FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Social network analysis (SNA) in animal health

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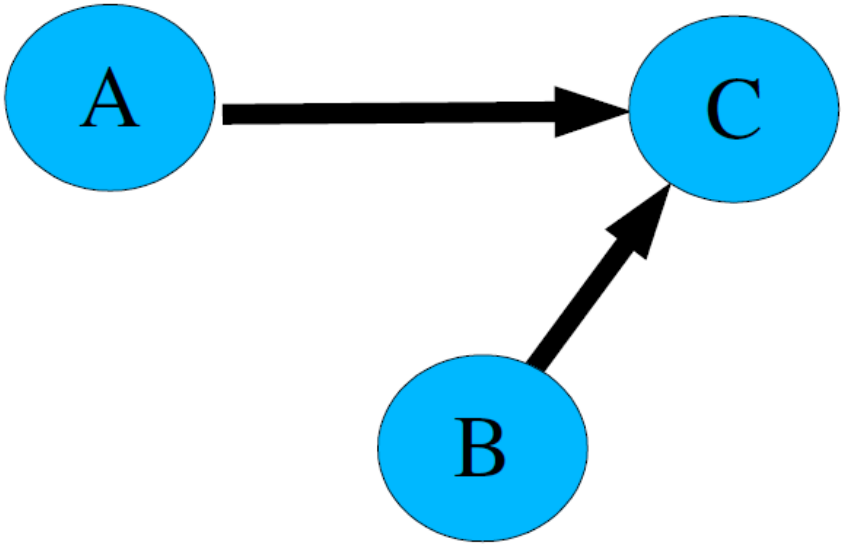
Outline

- What are networks?
- What is Social Network Analysis (SNA)?
- Network data representation
- Network vs traditional data analysis
- Study design and data collection
- Analyses types
- Categories of uses in animal and public health
- Examples of SNA

What are networks?

- Refers to a group of elements (*"nodes"*) and connections ("links") between them:
  - Nodes: regions, farms, markets, country
  - Links: "trades with" , "makes contact with", collaborates with …,



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What is SNA?

- A set of tools used to analyze the role of nodes and groups within a network:
  - Identify important nodes in a network (e.g. hubs or receivers, sinks)
  - Identify network super spreaders (important components)
  - Structure of networks(types)
- Increasingly being used in animal health to:
  - Target surveillance for animal diseases (e.g. indegree, betweenness)
  - Predict disease spread (network structure)
  - Risk factor analyses – relate node –level parameters with disease occurrence

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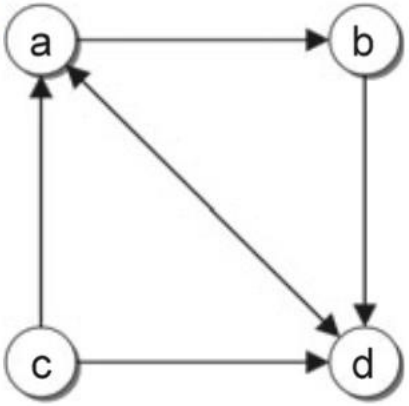
Network data representation

(a) G = {(a, b), (a, d), (b, d), (c, a), (c, d), (d, a)}

Mathematical notation

(b)



Diagram

(c)

	a	b	c	d
a	0	1	0	1
b	0	0	0	1
c	1	0	0	1
d	1	0	0	0

Matrix

Fig. 1. Use of notation (a) a graph (b) and an adjacency matrix (c) to represent a directed social network with four nodes and six contacts.

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Networks vs traditional analysis

- Concerned with attributes of individuals:
  - the age, breed, sex, disease status (etc) of an animal
  - the type, location, population, area, biosecurity practices (etc) of a farm
  - Relationship between feed and weight ..

- Concerned with relationships between pairs of individuals:
  - the “amount” of interaction between animals,
  - the distance between farms
  - the movement of animals between farms
  - ….

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Study design - data collection

- Census – "Complete or bounded":
  - A complete list of the members of a network is needed before data collection can start
  - Valid when boundaries are clear (e.g. pig farms – an official register exists)
- Snowballing or respondent driven sampling:
  - Begin with an initial list of network members (e.g. farmers identified by a veterinary supply shop) - these are then asked to nominate others – this is continued until…
  - After several waves, names are repeated..

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Data analysis for networks

- Network visualization
- Network description

Data analyses – Network visualization

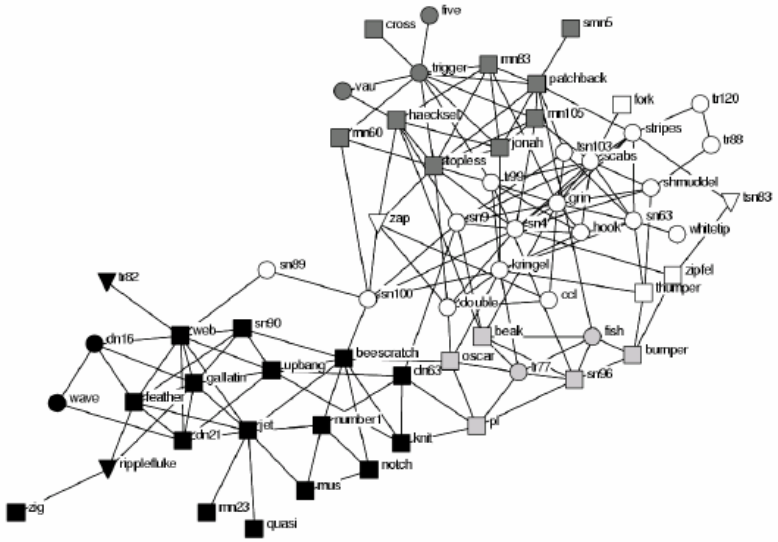
- A major aspect of network analyses
- Presentation of network information in graphic format
- Allows us to ask and answer questions that may not be statistically obvious

Chains of Affection: The Structure of Adolescent Romantic and Sexual Networks[1]

Peter S. Bearman
Columbia University

James Moody
Ohio State University

Katherine Stovel
University of Washington



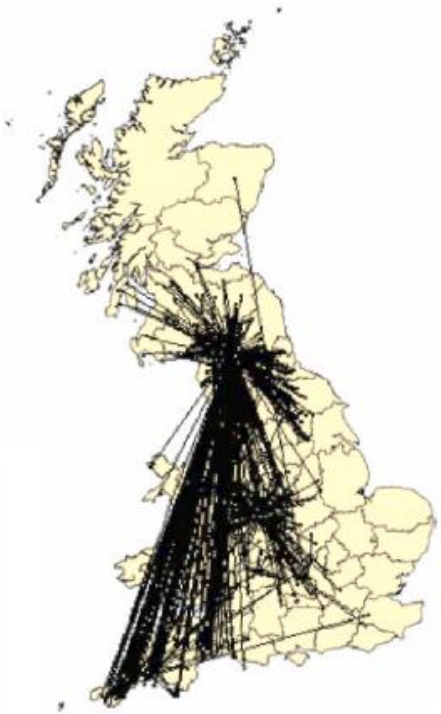


Fig. 2. Visualisation of the network.

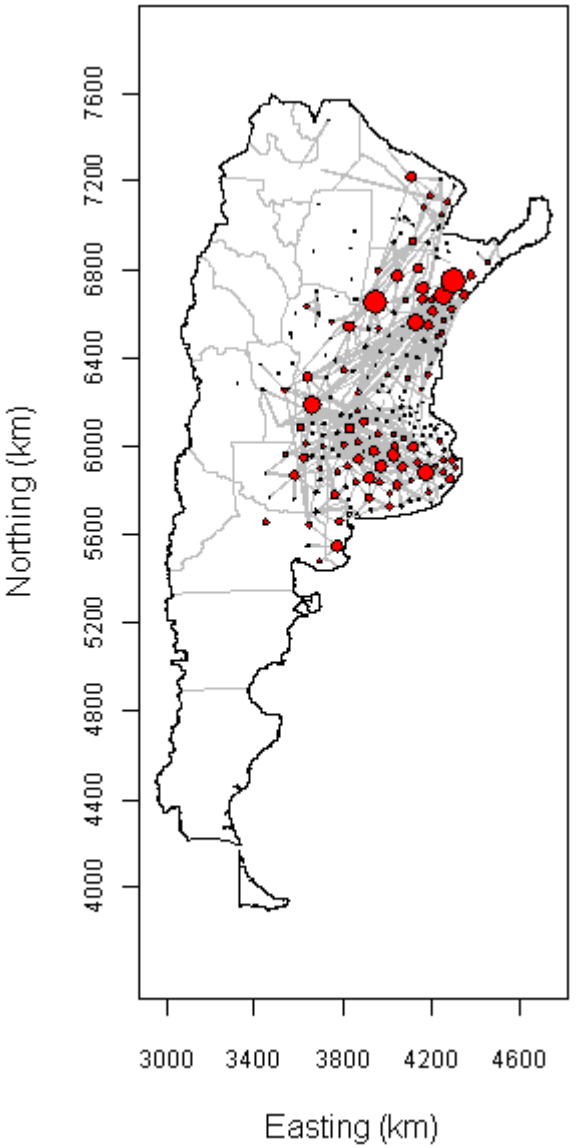


Figure 1 Communities and sub-communities identified in the dolphin social network using the betweenness-based algorithm of Girvan and Newman (2002). Vertex colour indicates community membership: black and non-black vertices represent the principle division into two communities. Shades of grey represent sub-communities. Females are represented with circles, males with squares and individuals with unknown gender with triangles.

Data analyses – Network description

Level	Definition and purpose		Standard network measures
Individual	A single actor or node	Degree	Connectivity of a given actor or node given by the number of lines that are incident (connected) to the node
	Identification of the position or location and characteristics of an actor within a network	Centrality	Importance or prominence of a given actor or node Following are several types of centrality: Betweenness: extent to which an actor lies between two nodes that would not otherwise be connected Closeness: how close an actor is to all other actors on the basis of distance between nodes Degree: extent to which an actor is connected to others; the simplest of the centrality measures Prestige: specifically for directed networks; extent to which other members choose a given actor or node
		Structural equivalence	Extent to which actors play similar roles within a network by having the same patterns of connections to other actors
Subgraph	A subset of the graph based on certain nodes or links	Dyad	A pair of actors and the possible tie between them
		Triad	Three actors and the ties between them
	Examination of characteristics of a group	k-core	All nodes in a network with degree $\geq k$
		Clique	Three or more actors connected by all possible connections
Network	The entire system of nodes and links	Density	Ratio of observed ties to possible ties
		Diameter	Longest of all geodesics (shortest path between two nodes)
	Description or inference based on the structure of the entire network	Centralization	Extent to which the graph shows a hierarchical or centralized structure

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Use of SNA in public and animal health

- Three main categories (Luke and Harris, 2007):
  - Transmission networks:
    - Most commonly used
    - Focus is on what flows between actors
      - Disease transmission networks
      - Information transmission networks
  - Social networks
    - Focus is on how social structure and relationships act to promote or influence health or health behavior
  - Organizational networks
    - Networks comprising agencies as opposed to individuals
      - Business and political science – recent use in public health

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Contact structure of the New Zealand poultry industry: A social network analysis

- Background
  - The entry and establishment of infectious diseases (e.g. HPAI) would have severe consequences for the New Zealand poultry industry
  - Identifying weak points where disease might enter and establish is important because it provides focus for border control efforts and disease surveillance activities
  - Knowledge of the means by which infectious disease might disperse from an entry point is useful because eliminating routes of transmission will help reduce the number of enterprises affected

Objectives

- Describe the network of contacts within the New Zealand poultry industry related to movement of feed, live birds and hatching eggs, table eggs and products, manure and litter
- Identify patterns in these movements
- Better understand the potential for farm-to-farm transmission of disease mediated through movement

Materials and methods

- Study population
  - 420 poultry industry members recorded in the PIANZ database in August 2007
- Questionnaire administered by mail (in conjunction with industry personnel)
- Information requested:
  - general enterprise data
  - movement details related to:
    - feed, live birds and hatching eggs, table eggs and poultry product, and manure and litter

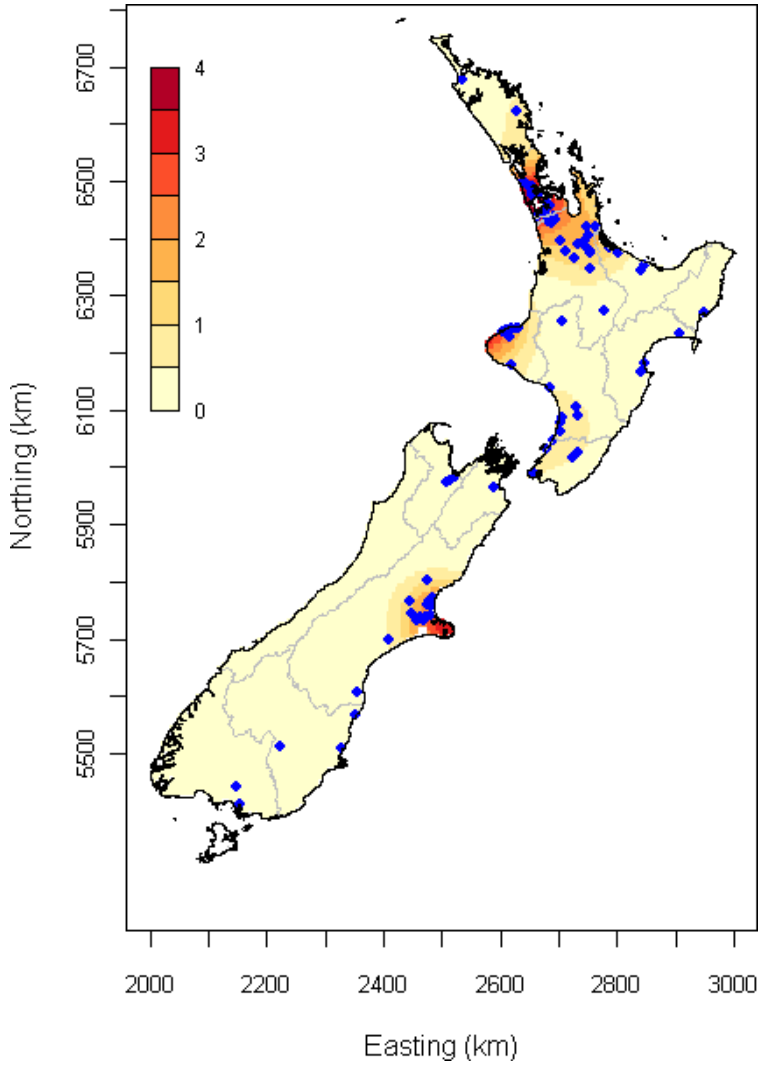
Materials and methods

- Movement data
  - identity of enterprise or town location of the enterprise(s) they had contact with
  - contact type (feed, live birds etc)
  - frequency of contact
  - quantity of material moved (if any)
  - how the frequency of these contacts varied over the previous 12 months

Results

- The response rate was 58% (244 of 420)
  - relatively good, given the size and complexity of the information requested
  - responses uniformly distributed by farm type and region
  - because networks incomplete, inferences drawn from relative (rather than absolute) comparisons of the four network types

Map showing the location of survey respondents(.) superimposed on a density plot of enterprises listed in the PIANZ database



Counts of poultry industry participants stratified by response and production type

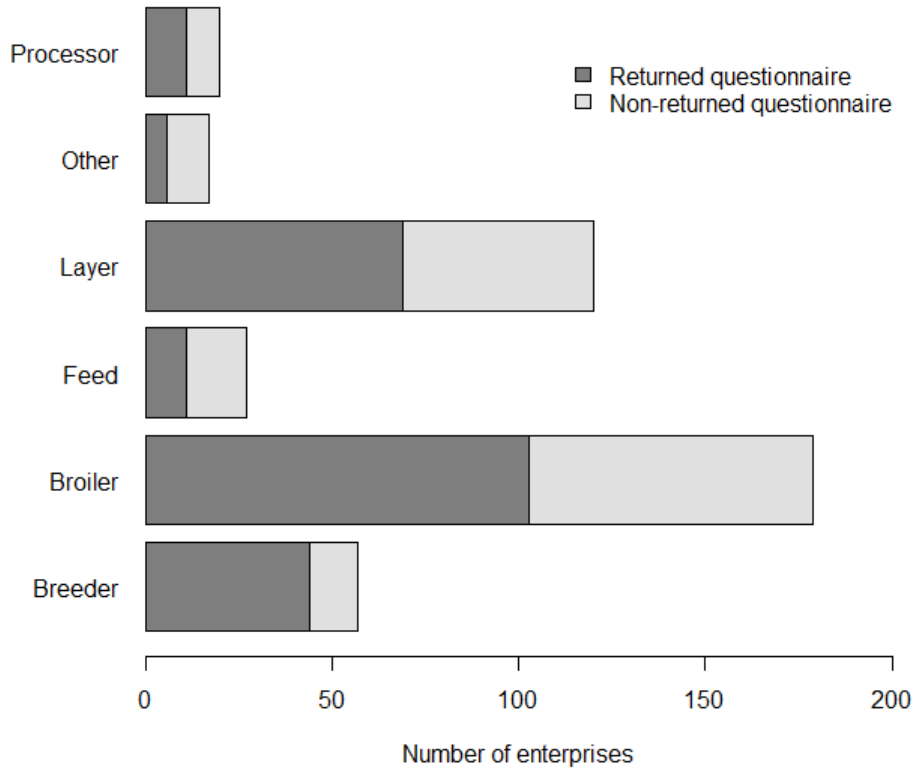
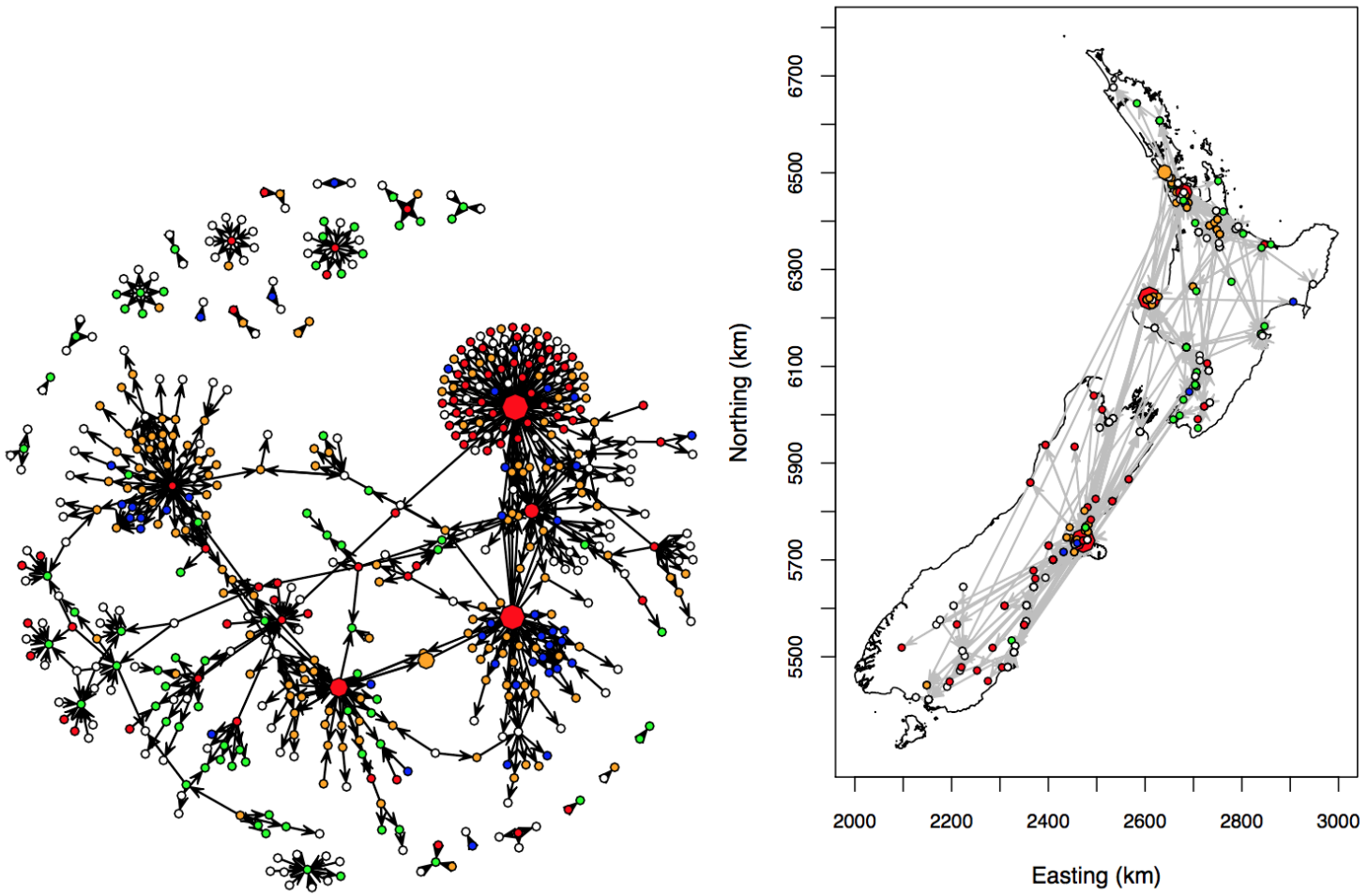


Figure: Social network study of movement patterns: (a) graph of feed-related contacts, (b) map of the actual location of enterprises that reported feed-related contacts. Key: feed producers (•), breeders and hatcheries (•), layer farms (•), broiler and other poultry farms (•), other enterprise types (○).



Conclusions

- Knowledge of network characteristics provides opportunity to tailor surveillance and disease control strategies
- For example, if dioxin were to contaminate poultry feed
  - target feed distributors and;
  - non-feed distributor enterprises identified as bridges within the network
- Two broad categories of network type:
  - Hub and spoke networks - feed, live birds and hatching eggs, table eggs and poultry product target feed distributors and;
  - Fragmented networks - manure and waste litter

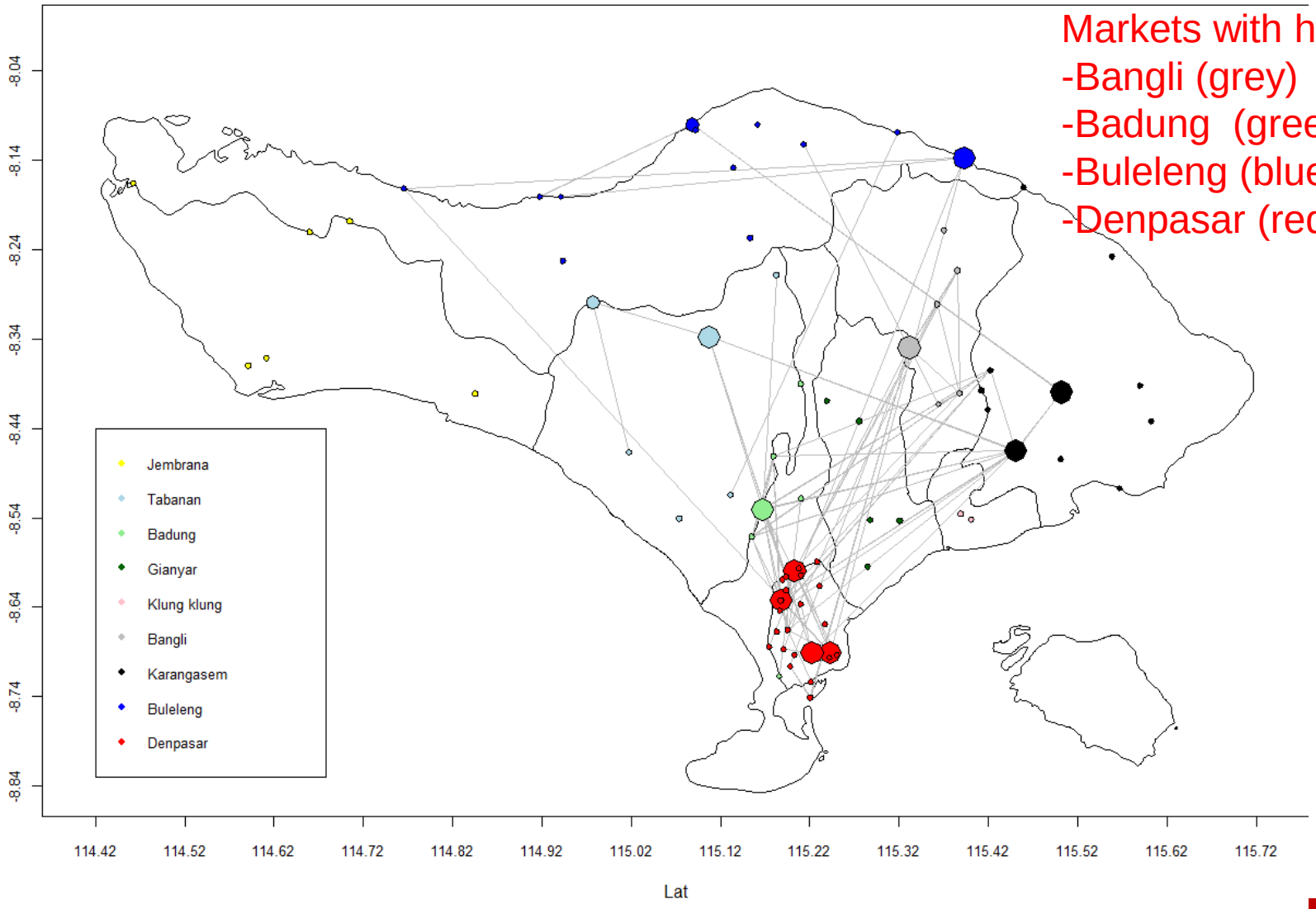
Conclusions

- In all networks there were relatively small numbers of enterprises which had large numbers of contacts
- Potential for these to act as superspreaders of disease
- These enterprises (which are not always farms) should be targeted for surveillance

Bali: SNA in live bird markets (September 2010)

- Objectives:
  - To describe the structure of contact within the live bird market system in Bali
  - To identify important sources and destinations locations of live birds
  - To identify areas at higher risk of HPAI incursion/transmission based on movement of live birds via the poultry market chain
- Study design
  - Cross sectional survey
  - Units - Live bird markets (86 markets)
  - Questionnaire – Vendors, drivers, market authorities

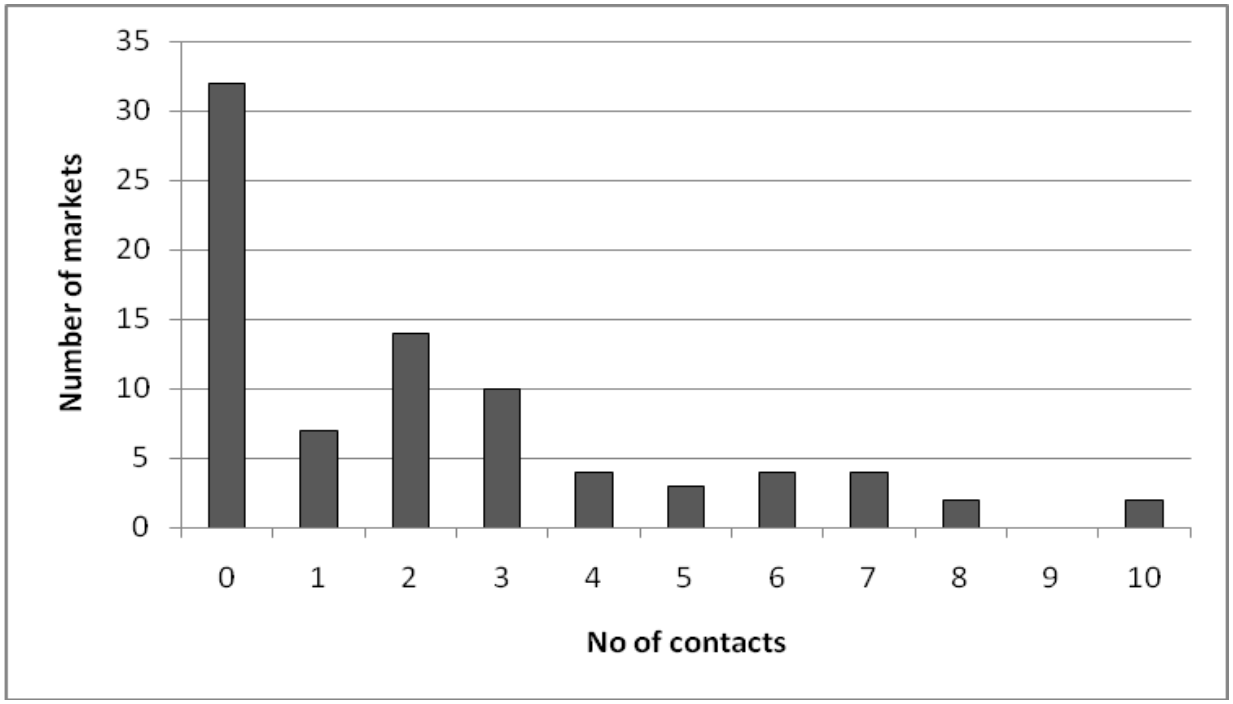
Network structure showing the contacts made between markets (circles) as a result of live bird movements during the last week of trading. The lines show contacts between markets. The size of the nodes are proportional to the node betweenness which is an indication the amount of flow controlled by a node(market).



Does the market network have scale free properties?

Scale-free network:

- the degree distribution of the observed network is skewed (large numbers of nodes have few contacts, smaller numbers have many contacts (so-called 'superspreaders').
- Effective disease control strategies can be applied in scale-free networks if they focus on highly connected nodes

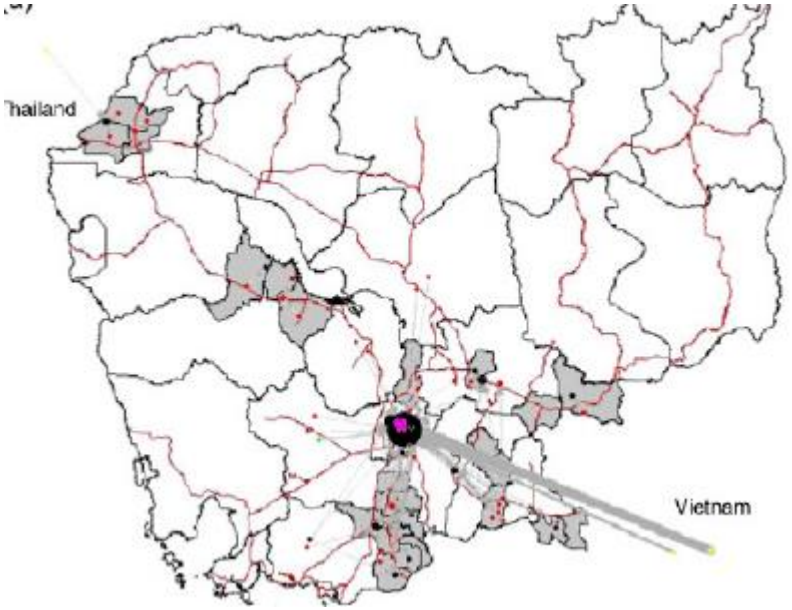


Cambodia: Poultry movement networks

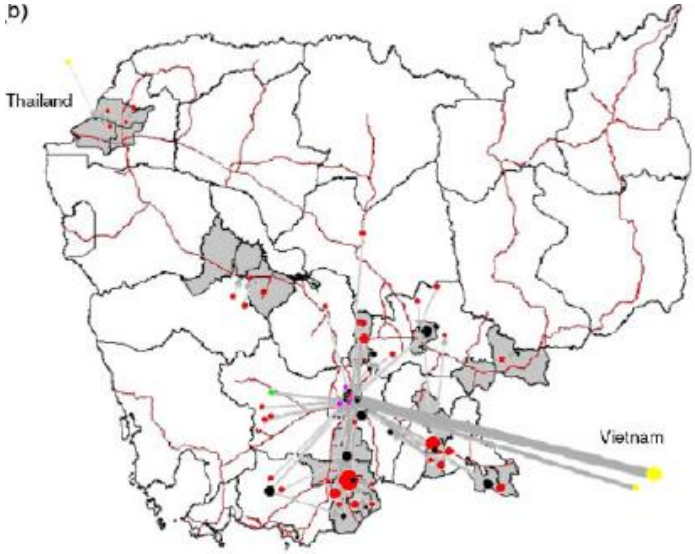
- Objectives:
  - To describe patterns of live birds movements in South Cambodia
  - To determine how these movements influence potential spread of HPAI locally, nationally and regionally
- Conclusions
  - Live bird movements highly connected and centralized
  - Live bird markets, namely wet markets in Phnom Penh, where live poultry are slaughtered at the market, are ideal for surveillance and control

Cambodia: Poultry movement networks (Ducks)

Node size – In-degree



Node size – Out-degree



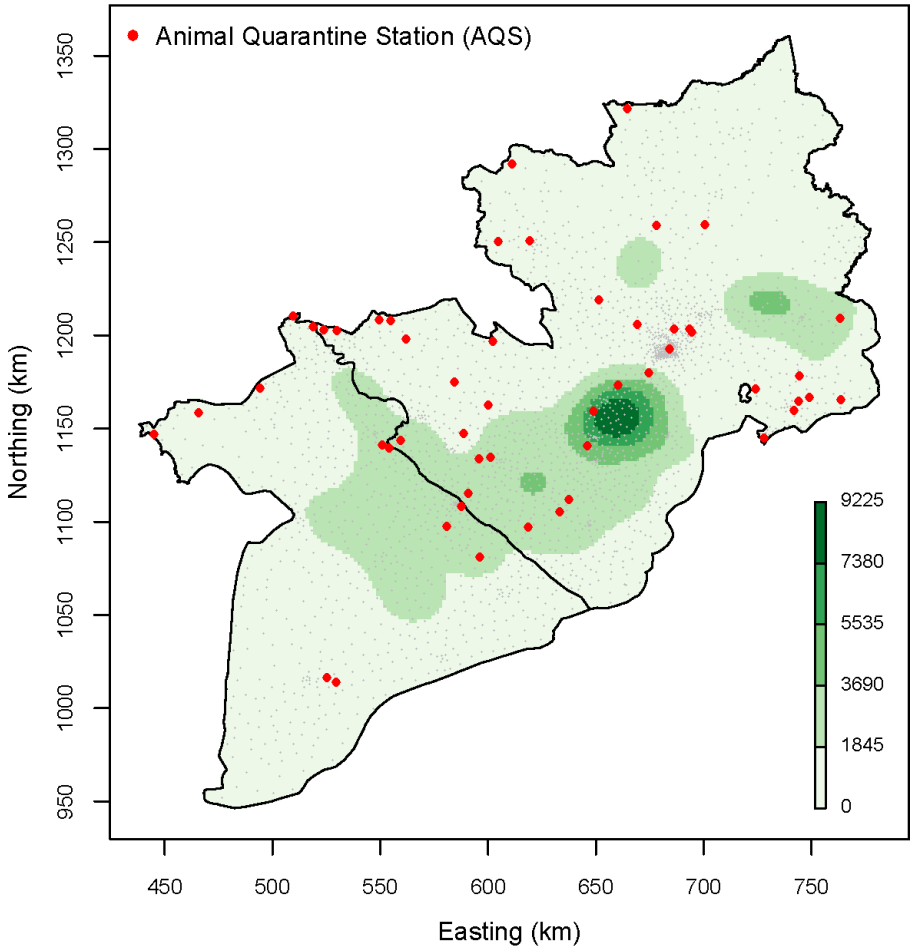
Kerkhove et al, 2009

Location type:
Markets – Black; Stockhouse – purple
Rural farm or household- red; Commercial farm – light green
Semi-commercial – grey; Foreign source - yellow

Viet Nam- patterns of poultry movement

- Objectives
  - To gather information on poultry movements between communes and reasons for movements in South Viet Nam
- Study design
  - Cross-sectional survey
    - Quarantine stations (n = 52) in provinces (n = 19)
    - September 2009 – July 2010
- Results:
  - >26,000 commune to commune movements involving 21 million poultry
  - Movements originated from 34% of communes within the study area

Movement of poultry in South Viet Nam



Reasons for moving:

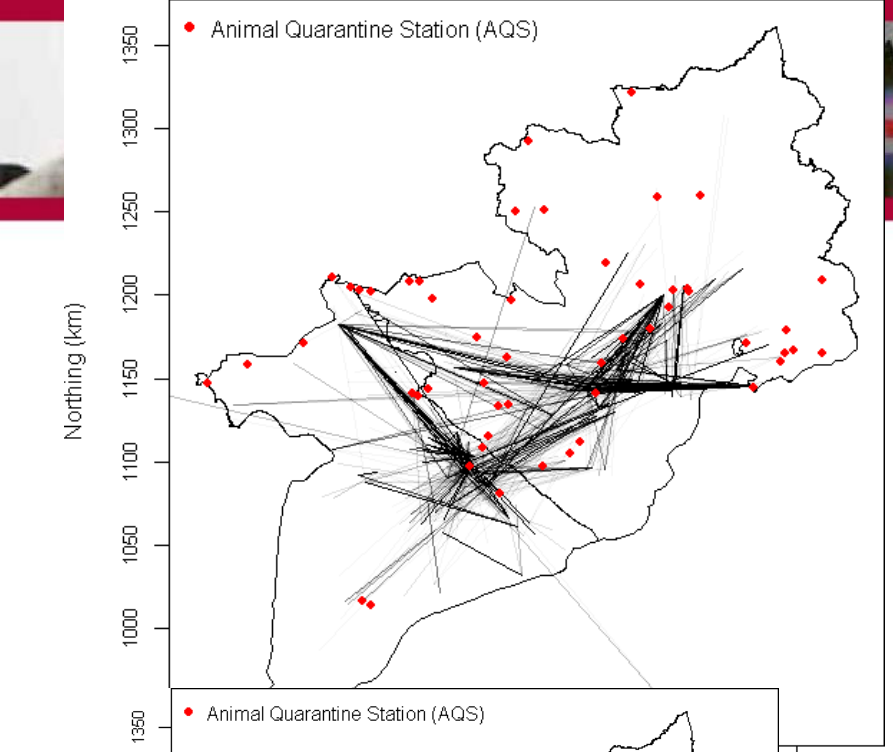
-Shift birds to alternative places for grazing (46%)

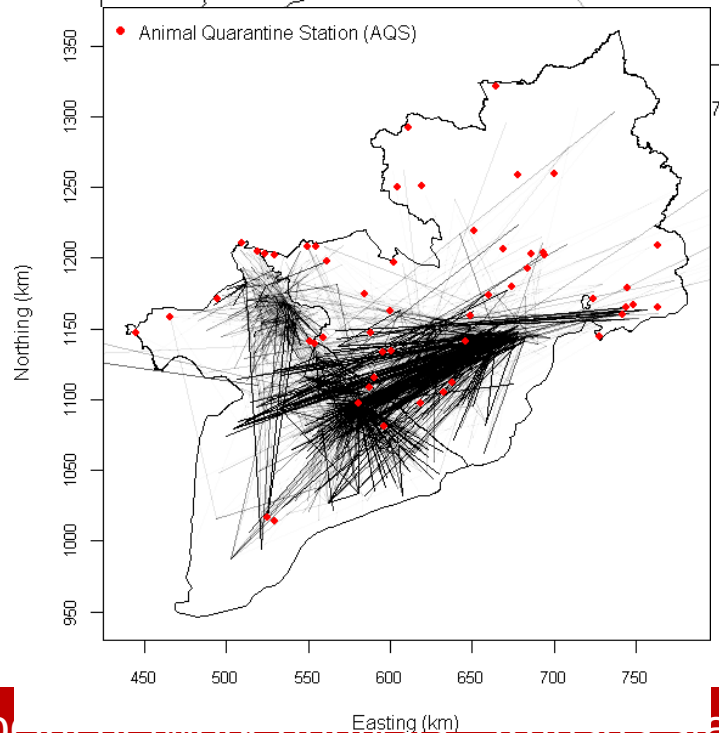
-Movements to live bird markets (35%),

-Slaughterhouses (16%)

-Other reasons (3%)

Long et al, 2013



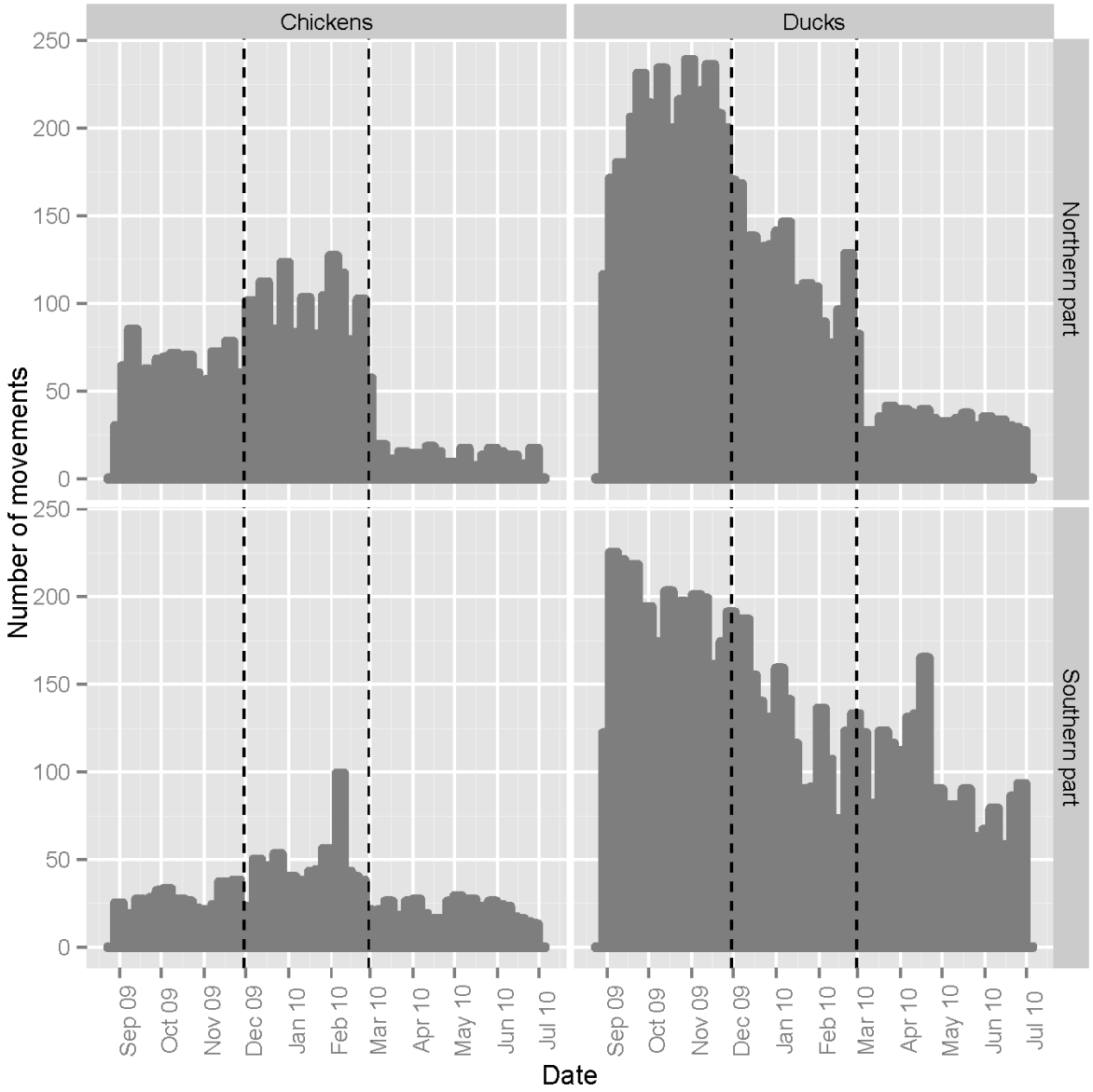


- Poultry more likely to be moved between communes with provincial roads

- Communes with large numbers of people were less likely to be connected by poultry movement events

- Highly connected communes should be targeted for disease control and surveillance

Movement of poultry in South Viet Nam:



Higher volumes of ducks moved vs chicken (6 x)

Different patterns:

- Ducks (Sept – Nov)
- Chickens (Dec - Feb)

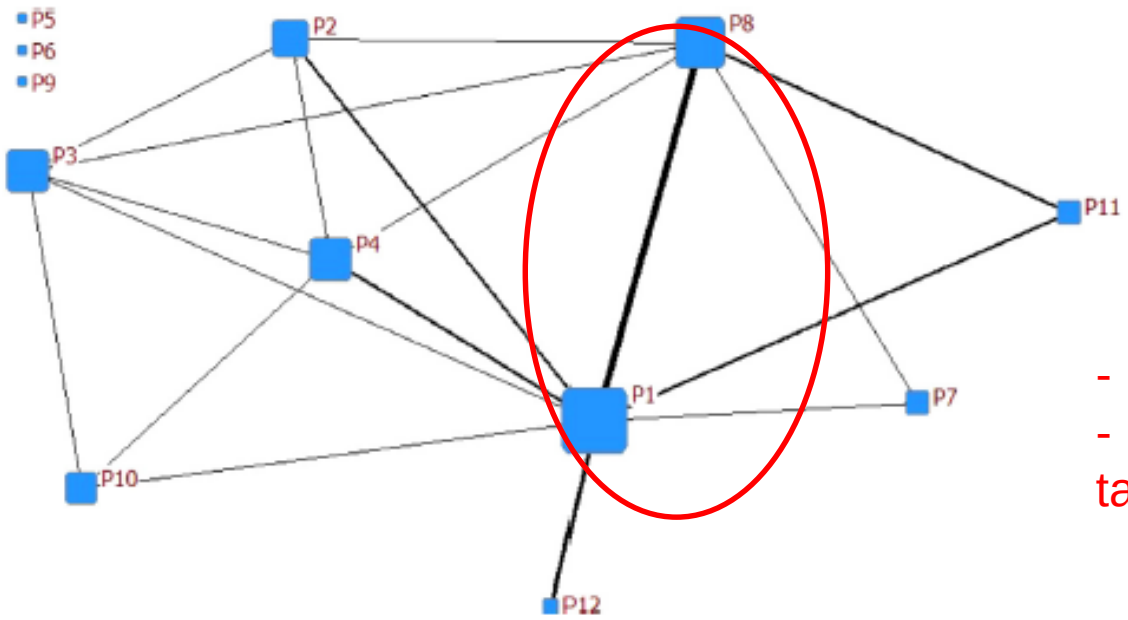
Higher volumes of ducks moved vs chicken (6 x)

Long et al, 2013

Thailand – Backyard chickens(Jan – Dec 2009)

- Objectives:
  - To understand movement and trading patterns within the backyard farming system in Ratchaburi province – an area considered ‘high risk’ for HPAI H5N1
  - Quantify elements likely to be involved in disease transmission and implications for disease control
- Study design:
  - Cross-sectional survey – snowball
  - Units- villages (19)
  - questionnaires

Thailand: Ego- networks of ties among backyard chicken members



Most central nodes :
- Chicken owner houses
- Fresh markets

- Most likely affected by disease –
- Disease control measures to be targeted

Poolkhet et al, 2013

- Questions?

- Thank you!