



Combined application of social network and cluster detection analyses for temporal-spatial characterization of animal movements in Salamanca, Spain[☆]

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ABSTRACT

Social network analysis was used in combination with techniques for detection of temporal-spatial clusters to identify operations at high risk of receiving or dispatching pigs, from January through December 2005, in the Spanish province of Salamanca. The temporal-spatial structure of the network was explicitly analyzed to estimate the statistical significance of observed clusters. Significant ($P < 0.01$) temporal-spatial clusters identified were grouped into two compartments based on the nature and extent of the contacts among operations within the clusters. One of the compartments was identified from January through April, included a high proportion of extensive farms (0.39), and was likely to be related with the production and trade of Iberian pigs. The other compartment encompassed a smaller proportion of extensive farms (0.11: $P < 0.01$), took place from May through December, and was probably related to intensive production systems. Analysis of a sub-section of the network, which was selected based on the administrative division of Spain, yielded to the identification of a different set of clusters, showing that results of social network analysis may be sensitive to the extension of the information used in the analysis. The approach presented here will be useful for the implementation of differential surveillance, prevention, and control strategies at specific times and locations, which will aid in the optimization of human and financial resources.

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1. Introduction

Identification of groups or clusters of individuals or populations at high risk for the introduction and spread of animal diseases is a fundamental objective of veterinary epidemiology. The Office International des Epizooties (OIE) has recommended the identification and characterization of groups of herds at risk for a particular animal disease as a means to limit the economic and social impact of animal disease epidemics. The rationale behind this recommen-

dation is that clusters of herds at high risk may be selectively targeted as part of an active surveillance program, optimizing the use of human and financial resources, and increasing the probability of early detection and control of epidemics.

The two OIE-recommended strategies for the identification and characterization of risk are referred to as zoning and compartmentalization (OIE, 2006). Zoning refers to the geographical delimitation of regions where herds are considered to be at similar risk for the disease based on the presence or absence of factors that promote or prevent the occurrence of the disease. Argentina, Brazil, Bolivia, and Colombia are examples of the countries that have utilized a zoning approach to delimit geographical areas and to apply differential strategies for the control of foot-and-mouth

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disease (OIE, 2007). Compartmentalization refers to the delimitation of groups of herds based on the nature and frequency of contacts among herds. The compartmentalization approach has been used in the implementation of control programs for Aujeszky disease in Spain (MAPA, 2007) and paratuberculosis in the United States (USDA, 2006), in which introduction of susceptible animals into an operation is permitted only if the animals originate from a herd at a similar or lower level of risk for the disease. The analytical techniques utilized by the compartmentalization and zoning approaches are different. Some have suggested that techniques for the localization of spatial clusters of high risk of disease, such as the spatial scan statistic, may be applied to a zoning approach for the implementation of differential control and surveillance strategies (Abrial et al., 2003; Perez et al., 2002, 2005; Guerin et al., 2005; Sheridan et al., 2005). Social network analysis (SNA) has been used for the identification and characterization of contacts among herds, and it has been suggested that these networks of contacts may be useful in the implementation of control and prevention policies that resemble the application of compartmentalization strategies (Christley et al., 2005; Bigras-Poulin et al., 2006; Kiss et al., 2006; Ortiz-Pelaez et al., 2006; Robinson and Christley, 2007).

Although the use of either zoning or compartmentalization to identify clusters of herds has functioned in the design and implementation of some animal disease control and surveillance programs, the integrated application of both approaches, rather than separately or independently from each other, is likely to result in a more refined characterization of the risk. Application of cluster analysis techniques without taking into account the number and frequency of shipments among herds can be misleading because herds located within a geographical area perceived to be at low risk for a disease may receive frequent shipments from herds located outside the low risk area and, for that reason, could be at a higher risk compared with other herds in the region. Conversely, social network analysis techniques that overlook the geographical distances between herds may underestimate the risk associated with local spread of disease, including for example, vector- and air-borne spread of the agent. Moreover, classification of herds and regions is likely to be influenced by the temporal variation of factors associated with the risk for a disease. For example, the seasons for mating, breeding, and calving differ among regions. Thus, the risk for animal shipments associated with management practices will also vary spatially and temporally. One would expect that over the course of a year, certain regions would alternatively be at higher and lower risk for animal disease introduction and spread compared with the background risk of the country.

The objective of this publication was to present a methodological approach for the characterization of risk related with animal shipments that combines elements of SNA and techniques for the detection of temporal-spatial clusters. The approach was used to identify temporal-spatial clusters of agricultural operations at high risk for the introduction and spread of diseases via shipment of live pigs in the Spanish province of Salamanca. To the best

of our knowledge, this contribution is also the first application of social network analysis for the characterization of pig shipments that has been published in the peer reviewed literature.

2. Materials and methods

2.1. General approach

The first section of the paper describes and illustrates the combined application of social network analysis and techniques for the detection of temporal-spatial clusters to the characterization of agricultural operations at high risk for pig shipments in Salamanca. The second section of the manuscript assesses the potential impact that the use of an incomplete dataset may have had in the results of the analysis.

2.2. Identification of temporal-spatial clusters of agricultural operations at high risk for pig shipments in Salamanca

2.2.1. Data source

Salamanca is a province located in the Spanish region of Castilla y Leon and is next to the border with Portugal (Fig. 1). The pig population of Salamanca represents 2.4% of the total number of pigs in Spain and 7.6% of the population of a local breed referred to as Iberian pigs. Iberian pigs are typically raised on extensive farms, whereas raising other breeds involves the development of more intensive farming and production systems. Conditions required for the designation of an extensive or intensive production system have been established by the Spanish legislation (Real Decreto 324/2000). Intensive and extensive production systems represent 70.4% and 29.6% of the pig farms in Salamanca, respectively. Information on the number of shipped pigs, the date of shipment, and the identification and geographical location of the agricultural operations of origin and destination of all pigs shipped from and to agricultural operations in Salamanca from January 1st through December 31st, 2005 was provided by the Castilla y Leon regional government. Agricultural operations in Salamanca are routinely georeferenced as polygons by the regional veterinary service by using a Global Positioning System (GPS). Here, the centroid of the polygon was used to represent the geographical location of the operation. An animal shipment was defined as a group of animals dispatched simultaneously from one operation to another. Those operations with incoming shipments were said to “receive” pigs, whereas those operation with outgoing shipments were said to “dispatch” pigs. Reporting of livestock shipments is mandatory in Spain, and for that reason the information collected in the database likely represents an accurate estimate of the true value of the parameters analyzed. Agricultural operations engaged in the production or trade of pigs in Salamanca, including farms, slaughterhouses, and markets, have been referred to as *operations* throughout this document. Because the province and the largest city in the province share the same name, here we refer to the city of Salamanca as C. Salamanca, to differentiate it from the province, which is simply referred to as Salamanca.

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