Characteristics of swine shipments in southwestern Ontario, Canada

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Background

- Network analysis (NA) of animal shipments between premises can provide useful insights into topologies of contact networks, disease transmission pathways, epidemic sizes, and effectiveness of control strategies (Brigras-Poulin *et al.*, 2007; Kiss *et al.*, 2006; Ortiz-Palaez *et al.*, 2006; Robinson & Christley, 2007; Webb, 2005).
- Only a single NA study, on dairy cattle shipments, has been reported for the Canadian farming sector (Dubé *et al.*, 2008).

Objectives

- Characterize swine shipment networks in southwestern Ontario.
- Generate contact parameters for modeling disease spread in swine populations.

Materials and Methods

Study population

- Data on daily swine shipments between premises (farm to farm and farm to abattoir) for the period 2006 to 2007 were extracted from a company database.
- 20 sow, 69 nursery, and 162 finishing farms and 91 abattoirs were involved in the shipments of pigs. Information on farm types, date and size of shipments, and types of animals were also extracted.

Network Analysis

- Networks consisted of *nodes* (premises) and *links/edges* representing the nature and extent of relationships formed through the shipment of pigs.
- Separate NA were carried out for shipments with (2-mode: Network A) and without abattoirs (1-mode: Network F).
- Social network analysis methods (Newman, 2003, Wasserman & Faust, 1994) were used.
- Node and network level centrality and cohesion measures were estimated.
- Network F was examined for scale-free (power law distribution) and small-world properties. Power law distribution parameters were estimated using the approach of Clauset *et al.*, 2009, and goodness of fit was assessed using Kolmogorov-Smirnov (KS) statistics.
- Monthly outgoing/ingoing infection chains measuring all direct contacts between nodes, plus indirect contacts through further shipments accounting for time sequence of shipments (Dubé *et al.*, 2008; Nöremark *et al.*, 2011), were estimated.
- UCInet version 6.360 was used for NA and monthly infection chains were generated using the EpiContactTrace package of R software. Data were analyzed using Stata® version 11.

Results

- A total of 7,417 shipments between 740 linked pairs of 209 farms and 91 abattoirs were observed in Network A. The network density was 0.039.
- Farms shipped pigs to a median (range) of 3 (1-24) abattoirs, whereas abattoirs received pigs from 2 (1-144) farms. Three abattoirs accounted for 55% of the links.

Table 1: Descriptive statistics of swine shipments between premises

Premises type					
Source (no.)	Destination (no.)	Total links	Total shipments	Weekly median (range) of links	Weekly median (range) of shipments/pair
Sow herd (20)	Nursery (54)	152	3690	2 (1-5)	2 (1-7)
Sow herd (12)	Abattoir (7)	28	198	1 (1-2)	1 (1-3)
Nursery (38)	Nursery (35)	47	108	1 (1)	1 (1-2)
Nursery (53)	Finishing (134)	516	1527	1 (1-5)	1 (1-5)
Nursery (54)	Abattoir (43)	188	726	1 (1-3)	1 (1-4)
Finishing (63)	Finishing (61)	95	435	1 (1-3)	1 (1-9)
Finishing (143)	Abattoir (73)	524	6493	1 (1-12)	1 (1-6)

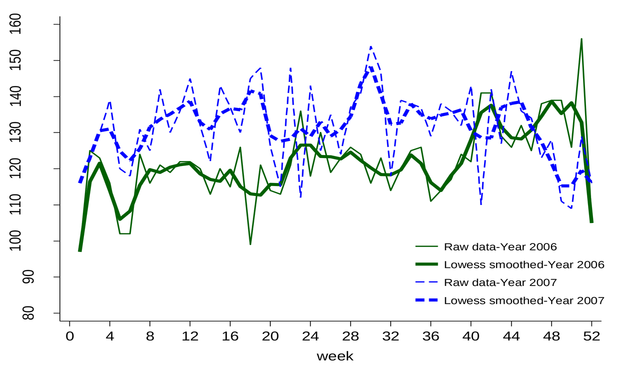


Fig. 1: Frequency of weekly shipments. No significant seasonal variations were observed in either year. However overall shipments were significantly higher in 2007 than in 2006

Results

- Network F (farms only) consisted of 5,760 shipments between 810 linked pairs of 147 source and 211 target farms. Network density was 0.014.
- Total degree distributions of Network F exhibited **scale-free** property - a few farms with relatively high degree of contacts (Fig. 2).
- Degree distributions had a power law scaling exponent (γ) of 2.7 for nodes with degree ≥6 for Network F. The KS test failed to reject the power law model as plausible ($p>0.05$) (Fig. 2(c)).
- Relatively large number of nursery farms had high betweenness scores as well as high in- and out-degrees (Fig. 3 and Fig. 5(b)).

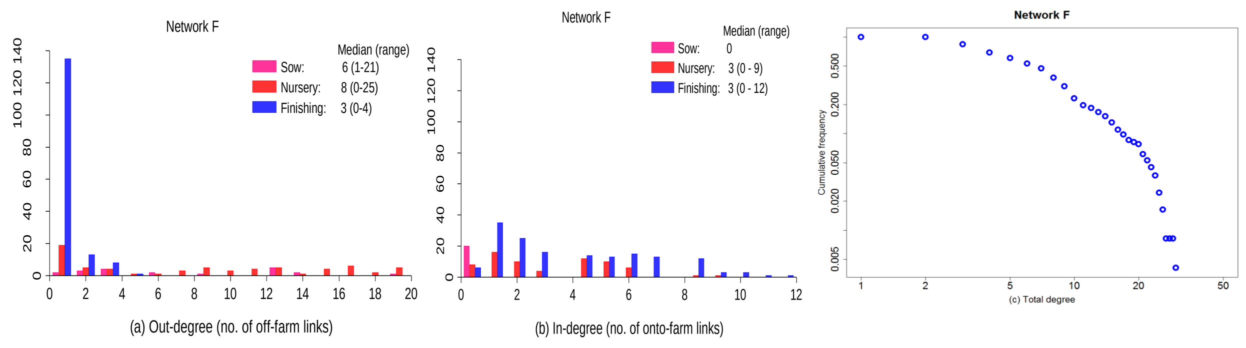


Fig. 2: Distributions of: (a) out-degree, (b) in-degree, and (c) total-degree (log-log scale)

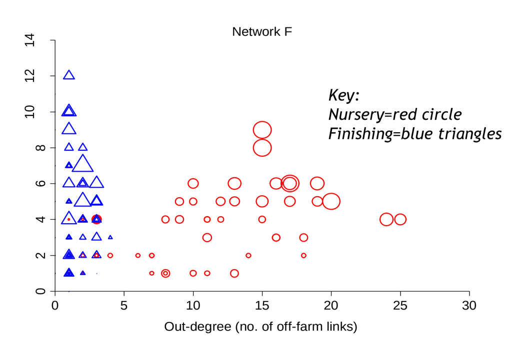


Fig. 3: Plots of out- and in-degree with marker sizes proportional to betweenness scores

- Monthly distributions of in-degree and ingoing infection chain, and as well as out-degree and outgoing chain, were similar (Fig. 4).
- Heterogeneity in these measures amongst the three farm types was significant.

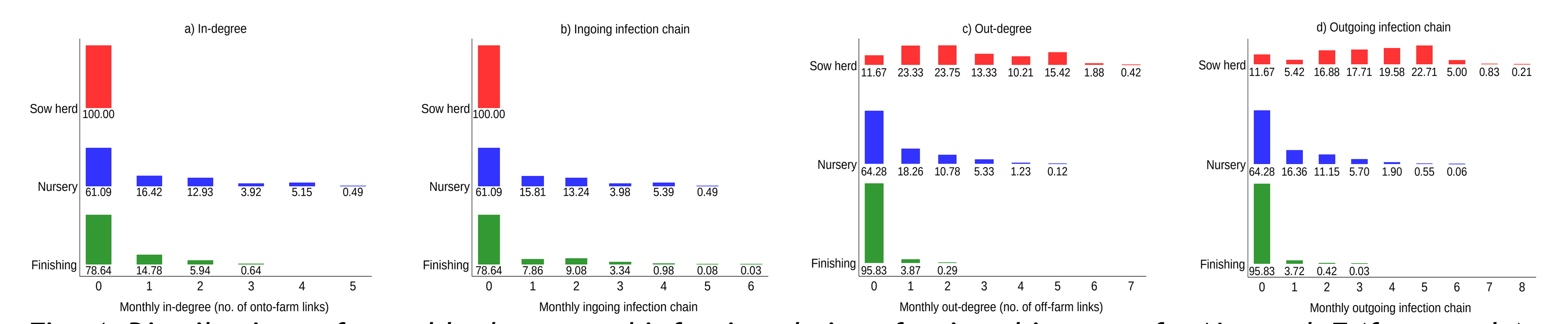
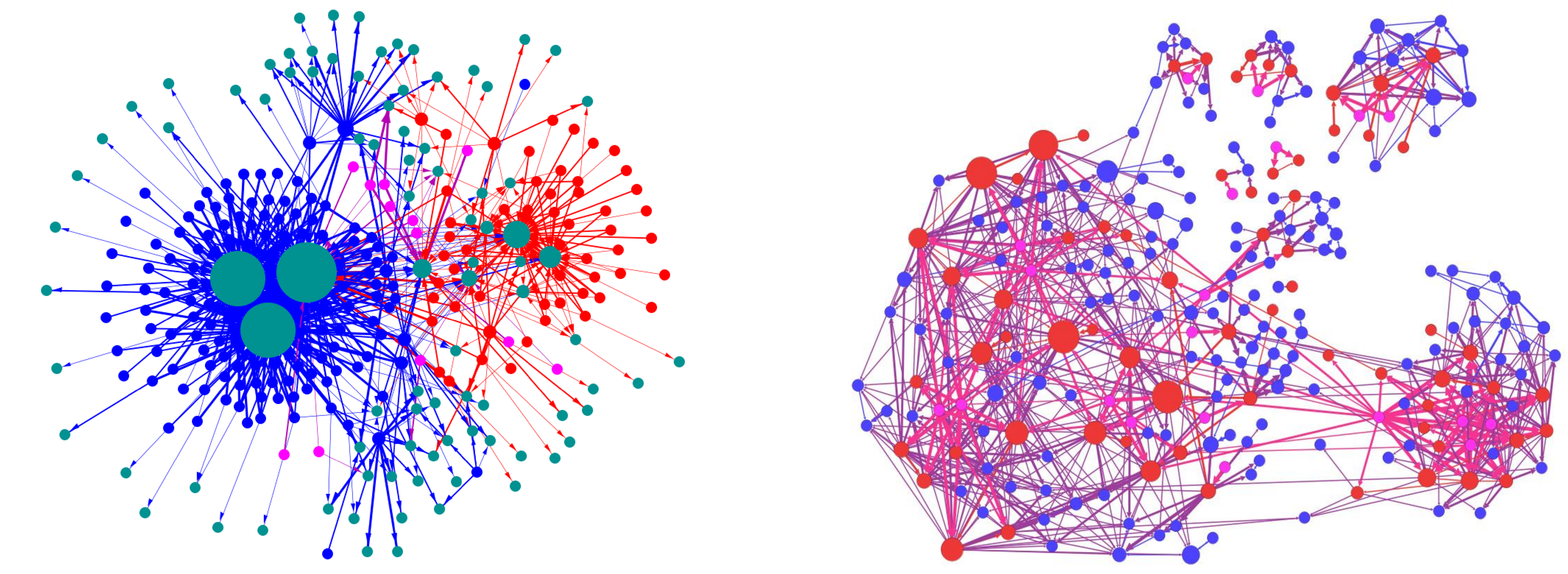


Fig. 4: Distributions of monthly degree and infection chains of swine shipments for Network F (farms only)

- Network F exhibited a **small-world** property - had a relatively shorter geodesic distance (2) and a larger clustering coefficient (0.09) than random graphs of equivalent sizes (average geodesics distances of 4 and clustering coefficients of 0.013) (Fig. 5 (b)).



(a) Network A (2-mode) **(b) Network F (farms only)**

Fig. 5: Networks of pig shipments. Nodes sizes are proportional to degree (Network A) and betweenness scores (Network F). Thicknesses of edges are proportional to: (i) single, (ii) 2-10, and (iii) 11-117, 11-258 shipments for Networks A and F respectively. Color key: sow farms (pink); nursery farms (red); finishing farms (blue); abattoirs (green).

Discussion

- Results suggest that risk of disease spread ranged from 1-5 farms/week or 1-8 farms/month per infected source farm.
- Farms with high out-degree can potentially act as '**super-spreaders**' (e.g. sow and nursery farms).
- Nursery and finishing farms with high onto-farm or ingoing infection chains might be at greater risk of disease introduction.
- The scale-free and small-world properties observed indicate that a disease could spread rapidly to topologically distant clusters of the network.
- Knowledge of the existence of high risk premises, particularly nursery farms with high betweenness and relatively high off- and onto-farm links (i.e. acting as a hub) would facilitate implementation of risk-based surveillance and improve effectiveness of control measures by selectively targeting them on a priority basis.

Conclusion

- The scale-free and small-world properties observed were consistent with other livestock shipments studies reported from a range of countries.
- Heterogeneities in contacts between different farm types and network topologies should be considered when modeling diseases spread in swine populations.

References

Bigras-Poulin, MK *et al.* (2007) *Prev Vet Med*, 80, 143-165.
Clauset, A *et al.* (2009) *SIAM Review*, 51, 661–703.
Kiss, IZ *et al.* (2006) *J R Soc Interface*, 3, 669-677.
Newman, MEJ (2003) *SIAM Review*, 45, 167-256.
Nöremark, M *et al.* (2011) *Prev Vet Med*, 99, 78-90.
Ortiz-Pelaez, A *et al.* (2006) *Prev Vet Med*, 76, 40-55.
Robinson, SE *et al.* (2007) *Prev Vet Med*, 81, 21-37
Wasserman, S *et al.* (1994) Social Network Analysis, Methods and Applications. Cambridge University Press, New York.
Webb, CR (2005) *Prev Vet Med*, 68, 3-17.

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