# Analysis of cattle movements in France Characterizing the role of the markets and dealers

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## Introduction

Animals moving between farms either directly or through merchants (markets and dealers) function as direct contacts between herds and represent the main transmission risk for any infectious disease. Since 2001, France, like most countries in European Union, has considerably enhanced animal traceability, particularly in cattle. Routine recording procedures supply rich data sets for epidemiological studies. Social network analysis (SNA) allows to characterize these contact structures. SNA is based on the study of the relationships among social entities, and on the patterns and implications of these relationships (Wasserman and Faust, 1994). We investigated the network of cattle movements in France using this method, in order to identify features that could have implications for disease spread.

## Materials & Methods

### Source data

Cattle movements data were obtained from the National Bovine Database of Identification (BDNI) which is managed by the Ministry of Agriculture. Each record indicates the date of the movement, the unique identification code of the animal, and the codes of the origin and destination holdings. We used a subset of this database, containing individual cattle movements recorded in 2005 (before movements limitations due to bluetongue epizootic).

### Network analysis

Each of the holding (farm, market, dealer) was considered as a node and each movement of animals between two holdings was considered as an arc. This network was calculated for each month of 2005 (12 monthly networks) and for the whole year (1 global network). The analysis was focused on the "giant strong components" (GSCs), whose nature and extend was analyzed. Strong components are sections of the network where every node can be reached from every other node via directed path(s). The GSC is a very large strong component that emerges in many networks.

The GSC was first computed for the global network. The main centrality measures (degree centrality, betweenness centrality and closeness centrality) were calculated for every holding type.

The GSCs of the monthly networks were then analyzed to characterize their sizes, spatial extension and structure. The role of markets and dealers in GSCs emergence was evaluated by recalculating the GSCs after having replaced indirect animal movements (involving a market or a dealer) by direct movements (from farm to farm).

Network analyses were performed using the Pajek Programme for Large Network Analysis (v1.25).

## Results – Part I

### Giant Strong Component (GSC) of the global network

- The network of cattle movements for the year 2005 was composed of 244 097 nodes and 1 416 208 arcs. A giant strong component with 108 904 nodes and 804 331 arcs emerged. Other strong components were also observed in the network (n=1 259) but of much smaller sizes (2 to 9 nodes).

- Markets and dealers had always the highest centrality measures (fig1). These measures characterize their central position and their reachability. The 'degree centrality' is the number of nodes directly connected to a given node. The 'betweeness centrality' is the proportion of geodesics (shortest paths) between pairs of nodes in which a given node appears. The 'closeness centrality' is the number of nodes in the GSC, divided by the sum of distances between a given node and all the others.

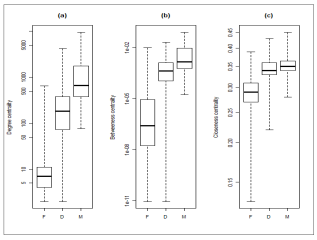


**Fig 1** Centrality measure distribution in the GSC of the global network : (a) 'degree centrality', (b) 'betweeness centrality', (c) 'closeness centrality' by type of holdings : F=Farms ,D=Dealers, M=Markets

## Results – Part II

### GSCs of the monthly networks

- Each month, a giant strong component was observed (fig 2). Its mean size was of 10 277 holdings, connected by 39 592 arcs. A seasonal effect was observed with spring and autumn peaks.

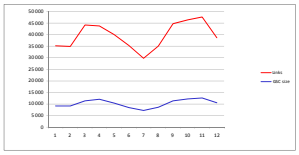

**Fig 2.** GSC size distribution

- The GSCs of the monthly networks were widely distributed in the country (fig 3).
- Geodesics ranged from 1 to 16 arcs. The average shortest path was 4.6. In brief, holdings were linked in average by less of 5 animal movements (through 4 holdings).

The mean of clustering coefficient was 0.25. In comparison with equivalent random networks (having the same number of nodes and arcs), monthly GSCs were characterized by a shorter average path length and by a higher clustering coefficient. Thus, GSCs can be considered to have "small world" properties.

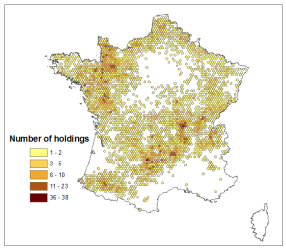


**Fig 3.** Cattle holdings distribution in the giant strong component of January 2005 - 9193 holdings.

- Among 56 809 holdings involved in any of the 12 monthly GSCs, 932 appeared every month. These holdings were mostly dealers and markets (fig 4).

### Role of the markets and dealers

- Ninety seven percent of the dealers and 100% of the markets were involved in the GSC for at least one month. Forty two percent of the dealers and 64% of the markets appeared in the twelve GSCs. This particular involvement of merchants suggests that they have a strong cohesive role for the emergence of GSCs.

- GSCs disappeared from monthly networks only when all indirect animals movements (markets and dealers) had been replaced by direct (farm to farm) movements. Only small and local strong components were obtained, with about 10 holdings (fig 5). GSCs were observed in each monthly network when only indirect movements involving markets (or, alternatively, dealers) were removed.


**Fig 4 .** Detailed holdings which appeared every month – 932 holdings.

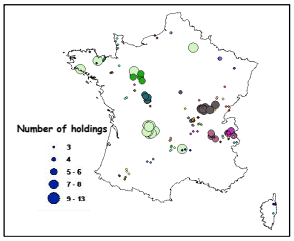


**Fig 5** Cattle holdings distribution in strong components with > 2 holdings – with only direct movements farm to farm - January 2005 - 46 groups of components represented by color - 165 holdings.

## Conclusion and Perspectives

- The 'giant strong component' is considered as a risk structure for disease spread. A GSC was observed every month, the nodes of which were spread all over the country.
- Markets and dealers have a similar connectedness role within GSCs. Their removal leads to GSCs disappearance.
- The same study conducted for weekly period demonstrates the same trends. A GSC emerges in every weekly network, having wide geographic range. Markets and dealers are largely involved in these GSCs.
- These studies demonstrate the vulnerably of the holding network structure to the spread of infectious diseases. They suggest disease control recommendations targeted to markets and dealers. Specific sensitization and preventive disease measures should be dedicated to this population.

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