Improved risk-based strategies for disease management in the pig production chain

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Abstract

To minimize financial losses in times of crisis, it is necessary to prove methods of maintaining trade in a case of disease. This work shows that the identification of modules and clusters could be of high relevance if these clusters impede disease spread or if so-called Ad hoc-connector-points serving as routes of transmission between clusters could be identified. Furthermore the advantages of a risk-based selection of critical control points for surveillance or monitoring can be shown. This work provides new approaches to review and possibly optimize existing disease prevention and control strategies.

Introduction

One objective of animal disease control is to maintain the trade of live animals and animal products. Nevertheless, control measures itself cause financial losses within agricultural production chains. Therefore veterinary research has to give guidance to decision makers in order to limit the control measures to the necessary level. In this paper, results of research on risk-based strategies for disease management in the pig production chain are presented.

Movement of live animals between farms is a major risk factor for livestock disease spread. With access to data of the German animal movement database (Herkunftssicherungs- und Informationssystem für Tiere – HI-Tier) and by using methods of network analysis the German pig trade can be analyzed. The German pig trade network is very complex. It contains 119.858 pig premises or related enterprises (nodes) and 327.972 trade connections (edges). Lentz et al. (2011) showed that the German pig trade network is modular and can be divided into modules. A module is defined as subsets of nodes in which are significantly more edges (trade connections) than expected by chance [Newman, 2006, Lentz et al., 2011, 2009]. These modules are computed without any geographical information. By adding the geographical information, i.e. the location of premises, modules become to clusters. These clusters are regional delimited. Such structure can be of crucial importance in case of a crisis like an epidemic. The question is if the existence of modules and clusters can impede the spread of an infectious disease and in what way we can benefit from it regarding to optimize control strategies.

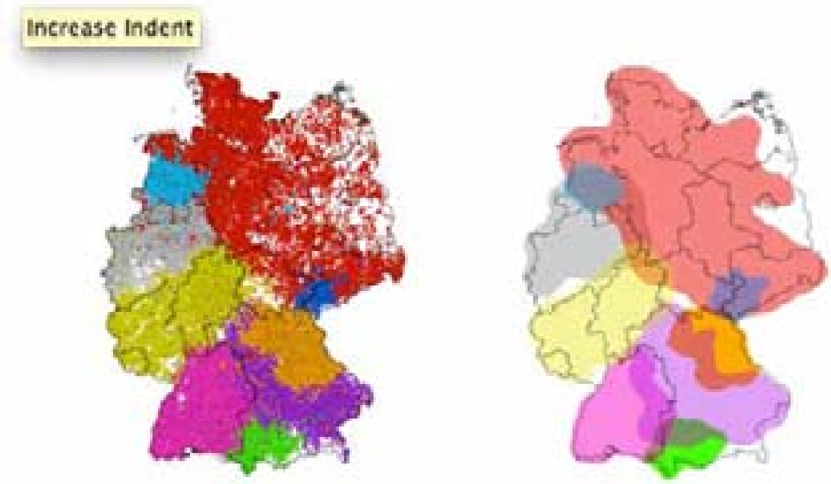

Figure 1: Spatial distribution and overlap of the trade communities. Left: dots represent premises at their approximate locations. The coloring indicates their community membership. Right: regions of spatial overlap.[Lentz et al.,2011]

The World Organisation for Animal Health (OIE) laid down in their Terrestrial Animal Health Code concepts to facilitate trade in animal products and products of animal origin. For implementing the trade in crisis situations the OIE applied the concept of compartmentalisation and zoning. The OIE definitions for these concepts are:

"Compartment means one or more establishments under a common biosecurity management system containing an animal subpopulation with a distinct health status with respect to a specific disease for which required surveillance, control and biosecurity measures have been applied for the purpose of international trade.

Region/Zone means a clear defined part of a country containing an animal subpopulation with a distinct health status with respect to a specific disease for which required surveillance, control and bio-security measures have been applied for the purpose of international trade." [OIE]. At first sight it seemed that modules and compartments as well as cluster and region/zone share common characteristics. In the case of a significant relevance of the modules and clusters with respect to the spread of diseases, it is to prove if the concept of compartments and zones could be transferred to the German national pig trade network. On the supposition that modules and clusters are important in a case of disease outbreak, the premises (nodes) which connect different modules are of high interest. To identify these connectors it is essential in order to hinder disease spread.

Considering closed trade networks the knowledge of relevant premises can be highly relevant in terms of disease control and gives a possibility to review current methods of monitoring and surveillance particularly with respect to the selection of control points. "Monitoring means the intermittent performance and analysis of routine measurements and observations, aimed at detecting changes in the environment or health status of a population. Surveillance means the systematic ongoing collection, collation, and analysis of information related to animal health and the timely dissemination of information to those who need to know so that action can be taken." [OIE] The correct selection of the control points is essential for successful monitoring and surveillance.

In this work we tested two different approaches for the suitability of premises for monitoring and surveillance and evaluate which one is most qualified to identify relevant control points: The identification of control points can be based on random selection or on a risk based selection. To use a risk based approach it is necessary to assess the risk of premises of the pig production chain. The risk of a premise to spread an infectious disease can be associated with easy to collect parameters like trade volume, trade frequency or number of trade partners. Furthermore data on bio-security and health status are assumed to mitigate the risk.

Material and Methods

Data

According to EU directive EC/2000/15 (EUR-Lex, 2000) collection of livestock trade data is compulsory. EU member states are obliged to establish and operate animal movement databases. According to the German Animal Movement Directive (Viehverkehrsverordnung), each pig premise or related enterprise (including stock farms, breeders, fatteners, slaughter houses, traders) must notify the purchase of pigs within a period of seven days. Notification includes the unique identification number of the purchasing and the selling premise, the number of purchased pigs and the date of trade. If pigs are moved from another EU member state to a German premise, the unique identification number of the selling premise is replaced by its country identification number. All data are stored in a database, the Herkunftssicherungs- und Informationssystem für Tiere, HI-Tier. This database is administered by the Bavarian State Ministry for Agriculture and Forestry on behalf of the German Federal states. Data on trade contacts that were recorded for German pig enterprises between 01 June 2006 and 31 December 2008 were used in this analysis. Two premises were considered linked if there was at least one trade contact between them during the study period.

Definitions

Modularity: Modules are subsets of nodes in which are significantly more edges than expected by chance [Newman, 2006, Lentz et al., 2011, 2009].

Loyalty: Values the propagation of infectious diseases between modules. If N is the number of secondary cases causes by an index case, Loyalty (L) relates the number of secondary cases (n) inside that cluster the index case belongs to, to the total number of cases: L = n/N. Loyalty figures range between 0 and 1. A figure of 0 indicates that all secondary infections do not belong to the cluster comprising the index case. In contrast, a figure of 1 indicates that all secondary infections belong to the same cluster as the index case. With respect to the risk of spreading the disease to other modules, so-called Ad hoc-connectors are of high interest.

Loyalty of farms is determined with the help of a computer simulation model. We simulate a disease with an endemic character with a SIS-Model (susceptible-infectious-susceptible - this means that after a premise is infected it could be re-infected). First one premise in a selected cluster is infected at time t=0 and the chronology of contacts to other premises is followed. Cluster containing few premises and with a low spatial extent are chosen in this analysis. In the simulation it is assumed that a trade contact between the infectious farm and a susceptible farm immediately changes the status of the susceptible farm to infectious. All farms remain infectious for 20 simulation days. The simulation propagates the disease until there is no possibility to spread the infection further because there are no more trade contacts. This procedure is repeated for each premise in the chosen cluster. The simulation was done without any control measures preventing the spread of disease. Also notice that this simulation is a worst case approach, because the disease dynamics within farms is not considered here.

Ad hoc-connector: Connectors with a Loyalty of 0.

Risk-based selection: To use a risk based approach it is necessary to perform a risk assessment in order to find critical points in the production chain. In this work we assess the suitability of easy to determine network parameters like trade volume, trade frequency or number of trade partners. These parameters are used to perform a ranking of farms in order to identify premises which are of high relevance for risk based surveillance than others. The assessment is done by simulating an endemic disease using an SI-Model (susceptible-infectious – this means after a premise is infected it remains infectious). The principle of the infection follows the previously described simulation of a disease. But the focus here is on when (time period) the infection reaches one of the chosen control points. The results of the random-based and risk-based selection of critical points will be compared.

Results

Loyalty: First simulations have shown, that for all analyzed cluster secondary infections are mostly trapped within their initial modules, except one (module 53673) which shows the opposite (see figure 2). The reasons for this observation will be analyzed in further studies. In this case the high proportion of premises with a Loyalty of 0 is very interesting and these premises play an important role as Ad hoc-connectors between modules of the pig trade network.

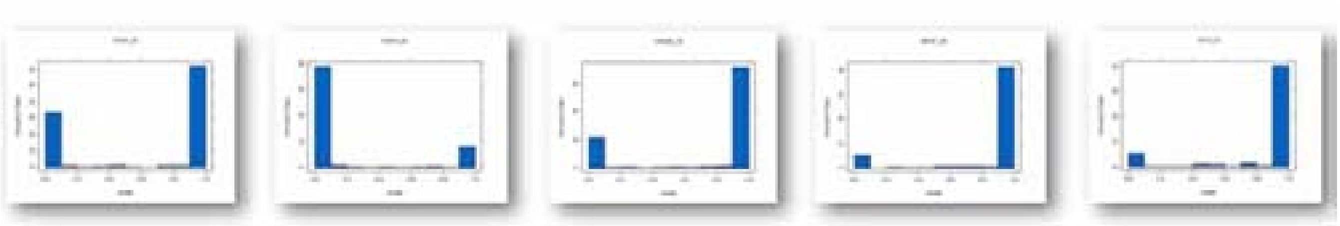

Figure 2: distribution of loyalty of the 5 chosen cluster. The number of farms within cluster decreaes from the left to the right figure. (from left to right: cluster ID 37424, 53673, 10456, 88797, 5574. The cluster Idsare arbitrarily chosen.)

Selection of critical control points: Furthermore the risk-based and random-based selections of control points were investigated. Here simulations have shown that surveillance on risk-based chosen points can detect a contamination or disease up to two months earlier than surveillance on randomly chosen control points. With the help of these methods useful tools for crisis intervention as well as prevention and surveillance can be developed. In terms of prevalence this can make the detection up to one hundred times faster.

Discussion

The first simulation provides information on the usefulness of the identified cluster and modules concerning the spread of disease. On the basis of the results, the modules may represent a starting point for the application of the principles of the OIE guidelines for compartmentalization for national trade.

Trade structure represents trade connections of premises in the pig production chain. These relationships are determined by management-decisions, which are made in respect to optimization of production processes. For this reason we presume that the creation of modules and clusters are determined by the influence of the production management. This assumption is supported by the results of the simulations to determine the Loyalty, because in most simulations the infections remained within the primary infected cluster. In order to implement the concept of compartmentalization, a module has to include the entire production chain. As the Loyalty is particularly high in small clusters, we assume the entire chain still exists in the modules and clusters. In addition to these finding, the detection of the Ad hoc-connectors is of a high relevance.

Nevertheless, it has to be noted that the Loyalty gives no information about the quantity of the secondary infections. Further analysis will be done in order to assess farms according to the number of secondary cases.

The second focus of this work is the assessment of a risk-based selection of control points. The simulation showed that with the use of this approach the detection time of a disease could decreased significantly in comparison to a random-based selection. Although it has been assumed that a perfect test is used, the simulation results enable to review existing control and prevention strategies.

Conclusion

Through simulations it could be shown that modular structures in the German trade network could be utilized to prevent a widespread propagation of a disease. The results of Loyalty support the thoughts of a combination of the OIE- compartmentalization and zoning with the module and cluster concept. In addition so-called Ad hoc-connectors with a Loyalty of 0 could be identified. The importance of these connectors has to be analyzed in further analysis. Furthermore, it was shown that a risk-based selection of control points in the trade network reduced the detection period of a disease significantly in comparison to a random-based selection. This work provides new approaches to review and possibly optimizing existing disease prevention and control strategies.

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