The dissemination of *B. mallei* on between-farm animal movement

Workshops of the European Reference Laboratories for Glanders

Gustavo, Machado[1]

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[1]North Carolina State University, College of Veterinary Medicine
https://machado-lab.github.io/

NC STATE UNIVERSITY

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Acknowledgement

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Motivation

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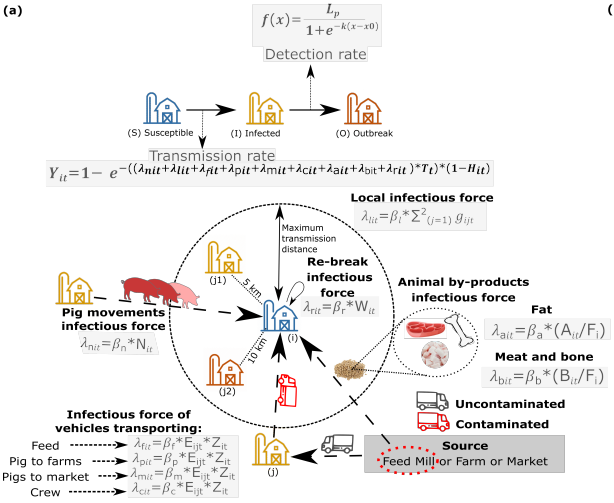
1. Approximately 80 % of between-farm transmission are driven by the movement of animals.

2. Remain unknown the contribution of other routes in the propagation of diseases among food-animal populations.

Motivation

(a)



(b) Model parameters

- β_n = Transmission rate of between farm pig movements
- β_l = Local transmission rate
- β_f = Transmission rate of between farm movements of vehicles transporting feed
- β_p =Transmission rate of between farm movements of vehicles transporting pig to farm
- β_m= Transmission rate of between farm movements of vehicles transporting pig to market
- β_c = transmission rate of between farm movements of vehicles transporting crew to farms
- β_a = Fat in the delivered feed rate
- β_b = Meat and bone in the delivered feed rate
- β_r = Re-break rate
- N = Number of asymptomatic and infected farms that sent pigs to "i"
- g = Gravity model with barrier effect
- E = Edge weight
- Z = Time vehicle stay on the farm
- A = Amount of fat in the meal
- B = Amount of meat and bone in the meal
- F = Pig population in the farm
- W= Re-break probability based on the time after last outbreak
- T = Monthly seasonality index
- H = Biosecurity index
- L = Detection probability
- x0 = Average time detection
- x = Time post virus introduction
- k = Logistic growth rate

[1]https://doi.org/10.1101/2021.07.26.453902

Modes of between-farm transmission

1. **Network.**
2. Distance (local transmission).
3. Transportation vehicles.
4. Vectors.
5. Environmental.

Detection and control

Detection

- Surveillance (clinical)-> most effective early detection.

Control

Detection and control

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- Trace-back.

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- National or sub-national standstill.

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- National or sub-national standstill.
- Implementation of control areas (zones).

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- Implementation of control areas (zones).
- Movement permits and contact tracing.
- Depopulation (complete or test and removal).
- Vaccination.

Dissemination and control questions

Burkholderia mallei

- Spread can occur by direct or indirect contact with an infected animal.
- Ingestion of feed or water that has been contaminated by nasal discharges from infected animals.
- Crowded conditions.
- Acute or chronic disease.

1. Can it spread via animal movement?
2. What would be the best way to stop propagation?

Aims

1. Dynamics of Glanders disease on between-farm movements.
2. Characterized the spatial and temporal patterns of the horse networks and identified regional trade communities.
3. Establish possible ***B. mallei*** causal paths between farms.

Real-time movement data

National policy

- Every animal or sub product movement must complete an electronic request (mandatory).
- Penalty notice.
- Premise identification, lat and long, reason of the movement, number of animals.

Methods

Real-time movement data

Fair/sales

Sport

Every site must provide:
1. Farm ID.
2. Lat & long.
3. Population.

11/12/2020

01/10/2021

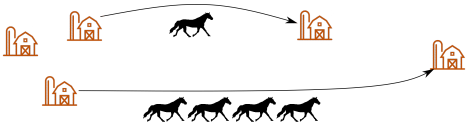
Methods

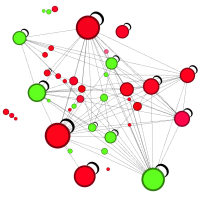
Movement data

1. 103,000 registered horse farms.
2. 537,159 horses.
3. All between farm movements from January 2014 to December 2016.
4. ***B. mallei*** infection (n = 30) and 10 in 2017 and 2018.

Network analysis

1. Farm locations represent the “nodes”.
2. Movements between farm “edges”.





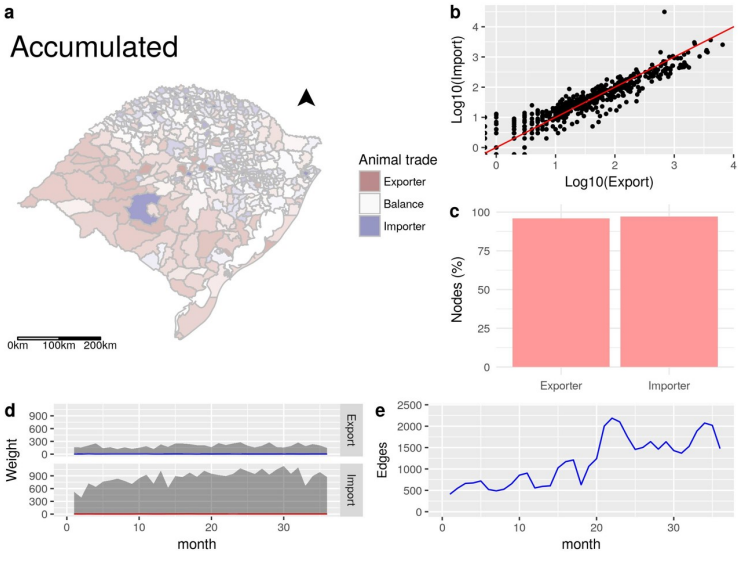
Methods

Association between animal movements and *B. mallei* outbreaks

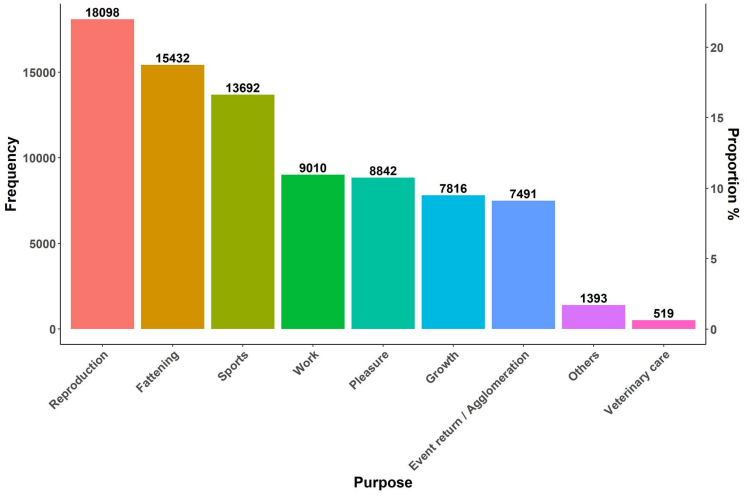
1. To test the hypothesis of direct association between animal movement and *B. mallei* via the k-test.
2. Possible outbreaks that may occur within n steps from an infected node.
3. All between farm movements from January 2014 to December 2016.
4. The contact network for the movements involving infected movements was traced.

Results

Network


a
Accumulated
0km 100km 200km
Animal trade
Exporter
Balance
Importer
b
Log10(Import)
Log10(Export)
c
Nodes (%)
Exporter
Importer
d
Weight
Export
Import
month
e
Edges
month

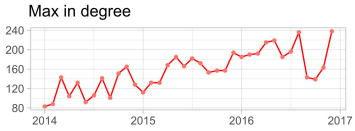
Network

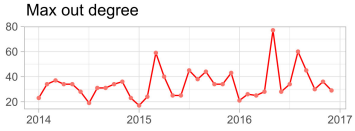

18098
15432
13692
9010
8842
7816
7491
1393
519
Frequency
Proportion %
Purpose
Reproduction
Fattening
Sports
Work
Pleasure
Growth
Event return / Agglomeration
Others
Veterinary care

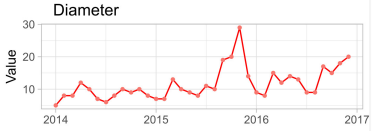
General network metrics

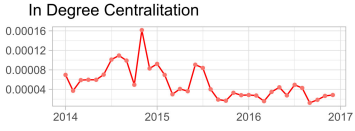
Parameter	Municipality	Farm
Nodes	491	38,263
Edges	59,161	82,293
Mean of horses per movement	2.83	10.51
Graph density	0.050	4.24 x 10-5
Max value of in degree	183	3868
Max value of out degree	184	400
Max size of GWCC	488 (99.39%)	30470 (79.63%)
Max size of GSCC	476 (96.94%)	6606 (17.26%)
Diameter	8	26
Mean of the shortest path	**2.86**	**6.29**

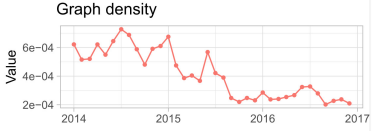
Temporal network metrics

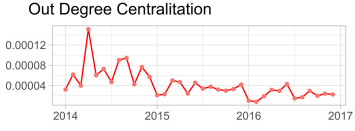












Infected network

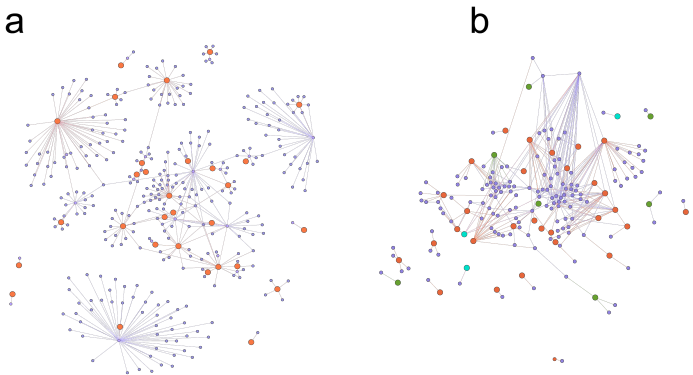
In- and out-going from infected farms

Contact chain	Measure	2014 n=8	2015 n=16	2016 n=23	All years
In-going	IQR	(1-423)	(5-861)	(1-1351)	(2-5115)
	Maximum value	758	1394	1858	5908
	Median value	4	22	3	2185
Out-going	IQR	(2 -726)	(4-1172)	(2-1075)	(4-5679)
	Maximum value	1101	2034	2204	12537
	Median value	3	96	12	1858

Infected network

a) Each red circle (infected) represents a farm where at least one horse tested positive.

b) Green and pink circles represent the positive farms in 2017 and 2018.



Outbreak associations with the network metrics at the farm level

	Univariable analysis		Multivariable analysis			
Variable (cutoff)	*p*-value	OR (CI 95%)	*b*	*SE*	OR (CI 95%)	*p*-value
Betweenness						
≤2,706.82	–	–	–	–	–	–
>2,706.82	0.02	2.50 (2.22–2.83)	–	–	–	–
Closeness centrality in						
≤0.0001459	–	–	–	–	–	–
>0.0001459	0.94	1.00 (0.99–1.01)	–	–	–	–
Closeness centrality out						
≤0.0002577	–	–	–	0.47	–	–
>0.0002577	0.001	4.46 (3.72–5.35)	1.63		5.11 (4.31–60.7)	<0.001
In degree						
≤73	–	–	–	0.42	–	–
>73	0.05	2.05 (1.82–2.32)	0.87		2.40 (2.01–2.86)	0.03
Out degree						
≤81	<0.001	–	–	–	–	–
>81		3.57 (3.26–3.90)	–	–	–	–
Degree total						
≤153	0.04	–	–	–	–	–
>153		3.02 (2.73–3.34)	–	–	–	–
PageRank						
≤0.005425	0.20	–	–	–	–	–
>0.005425		1.77 (0.99–2.06)	–	–	–	–

Discussion and conclusion

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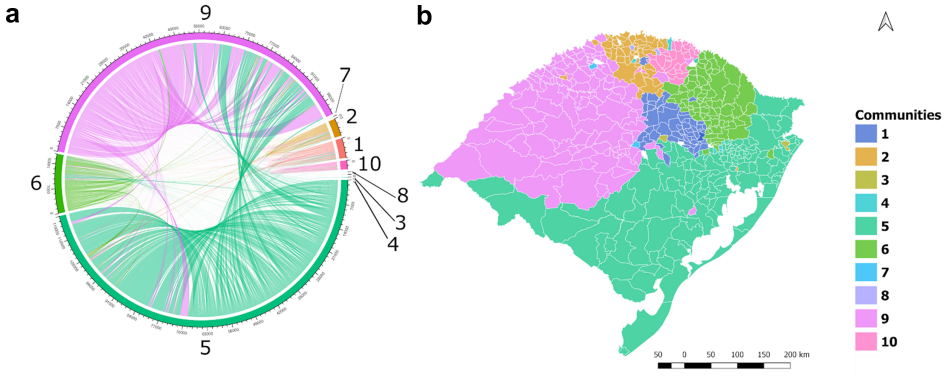
- 10 communities, suggesting that infected horses tend to readily move between the farms of a given community and later reach farms of other communities.
- The outbreaks of ***B. mallei*** showed a clear causal association through the network paths, two steps!!.
- OR 2.40 and 5.11, in-degree and centrality, local and a more complex dynamics.


a
9
7
2
1
10
8
3
4
6
5
b
Communities
1
2
3
4
5
6
7
8
9
10
50 0 50 100 150 200 km

Limitation and further remarks

1. So many assumptions.
2. Currently only including animal movement.
3. Questions about the trace-back and movement restriction implemented by the state.
4. All animals transported are required by law to be tested for ***B. mallei*** (?).

General conclusion

- Network information has the potential to inform ***B. mallei*** control.
- **Mathematical simulation** could provide a better inside to the over all dynamics.
  - Local transmission.
  - Environmental transmission.
  - Proper farm closure intervention.
- Questions about the trace-back and movement restriction implemented by the state.

Questions?