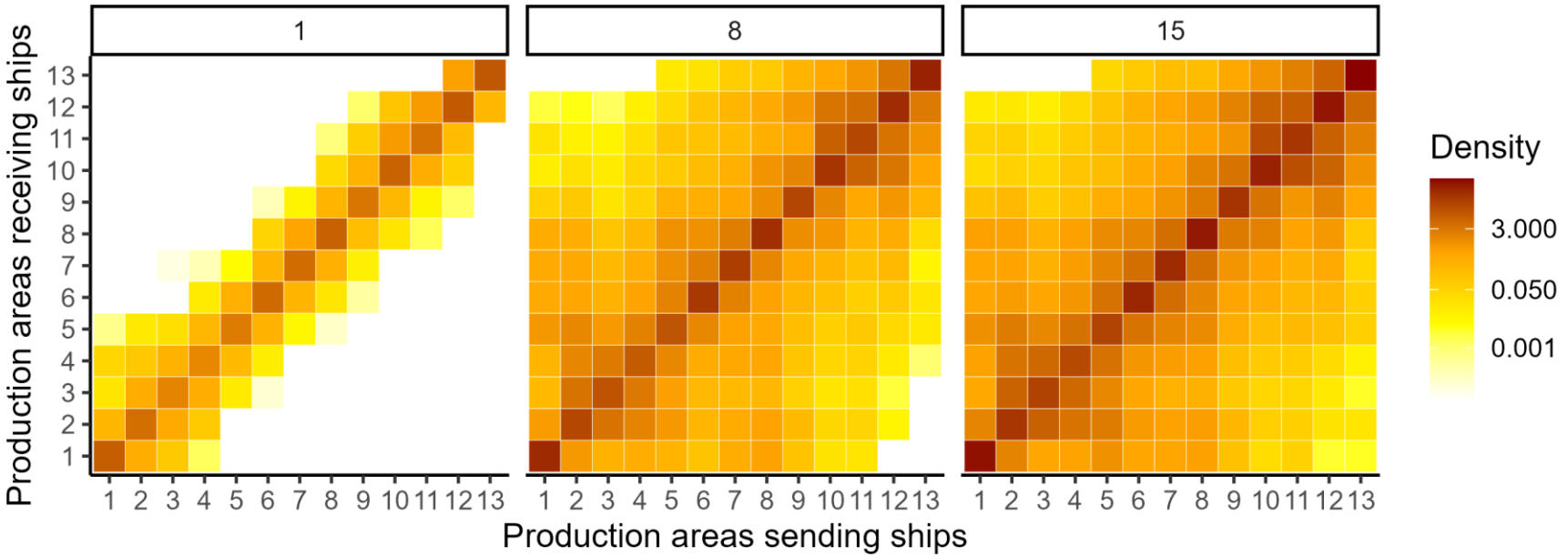
B. Density estimated within and between production areas.

C. Ratio between the average Shannon diversity index of all 13 production areas and the Shannon diversity index of the entire network.

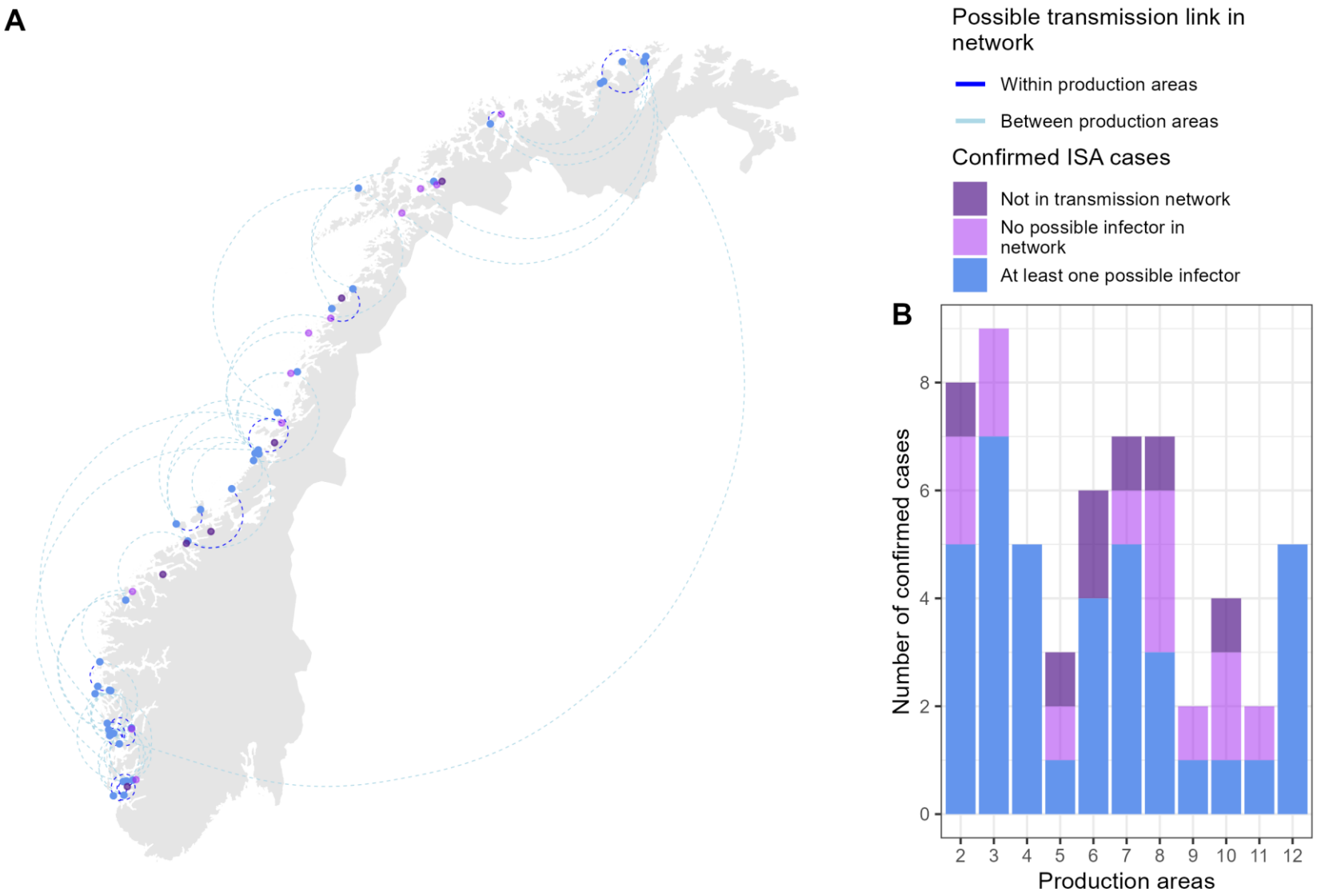


# Results: Production areas

Weighted density between and within production areas over the study period (2021-2023).

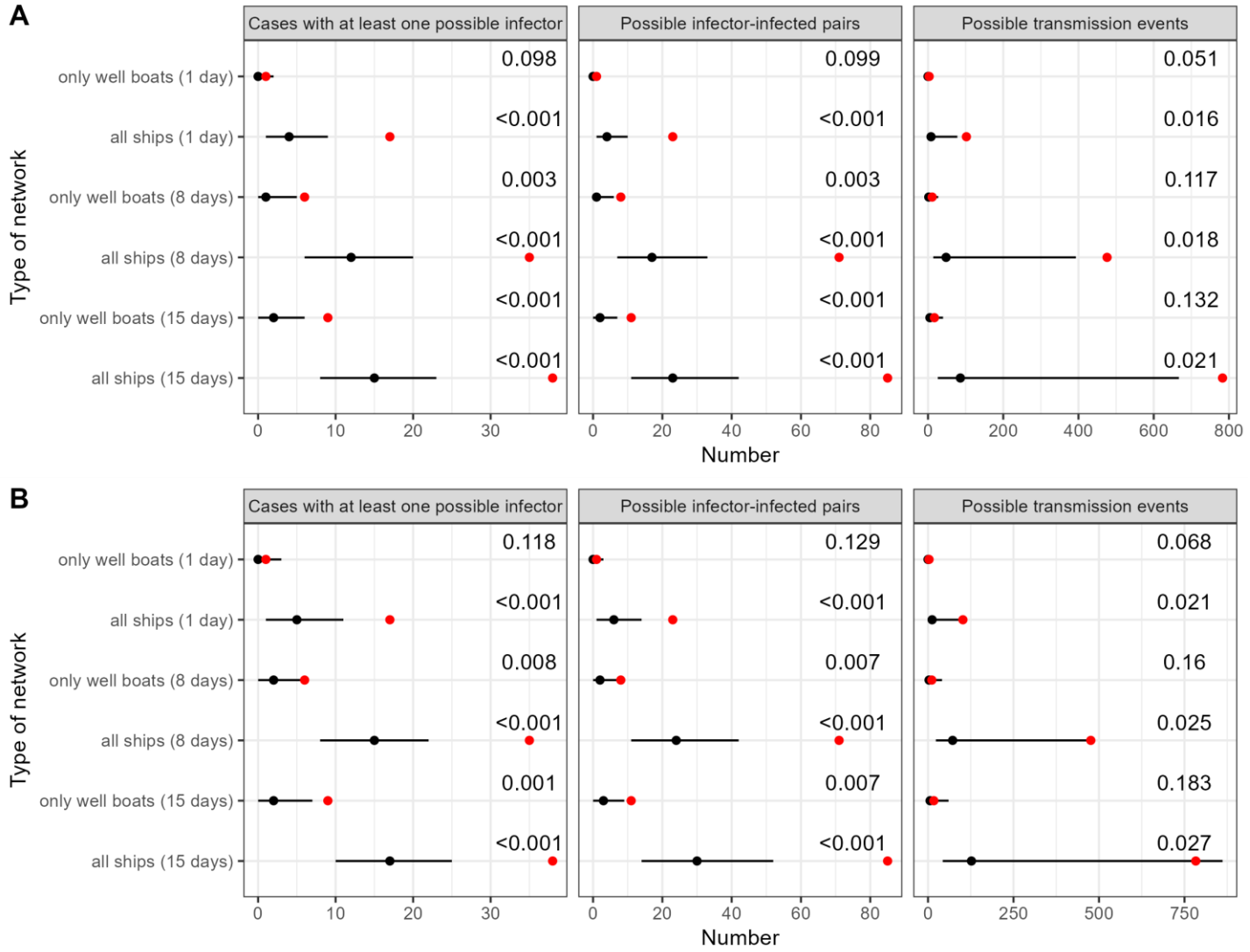


# Results: Potential transmission network



# Results: Potential transmission events

Results from the permutation tests on the temporal network.
With (B) or without (A) controlling for production areas.



# Discussion

- ✓ Highly connected and strong community structure:
  - Previously observed in Scotland (Green *et al.*, 2009, Green *et al.*, 2011) and Ireland (Yatabe *et al.*, 2015)
  - Within production areas BUT potential long-distance transmission.

# Discussion

- ✓ Highly connected and strong community structure:
  - Previously observed in Scotland (Green *et al.,* 2009, Green *et al.,* 2011) and Ireland (Yatabe *et al.,* 2015)
  - Within production areas BUT potential long-distance transmission.

- ✓ Potential presence of primary outbreaks:
  - *i.e.* HPR0 mutating into HPRΔ
  - Nearly 40% of outbreaks (Aldrin *et al.,* 2021)
  - Need for genetic data…

# Conclusion

Ship movements = potential viral transmission pathways between farms.

Further investigation : include genetic data to confirm or refute possible transmission events.

To be continued...

# Thank you!

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Dr Sarah Hill

Dr Mingli Zhao

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