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Poultry Movement Networks in Cambodia

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Key Findings

- Live poultry movement in Southern Cambodia is unidirectional, highly connected and highly centralized.
- Live bird markets, namely wet markets in Phnom Penh, where live poultry are slaughtered at the market, are ideal for surveillance and control.
- Gravity models can be fitted to predict poultry movement, and hence are appropriate to use in spatial transmission models for HPAI.

Since late 2003, more than 6,500 HPAI/H5N1 outbreaks have been reported in 61 countries and human cases have been identified in 15 countries. While the mechanisms enabling persistence in poultry populations remain unclear, the movement of poultry through live-bird markets (LBM), which are common in Asian countries because of a cultural preference to consume freshly slaughtered meat, has been shown to be an important factor in the circulation of HPAI/H5N1 in Viet Nam and Hong Kong. The dense concentration and high turn-over rate of live birds in LBMs provide ample conditions for virus amplification and therefore LBMs may be an important reservoir for HPAI or "hub" of circulation. HPAI surveillance programs in several countries including Viet Nam, Thailand, Cambodia, China and Hong Kong have demonstrated that HPAI/H5N1 can be found in LBMs.

The degree of connectedness of animal networks, that is the frequency with which links between premises and LBMs are made via people, animal movement and/or sharing of equipment, can determine the potential for widespread epidemics of disease. Thus an understanding of animal movement practices and their contact structures is important in designing targeted surveillance, disease prevention and control activities. This is particularly important in resource-limited settings where such activities may be limited. However, little is understood about poultry market chains in countries where HPAI/H5N1 is endemic or recurrent.

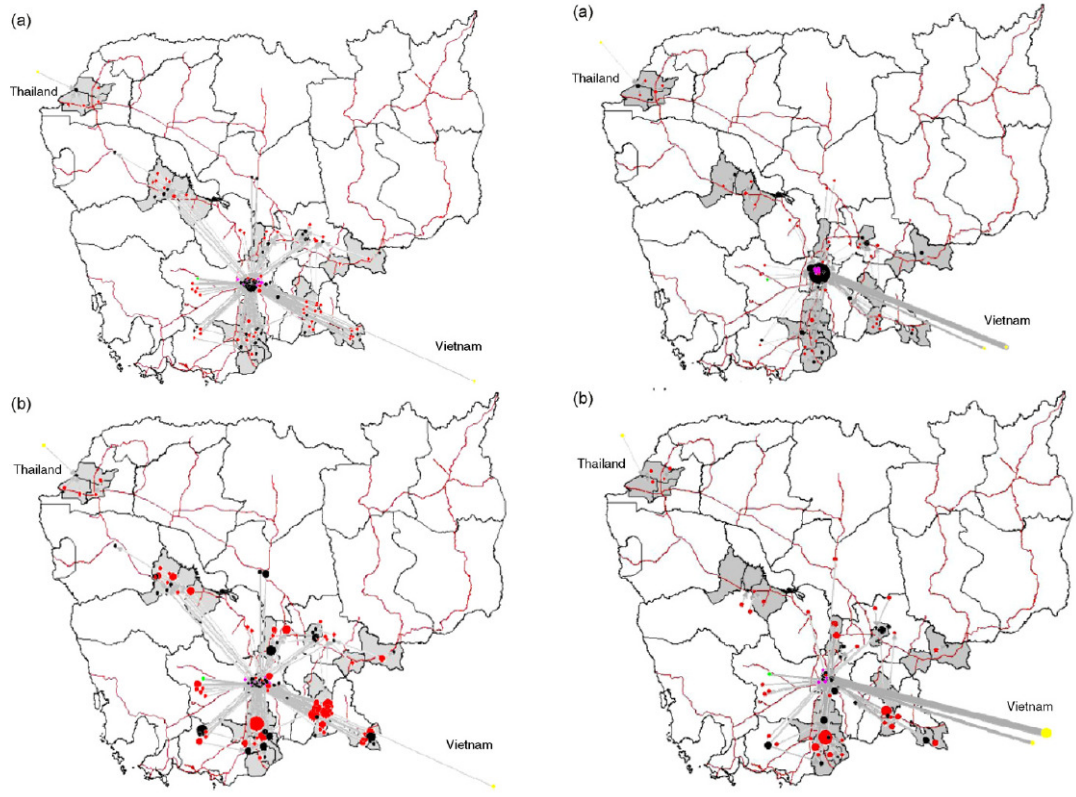
We therefore conducted a comprehensive study to describe the current movements of live poultry throughout southern Cambodia to understand how these movements could influence the potential spread of HPAI at local, regional and national levels.

Poultry Movement Networks in Cambodia: Implications for Surveillance and Control of HPAI/H5N1

Our results have demonstrated that live poultry movement in southern Cambodia is unidirectional, highly connected and highly centralized (Figures 1 and 2). We found:

- Approximately 83,000 live chickens and 35,000 live ducks are traded across the networks each week;
- Most poultry movement occurs via middlemen and market sellers on trucks and motorbikes into markets, semi-commercial farms and stock houses located in Phnom Penh;
- Approximately 85% of middlemen trade live birds >10 km from where they purchased the birds; and
- Live poultry originating in 11 of Cambodia's 24 provinces and from regions in Southern Viet Nam are sold directly to the three main LBMs in Phnom Penh.

Figure 1 (left) Chicken and **Figure 2 (right)** Duck trading networks in Cambodia with nodes weighted by (a) in-degree and (b) out-degree



The figures illustrate node sizes weighted by in-degree (a) above and the same network weights nodes by OUT-degree (b) below. Node colour indicates location type (black =market, purple = stock house, red = rural farm or household, light green = commercial farm, grey = semi-commercial farm, yellow= foreign source), ties show direction as indicated by the arrow and tie strength is indicated by the thickness of the arrow (the thicker the arrow, the more poultry passing between the two nodes).

Understanding poultry movement is essential to develop appropriate and targeted surveillance recommendations for active HPAI/H5N1 surveillance programs. We found that the premises involved in poultry trade are closely linked via middlemen carrying live poultry over long distances and that the unidirectional movement of poultry into Phnom Penh make LBMs in Phnom Penh a potential hub for the spread of H5N1. Domestic poultry outbreaks of H5N1 have occurred in the areas of the main network and therefore Phnom Penh LBMs, namely wet markets where live poultry are slaughtered at the market, would be ideal for surveillance and control.

The economic forces driving the trade of live animals and animal products have been shown to lead to widespread and often uncontrolled and/or illegal movement of animals over large distances, particularly in regions of the world where movement is not regulated. Yet, despite their likely role in the circulation and spread of HPAI/H5N1 virus in Asia, little is understood about within and between country poultry movements via trading in the region. We are unaware of any other published studies that have captured the movement of poultry via trading, although one study has evaluated poultry trading in northern Viet Nam.

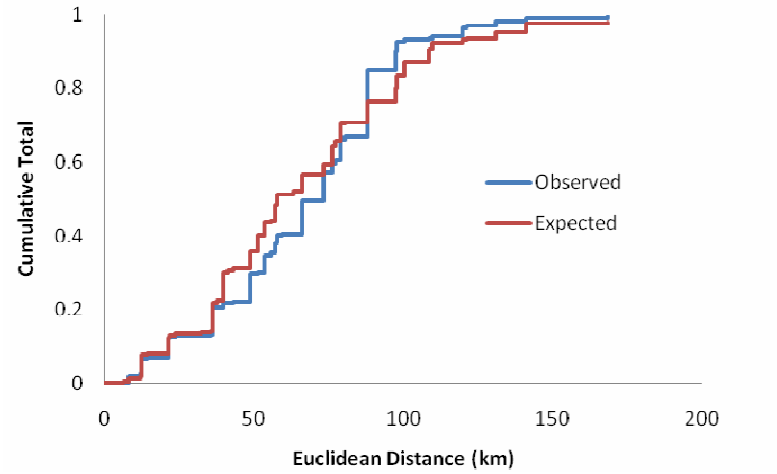
Fitting Gravity Models to Poultry Movement Data in Cambodia

In order to parameterise transmission models for HPAI, we need a model that captures the patterns of trade movements described above. Here a gravity model is fit to live poultry movement data in Cambodia using population data as an indicator of potential trade between the source where poultry are reared and destination of where poultry are sold to attempt to understand the potential driving forces behind the poultry movement patterns observed.

The main advantage of using a gravity model within transmission models rather than relying on the underlying movement data is that it can be applied outside the study area(s). Thus, by fitting a model to the poultry movement data from Cambodia, it may be possible to predict trade flows in areas not covered by the study as well as in the wider Mekong Delta Region which would be informative for HPAI control programs. Furthermore, as gravity models use information on the underlying populations, they should in theory be able to predict changes in movement patterns following underlying changes in the population, although such predictions have yet to be validated within an infectious disease context.

Our results illustrate that poultry movement is best described using poultry populations at the source (representing the supply of poultry), human population at the destination (representing the demand for poultry) and an exponential kernel (mean distance 120km) (Figure 3). Population exponents (ε=0.5, β=0.95) indicate that poultry are bred primarily for local consumption with excess being traded, while the demand for poultry is proportional to population of the destination.

Figure 3 Cumulative distribution of poultry movement by Euclidian distance



The plot shows the model $f(d, P1, H2)=GP_i^{\varepsilon}H_j^{\beta}\,k^*(d_{ij})$ fitted to all data where distance ≠ 0; where P_i is an attribute of source location *i* (here the poultry population), H_j is an attribute of destination location *j* (here the human population), $k^*(d_{ij})$ is the normalized spatial kernel, ε and β are parameters which scale the influence of the source and destination populations, respectively, and *G* is a scaling parameter.

Conclusions

Given the rapid global spread of HPAI/H5N1 in recent years, surveillance of poultry populations will remain a high priority, particularly in the Mekong Delta Region where a considerable number of human deaths have occurred. These studies have been able to identify critical points for active HPAI surveillance and have informed Cambodia's HPAI surveillance activities. However this does not replace the need for passive surveillance, which should be strengthened in rural areas of Cambodia by encouraging poultry owners to report poultry mortality to authorities. Since active surveillance in LBMs is likely to remain a component of the surveillance and control efforts for HPAI in Cambodia and elsewhere, our results can be used to inform the selection of markets that best suits particular objectives of the surveillance system, in particular whether the objective is monitoring of the HPAI status of poultry populations in rural areas or early detection of incursion in markets with high potential for spread. Collection of similar data in other countries could prevent outbreaks or incursions of HPAI within their borders.

Disclaimer: The views expressed in this paper are solely those of the authors and do not reflect an official position of DFID, MRC, FAO, RVC, IC or RDRC.

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