Grouping Scottish Agricultural Premises Based on Estimated Risk for Initiating Epidemic Veterinary Disease Outbreaks

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EXECUTIVE SUMMARY

We simulated undetected infectious disease spread on an observed cattle movement network in Scotland, and estimated the risk of an epidemic outbreak originating from any particular premises. Based on the simulation results, Scottish agricultural premises were grouped into *Negligible*, *Low*, *Medium* or *High* risk categories. Within the *Low* and *Medium* risk categories, we identified additional groupings showing elevated risk at particular times within the year. This work will help inform strategies for targeted disease surveillance, and disease control in the event of an outbreak.

METHODS

Data. Cattle movement data for ~16,000 premises (11,823 Scottish premises, plus all first-order neighbours outside of Scotland) for Jan – Dec 2013.

Model. Stochastic Susceptible-Infected (SI) compartmental model at each premises. Assumed homogeneous mixing within premises. Implemented within the SimInf modelling framework[1] in R. Movement of cattle between premises according to recorded historical cattle movements.

Simulation experiments. In each simulation run, on a randomly chosen day a single infected animal was placed at one particular premises. A total of 2,200 simulation runs were performed for each premises, with disease seeding dates spread out evenly across the year. The network was followed up for 28 days after disease incursion, recording whether an epidemic outbreak involving at least five secondary premises was observed. Probability of initiating an epidemic outbreak was calculated for each premises for each month.

Cluster analyses. Premises with zero risk for epidemic outbreaks were removed before clustering. Remaining premises were clustered using hierarchical clustering with Ward's method[2]. Clustering was done twice, using: a) the mean, standard deviation and `risk-ratio' (mean ÷ sd) of the monthly risk estimates; and b) the monthly risk estimates itself.

RESULTS

The first cluster analysis (a) allowed identification of four broad risk categories: premises posing *Negligible* risk (24% of total), *Low* risk (44%), *Medium* risk (32%), or consistently *High* risk (0.2%) for initiation of epidemic outbreaks affecting five or more secondary premises. The second cluster analysis allowed us to identify sub-groupings within these risk categories, for which the risk levels are elevated at various times of the calendar year.

Table: Mean risk (as percentage) for initiating an epidemic outbreak affecting five or more secondary premises within 28 days from disease incursion. Scottish agricultural premises (n = 11,823) are grouped into risk categories ranging from *Negligible* (2,845 premises; 24.1% of total), *Low* (5,207 premises; 44.0% of total), *Medium* (3,753 premises; 31.7% of total), and *High* (18 premises; 0.2% of total). Months of elevated risk are highlighted in the table (coloured cells).

Risk category	Number of premises (% of total)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Negligible	2845 (24.1%)	0	0	0	0	0	0	0	0	0	0	0
Low	2567 (21.7%)	1	1	1	1	1	1	1	1	2	2	1
	271 (2.3%)	15	6	4	4	1	0	1	2	3	2	1
	49 (0.4%)	2	21	8	9	1	0	1	3	7	4	3
	402 (3.4%)	1	4	19	5	1	0	1	1	2	2	1
	331 (2.8%)	1	2	3	18	2	1	1	1	4	2	1
	201 (1.7%)	3	2	4	6	16	2	1	2	3	4	1
	152 (1.3%)	2	3	3	5	3	15	4	2	5	5	3
	11 (0.1%)	0	0	2	3	3	16	22	2	3	0	0
	341 (2.9%)	3	4	4	4	2	2	12	5	7	5	3
	211 (1.8%)	0	1	2	1	0	1	1	20	12	3	1
	387 (3.3%)	1	1	2	1	1	0	0	1	22	5	1
	159 (1.3%)	2	2	1	1	1	1	0	1	8	24	2
	125 (1.1%)	2	2	2	1	2	0	1	2	4	5	21
Medium	287 (2.4%)	26	13	8	11	2	1	1	5	15	7	2
	454 (3.8%)	3	33	18	12	2	1	1	4	14	6	3
	158 (1.3%)	4	9	10	8	2	3	21	10	19	8	4
	442 (3.7%)	2	5	37	8	1	1	1	1	13	7	2
	376 (3.2%)	1	3	11	39	3	0	1	2	10	7	2
	240 (2%)	3	6	10	18	28	2	1	4	11	6	2
	2 (0%)	0	0	6	15	7	10	0	2	27	8	0
	107 (0.9%)	6	5	5	10	8	11	40	17	16	9	8
	109 (0.9%)	2	4	5	8	4	22	7	5	16	16	4
	378 (3.2%)	1	2	6	4	1	1	2	31	24	8	3
	541 (4.6%)	2	2	2	2	1	0	1	1	19	40	2
	253 (2.1%)	3	5	4	4	2	1	1	2	14	13	36
	406 (3.4%)	0	1	1	1	0	1	1	1	45	5	0
High	18 (0.2%)	59	64	63	56	48	51	54	64	57	45	38

DISCUSSION AND FUTURE WORK

The goal was to develop a general framework for classifying agricultural premises based on risk for initiating epidemic outbreaks due to animal movements, and we did not focus on any specific disease. The estimated risk groupings are likely to be different for different disease parameters, and for multiplex networks where movements for multiple species (such as cattle, sheep and pigs) are considered together.

This analysis considers solely risk due to animal movements. Many other factors are involved in the disease spread process. Our results show what may happen in the absence of any disease control, biosecurity, or separation facilities.

Future work includes evaluation of the predictive value of our classification system to subsequent years.

ACKNOWLEDGMENTS

REFERENCES

[1] WIDGREN S., BAUER P., ERIKSSON R., ENGBLOM S. (2018). SimInf: An R Package for Data-Driven Stochastic Disease Spread Simulations. arXiv preprint arXiv:1605.01421 [q-bio.PE], https://arxiv.org/abs/1605.01421

[2] RENCHER, A.C. (2002). Methods of Multivariate Analysis. Wiley.

Risk of initiating epidemic outbreak: Scottish premises

Medium (32%)
3,637 Farms
83 Landless keepers
20 Showgrounds
12 Markets
1 Other

High (0.2%)
14 Markets
4 Farms

Low (44%)
4,998 Farms
180 Landless keepers
28 Showgrounds
1 Other

Negligible (24%)
2,669 Farms
165 Landless keepers
7 Showgrounds
4 Others

x-axis: mean risk
y-axis: variability (sd)