A Collaborative Research Project Funded by:

Implemented by:

Avian Influenza, Public Health, and Smallholder Livelihoods: Assessing Alternative Solutions

Workshop Report; January 2010

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Introduction

Since its emergence, H5N1 HPAI has attracted considerable public and media attention because the viruses involved have been shown to be capable of producing fatal disease in humans. While there is fear that the virus may mutate into a strain capable of sustained human-to-human transmission, the greatest impact to date has been on the highly diverse poultry industries in affected countries. In response to this, HPAI control measures have so far focused on implementing prevention and eradication measures in poultry populations, with more than 175 million birds culled in Southeast Asia alone.

Until now, significantly less emphasis has been placed on assessing the efficacy of risk reduction measures, including and their effects on the livelihoods of smallholder farmers and their families. In order to improve local and global capacity for evidence-based decision making on the control of HPAI (and other diseases with epidemic potential), which inevitably has major social and economic impacts, the UK Department for International Development (DFID) has agreed to fund a collaborative, multi-disciplinary HPAI research project for Southeast Asia and Africa.

The specific purpose of the project is to aid decision makers in developing evidence-based, pro-poor HPAI control measures at national and international levels. These control measures should not only be cost-effective and efficient in reducing disease risk, but also protect and enhance livelihoods, particularly those of smallholder producers in developing countries, who are and will remain the majority of livestock producers in these countries for some time to come.

Project research teams have carried out a large number of research projects and studies in countries of the Mekong region relating to various aspects of HPAI and HPAI control. The intention to this workshop was to bring together all researchers that have participated in the project or related activities to review and synthesize the findings and assess their policy implications.

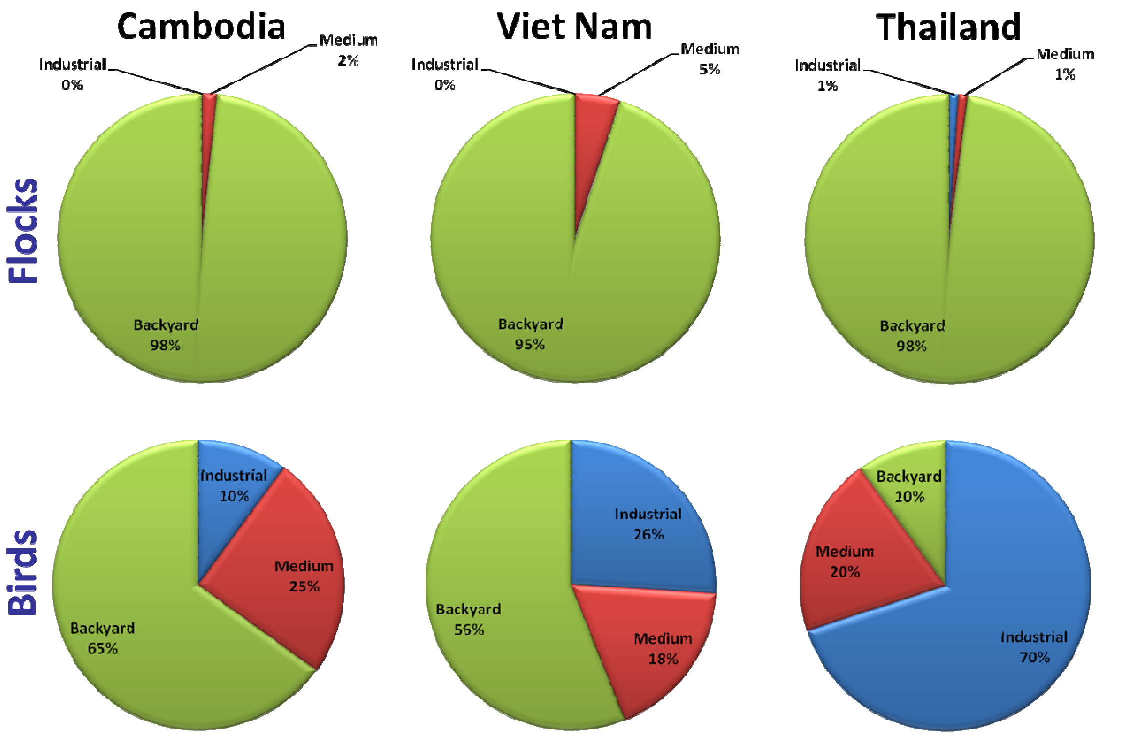
The report does not follow the order in which presentations were made but attempts to group these into related thematic clusters. The report starts by presenting an overview of the structure of the poultry industries in the study countries, namely Cambodia, Lao PDR, Thailand and Viet Nam. The following section deal with domestic value chains, poultry movements and their implications for disease spread and control. Section four reviews the temporal and spatial spread of HPAI H5N1 in the Greater Mekong Subregion, followed by a section that reports on the various risk assessments that have been carried out by the study teams. Section six reviews intervention measures to control and prevent HPAI H5N1 and their real and predicted impact on disease incidence in Thailand and Viet Nam. Section seven considers how HPAI control might be financed both from a local as well as from a global perspective. Finally, section eight draws some conclusions and policy implications, drawing on workshop presentations but also other research conducted under the auspices of the DFID-funded project.

Structure of the Poultry Industries in the GMS

Because of the complexity of the HPAI transmission process, policy makers need detailed information about the structure of the underlying poultry industry. Thus a central objective of the project was to develop high resolution data on poultry sector activities and interactions, including all scales of production and supply chains both up and downstream from poultry producers. To capture these complex structural characteristics of both operations and market channels, detailed producer and consumer surveys, as well as supply chain audits, were carried out in each of the subject countries.

Before presenting individual country results, one general observation is in order. For the countries considered, as well as any other countries with extensive poverty, backyard poultry will also be extensively (essentially proportionally) distributed and live in close proximity to humans. As the following figure makes clear, differences in the degree of modernization or headcount concentration for such sectors do not necessarily alter the flock count distribution. In other words, backyard poultry are ubiquitous in countries with large rural poor populations. An important challenge for policy is to convert these animals from an emblem of poverty to an agent of poverty alleviation.

Figure 1: Although Poultry Sectors May be Diverse: Backyard Poultry are Ubiquitous



Viet Nam (*J. Ifft*)

Methods

The project's survey work has emphasized representative sampling with either full coverage or large samples. Value chain analysis was undertaken in northern Viet Nam with over 1,100 surveys taken by 7 groups that comprised the key players in poultry supply chains serving Ha Noi. Surveys were used to assess: volume and frequency of trade, key trading partners, selling prices, and level of regulation. A representative consumer survey for Ha Noi focused on consumption of chicken and other meat, as well as demographic information and attitudes relevant to poultry consumption. This data was used to undertake demand estimation for different varieties of chicken in Ha Noi, using a LINQUD incomplete demand system model. Although the initial consumer survey used contingent valuation, a field experiment using discount coupons and choice experiment methodology was used to complement a certified chicken supply chain project in Ha Noi to measure willingness to pay for certified smallholder chicken. A similar field experiment and methodology (taking into account lesson learned in Ha Noi) will be used in Ho Chi Minh City to measure willingness to pay for certified smallholder ducks. Smallholder production and risk prevention responses to HPAI outbreaks using reduced form econometric analysis has been undertaken using a fixed effects model, and will also be undertaken with a structural model. This analysis takes advantage of a survey of 1,300 small scale poultry producers in the north and south of Viet Nam.

Findings

Value chain surveys have shown that (1) poultry supply chains are highly fragmented, with smaller/poorer players more likely to be in less formal systems, (2) trust is a key element of relationships and all supply chain players are well known to their buyers and sellers, (3) regulation is highly inconsistent across several dimensions, and (4) producers do not have an opportunity to be rewarded for improving biosecurity. Our consumer surveys in Ha Noi have shown that taste, as defined by free range/smallholder varieties, and safety are of critical importance to consumers and that price is only a secondary consideration. Demand analysis indicated that local chicken has positive income elasticity and is associated with higher levels of education. Willingness to pay for certification and traceability for chicken in Ha Noi is estimated to be US$0.50 to US$0.80 per whole chicken, or a 15% premium. For producers, in the short term HPAI outbreaks lead to lower production levels as well as lower investment in risk prevention. This is likely due to chicken production becoming less attractive, and the already-high level of diversification of smallholders. The impact of outbreaks on production behaviour only appears to be short term (1 year).

Implications

Our work on value chains indicates that producers need positive incentives and direct access to high-end urban markets to become involved in formal, regulated supply chains. Further, investment in farmer cooperatives, legal enforcement of contracts and support of third party labelling systems can play a role in enhancing development of private certified poultry supply chains. From a consumer perspective, demand for free range (local) chicken and ducks is unlikely to decrease in the medium term, given that higher incomes and education are associated with higher consumption. This preference for smallholder varieties combined with concern for safety emphasizes the need for certified supply chain systems. Consumers are willing to pay on average 15% more for certified poultry, but higher margins are possible if certified supply chains are initially aimed at high-end consumers. In the long term, economies of scale such as improved coordination of farmers can be realized to extend the supply chain to broader markets. The desired biosecurity investments of small scale producers in response to HPAI outbreaks further supports the need for such systems.

Table 1: Value Creation at Different Nodes in the Ha Noi Supply Chain (Summer 2007)

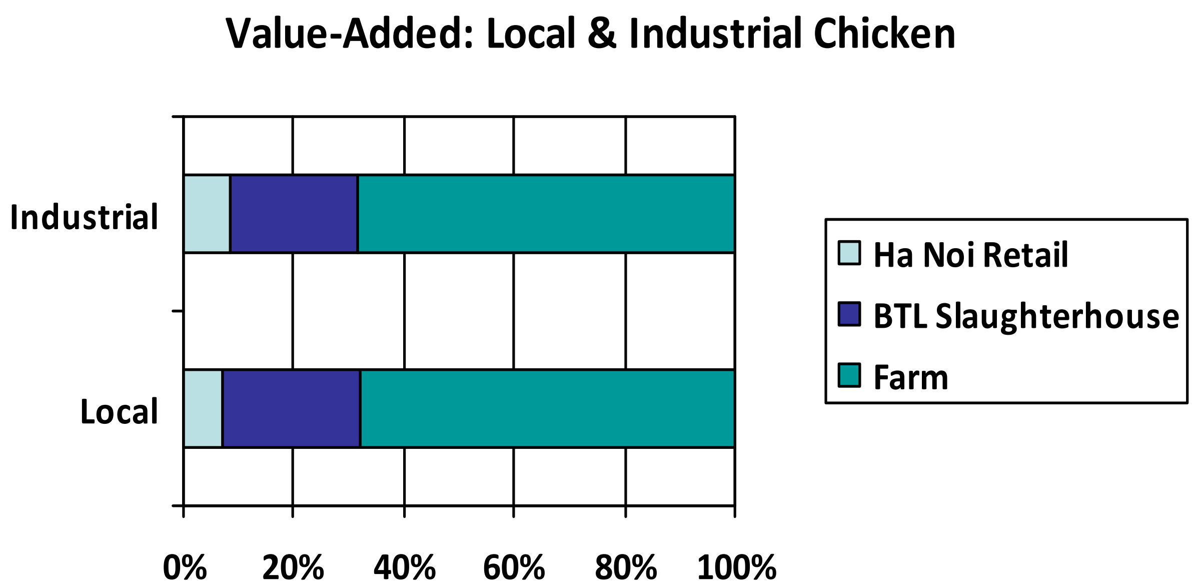


Table 2: Smallholder Response to HPAI: Initial Results for Reduced Form Analysis

	Broilers	Weighted Broilers	Broilers	Weighted Broilers
Outbreaks t-1	-0.72*** (0.27)	-1.04** (0.45)	-5.59* (3.06)	-3.64** (1.83)
Outbreaks t-2	-0.62 (o.56)	-1.43 (0.87)	-1.75 (1.61)	-1.19 (0.88)
IV			X	X
F-Stat	3.6	3.3	4.2	3.9

*Standard errors are robust to correlation at the commune level; interpretation of bold coefficient: a 1% increase in local HPAI incidence leads to average flock size of non-affected HHs decreasing by 5.59 birds; * = statistically significant at the 10% level, ** = statistically significant at the 5% level, *** = statistically significant at the 1% level*

Thailand (*S. Heft-Neal*)

Methods

Extensive surveys addressing the economics of poultry market chains and disease risk control (in particular HPAI) were carried out in Thailand between January and September 2008. The surveys were implemented across the low-income north and northeastern regions of Thailand in the provinces of Chiang Mai, Khon Kaen, and Nakhon Phanom. In total, more than 1,800 observations were collected from farmers, aggregators, and market vendors in addition to nearly 1,500 observations collected from urban consumers. Households selected for study inclusion were chosen by rigorous sampling techniques intended to generate a representative sample of the respective groups. Questionnaires were developed in conjunction with graduate students from the Faculty of Agriculture at Chiang Mai and Khon Kaen Universities. Students from these departments also implemented the surveys.

Findings

Our study of small-scale poultry market chains in Thailand concluded that, in light of the HPAI outbreaks that have occurred since 2004, small-scale farmers continue to raise local breeds of chicken within systems of production that require extremely low levels of resource inputs. In addition to producing birds for home consumption, rural households continue to receive cash income from marketing chickens (Figure 2). More than 85 percent of households that raise poultry reported receiving cash income from selling chicken in the past year. In addition, poultry production continues to play an important role in supplementing diets in low-income rural households.

The informal market chains that small-scale producers operate within are extremely localized and based on informal arrangements between market actors. The localized nature of the informal trade leads us to believe that these systems, particularly in the north and northeast, do not pose a major disease risk for the highly advanced industrialized poultry sector located primarily in central Thailand nor do these activities pose a significant health threat to the country.

Consumers in urban areas regularly purchase slaughtered chicken meat and prefer the taste of local breeds. However, for a variety of reasons, they primarily consume industrially raised of chicken (Figure 3). When asked to rank the importance of various poultry meat attributes, safety was rated the most important, followed by brand name and taste (Figure 4). Price was the attribute ranked the lowest.

Implications

In light of the low levels of disease risk perception and resource investment, it is unlikely that traditional small-scale poultry producers will alter their behaviour based on the interest of their own health. Moreover, we believe that these backyard activities do not significantly raise the overall level of livestock disease risk in Thailand. Meanwhile, consumers prefer the taste of chicken produced by small-scale producers and are willing to pay a premium for higher quality products. Therefore there may be potential for market transfers from relatively wealthier urban areas to low-income rural households in the form of quality premia for safe locally bred poultry products.

Figure 2: Motivation for Producing Poultry

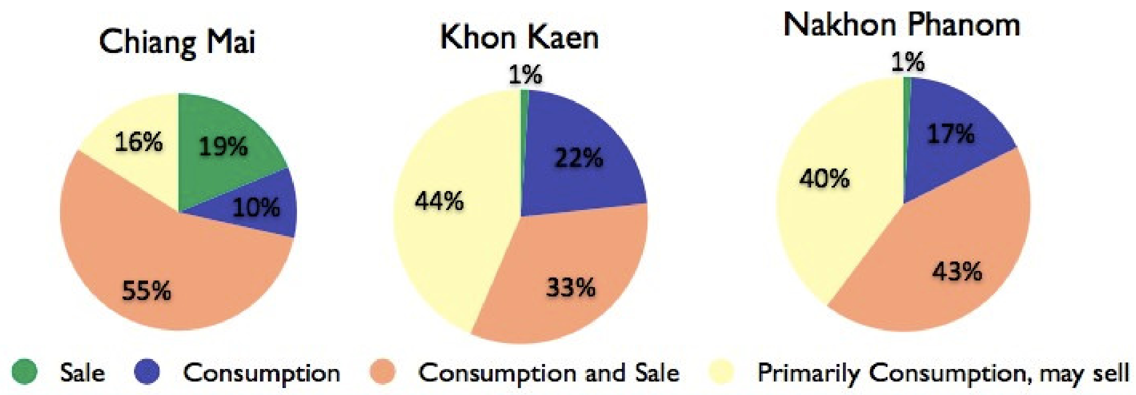


Figure 3: Urban Consumer Breed Preference and Purchasing Habits

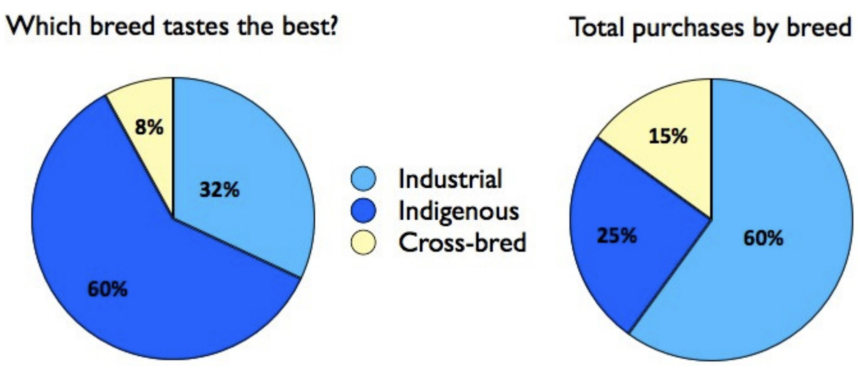
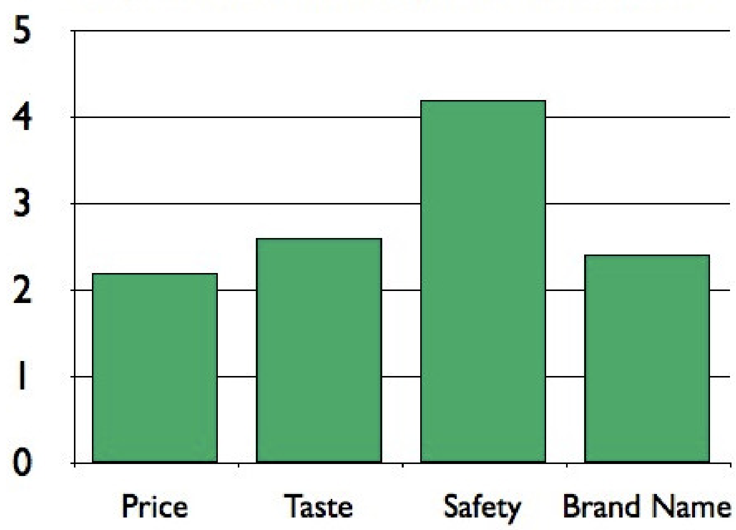


Figure 4: Importance of Poultry Meat Attributes for Urban Consumers



Cambodia (*S. Heft-Neal*)

Methods

Between January and July 2009, more than 1,600 detailed surveys of poultry market chain actors and 983 surveys of urban consumers were carried out in the Cambodian provinces of Siem Reap and Kampot. Respondents for the surveys were chosen using an intensive sampling method that intended to create representative samples of market actors and urban consumers within the selected provinces. Questionnaires were developed collaboratively with Cambodian researchers and locally hired high school graduates implemented the surveys.

Findings

Despite poultry production systems requiring minimal resource inputs/effort, sales of poultry products were found to account for 10 to 25 percent of total cash income in rural households. Moreover, the cash income generated by these sales went primarily towards food, paying school fees, and emergency savings (Figure 4). Marketing systems are extremely localized with the exception of duck eggs, which are produced in Kampot and sometimes sold in Phnom Penh. Informal market chains operate based on personal relationships as well as informal agreements and farmers often take an active role in marketing their birds by selling them on the side of the road or bringing them to market. All small-scale producers interviewed perceived little to no risk posed by HPAI and other livestock diseases to their flocks or families.

Raising layer ducks for egg production is the primary economic activity undertaken by duck producers. Within the duck market chain, hatcheries play an important role by purchasing fertilized eggs from a variety of farmers, hatching them, and selling the ducklings to layer producers. 30 to 40 percent of the fertilized eggs purchased by hatcheries in Kampot reportedly came from Viet Nam. Duck producers tend to raise several hundred birds with significant bio-security investment but continue to experience high levels of mortality (>20 percent).

Most urban consumers purchase duck eggs weekly, and many consume them daily. Most also purchase chicken meat weekly and it accounts for the largest volume/value of poultry consumption (1.4 US$/week). Urban consumers rated safety as the most important attribute that they look for in chicken meat (Figure 6) and they believe that the safety of the poultry products they purchase could be improved. Safety is generally judged by appearance a live bird in Kampot and by meat appearance in Siem Reap. More than 85 percent of urban consumers stated that they would be willing to pay a premium for higher quality poultry products.

Implications

Wide distribution, free-grazing practices, and cross border elements of the duck market chain suggest that duck production is a riskier activity (in terms of disease) than small-scale chicken production. Consequently, large-scale duck producers should be the primary target of education and outreach programs. Moreover, duck producers have more interest (and incentive) to invest in biosecurity since it is their main economic activity. In contrast, small-scale chicken production is extremely localized and does not appear to pose a major health risk to Cambodia. Moreover, because of low levels of perceived disease risk, small-scale producers are unlikely to be receptive to programs/policies that encourage them to change their behaviour based on appeals to self-interested health concerns. Lastly, urban consumers' stated willingness to pay a premium for high quality products suggest that there is potential for low-income rural households to receive higher returns for products if they increase investment in quality. However, this will only be possible if farmers are able to effectively relay quality information to consumers.

Figure 5: Use of Cash Income from Poultry Sales in Selected Provinces

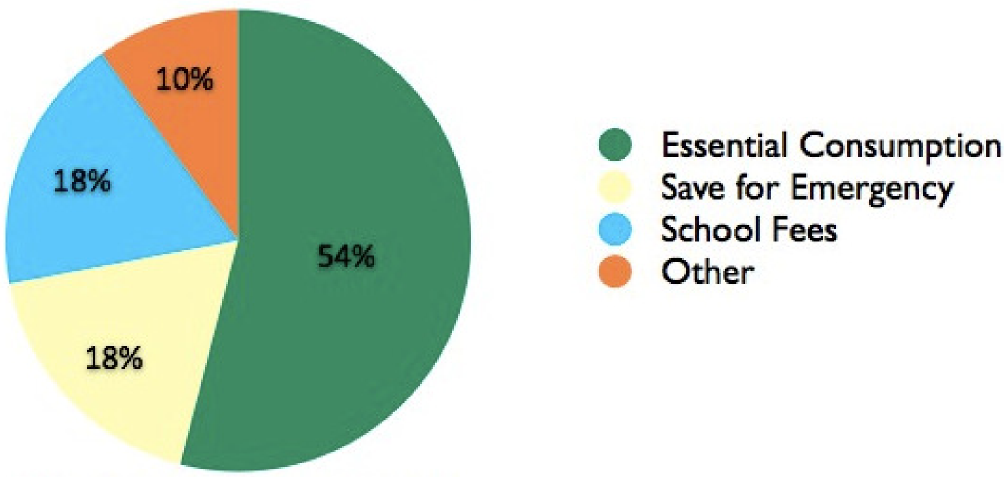
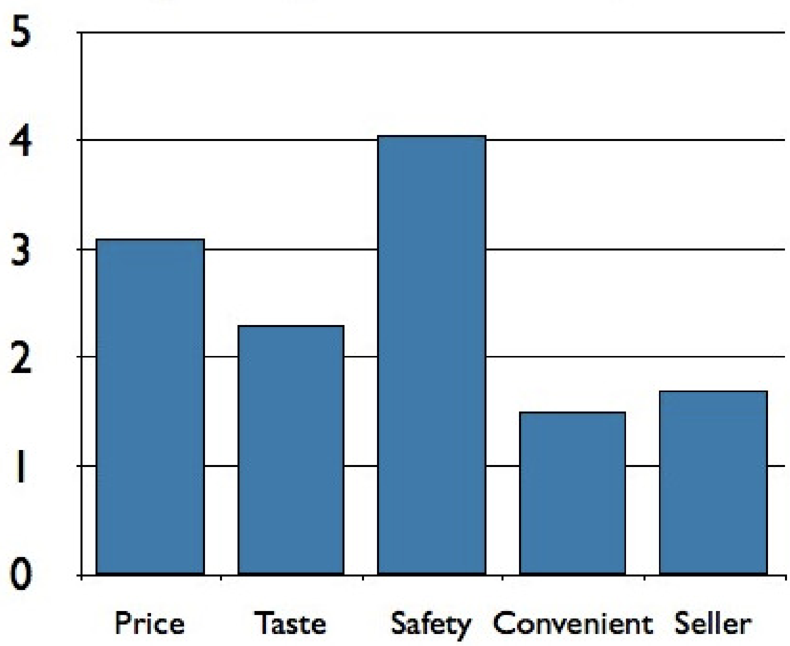


Figure 6: Ranking the Importance of Poultry Attributes among Urban Consumers



Lao PDR (*D. Behnke*)

Smallholder poultry production is ubiquitous in Lao PDR and represents a crucial income generating opportunity for one of the poorest countries in the GMS. Much like other countries in the GMS, HPAI outbreaks and related control measures have adversely affected smallholder production. Despite the importance and prevalence of smallholder poultry production in Lao PDR, there has been limited academic work conducted and information is extremely limited. This information gap creates a serious burden to the effective monitoring and control of HPAI, as a regionally coordinated effort is needed. Furthermore, people's livelihoods are at stake and an in-depth understanding of the smallholder poultry sector is needed to insure control policies do not adversely affect production.

Access to capital and contracting is often lauded as a tool for increasing value of poultry products and is worthy of further exploration as well. In Lao PDR, capital constrains became a major obstacle in re-stocking poultry production after the advent of local HPAI outbreaks. Capital constraints may also significantly limit market access among producers, as those who want to increase their flock size or improve production methods do not have the necessary resources. Micro-contracting presents a possible solution to reducing barriers to market access but both informal and formal systems remain undeveloped in poultry production. In recent years, the Lao PDR government has encouraged farmers to access financial services to reduce their capital constraints. This has been matched with increased microfinance services in rural areas to improve the commercialization of agriculture production. Despite these efforts, financial services are not typically utilized in the poultry production sector, particularly among smallholders.

Methods

Survey work in Lao PDR will provide data-driven results to these problems. Both market chain and consumer questionnaires will be implemented covering various actors in the poultry sector. Market chain surveys will include detailed producer, aggregator, and vendor surveys that will establish a supply chain audit. Surveys are currently being conducted in the Vientiane Capital province spanning 128 villages in all 9 districts. Sample villages were drawn from two sources. First, all 48 villages included in the 2007/08 Lao Expenditure and Consumption Survey (LECS IV) were included. However, additional villages were needed to reach the desired number of observations and 62 villages were added using a probability proportion to size (PPS) methodology. Different questionnaires require different implementation methodology. For small-scale producer questionnaires, all poultry-producing households from the LECS IV will be targeted directly. In LECS IV villages with less than 16 producers and rural villages selected using PPS, producers will be found by selecting a household at random and conducting surveys at every 4th household until 16 observations are recorded. For large scale producers, farms will be found both using data from the LECS IV and from talking to village chiefs in all PPS selected villages. This direct targeting approach aims to cover all large producers in the sample.

Aggregators will be located by talking with village chiefs in sample villages and enumerators are instructed to search for aggregators during surveys with producers and vendors. Vendor questionnaires will be recorded at the major wet markets in the Vientiane Capital metropolis and the smaller markets that serve the urban village sample. Consumer questionnaires will be implemented in urban villages only. Households will be selected either from the LECS IV directly or by selecting a household at random and conducting questionnaires at every 4th household until 16 observations are recorded. In total, 2,000 observations will be captured split between 1,250 market chain and 750 observations. There will be an equal distribution of observations between rural and urban areas with 1,000 observations each.

Questionnaires will produce detailed data on the total inputs and outputs regarding poultry production and marketing operations, which will be instrumental in understanding how future policies or projects may affect cost structures. Furthermore, surveys will identify the direct and indirect costs and other enterprise effects of culling and related HPAI control measures, financial access and capital constraints, the role of contract farming systems, and any other institutional factors limiting smallholder adaptability. Financial access data can provide insight into future financial service polices that encourage smallholders to effectively benefit from financial services and overcome capital constraints. Additionally, information on contract farming systems can be used to demonstrate that a micro-contracting system overcomes the problems of market access, capital constraints, quality incentives, and bargaining disadvantages. Surveys will be used to provide recommendations for sustainable market participation by smallholder producers and will strive to increase product quality, safety and revenue across the traditional poultry supply chain.

Survey work will also be conducted in northern and southern Lao PDR. In the north, Oudomxay and Phongsaly have been selected due to their proximity to China and Dien Bien Phu Viet Nam. Additional motivation for northern surveys will be to track illegal poultry trade flows from China, through Lao PDR, and into Viet Nam. In the south, questionnaires will be conducted in Savannakhet. Additional motivation for southern surveys is the attempt to demonstrate the relationship increased market access and transportation infrastructure has on livelihoods (specifically focusing on route 9 and the 'East-West Economic Corridor').

Figure 7: Poverty Indicators for Lao PDR

Incidence of Poverty

Poverty Density

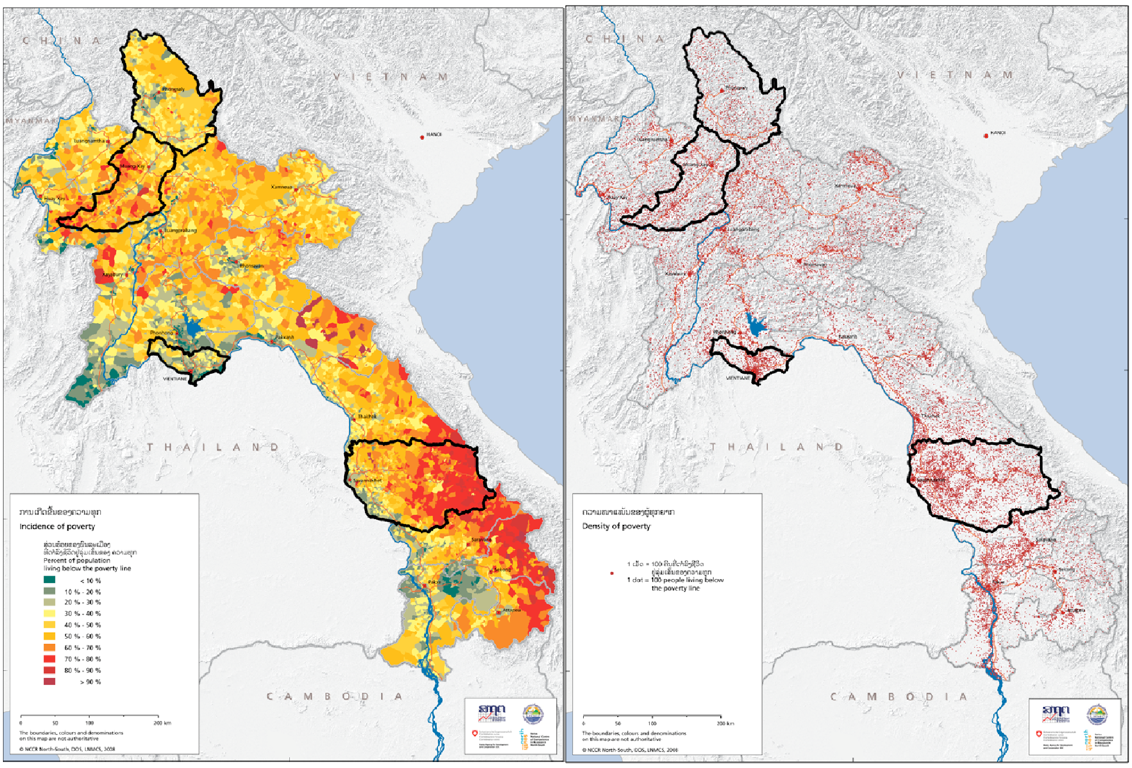


Figure 8: National Poultry Flock by Type, 2007/08

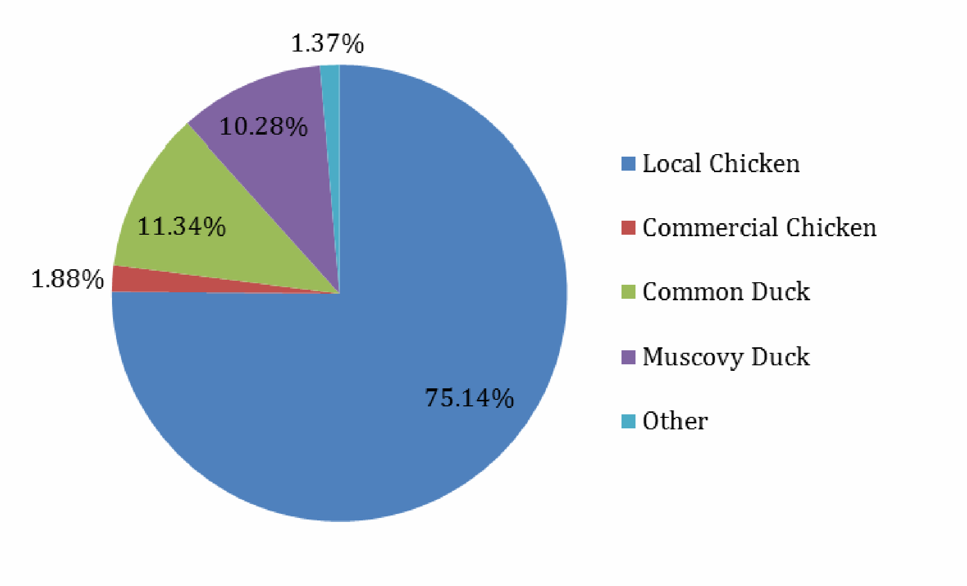


Figure 9: Poultry Population Distribution by Production System, 2006

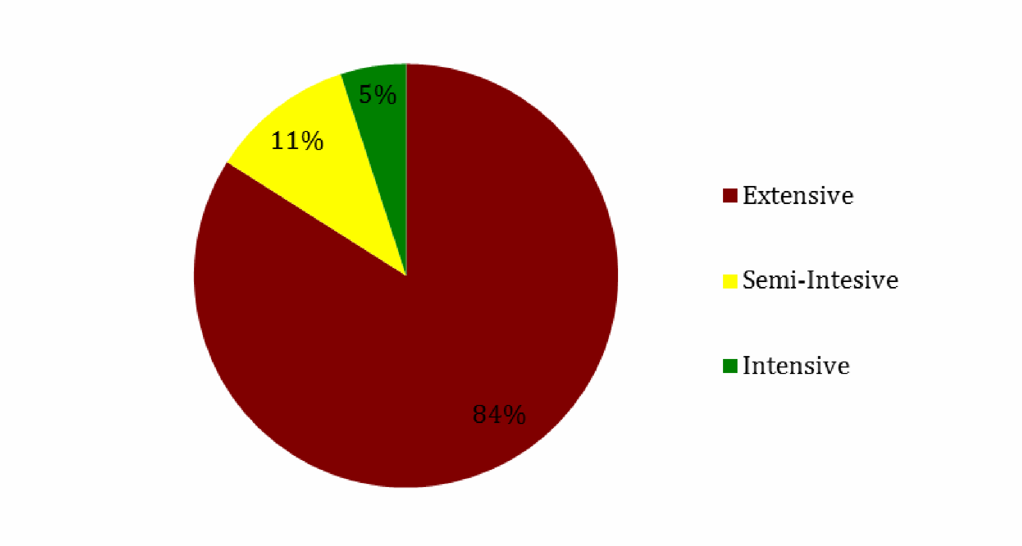


Figure 10: Temporal Patterns of HPAI Outbreaks, 2004-2009

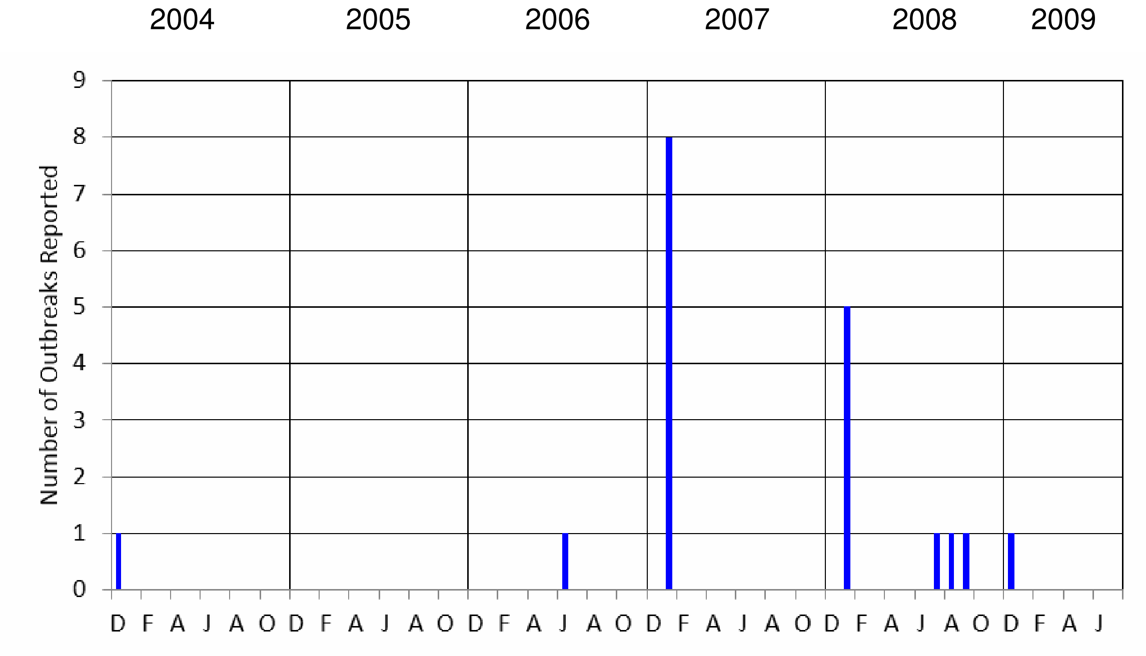


Figure 11: Chicken on the bus from Oudomxay to M. Mai, Phongsaly	Figure 12: Vendor Eggs in M. Mai, Phongsaly
	

Internal Value Chains, Livelihoods and Risk Transmission

Smallholder poultry supply chains (*D. Roland-Holst et al.*)

If policy makers want to reduce HPAI risk to animal and human populations, without undue adverse effects on the poor, a better understanding of markets is needed. Consumer surveys indicate that consumers continue to place a significant premium on traditional poultry varieties like those produced by smallholders and marketed across low income supply chains. Supply chain surveys indicate that conventional control measures can drive up transactions costs and encourage risky behaviour. Product quality/safety initiatives can be self-financed and incentive compatible, a socially effective substitute for open-ended fiscal commitments to public disease monitoring and geographically extensive control measures.

While globalization has stimulated growth in many low income urban areas, the world's rural poor majority can only participate in this process indirectly, via migrant sending or marketing farm products. Market access is thus the gateway out of long term poverty for most of the world's poor. The poultry-dependent are more likely to be poor, and poultry income thus offers a strong catalyst for poverty reduction. The policy challenge is then to facilitate improvements in this source of income, promoting self-directed poverty alleviation via improved market access.

As the figure below makes clear, the smallholder poultry supply chain is replete with information failures, all of which undermine value creation and many of which contribute to health risk. To support interventions that can overcome these problems, evidence on detailed supply chain structure is needed. To strengthen this basis of evidence, we conducted detailed supply chain audits in subject countries (e.g. Figure 14). These surveys provide high resolution information on vertical and horizontal transmission of risk, economic value, and incentives.

Figure 13: Smallholder Poultry Supply Chains and Information Failures

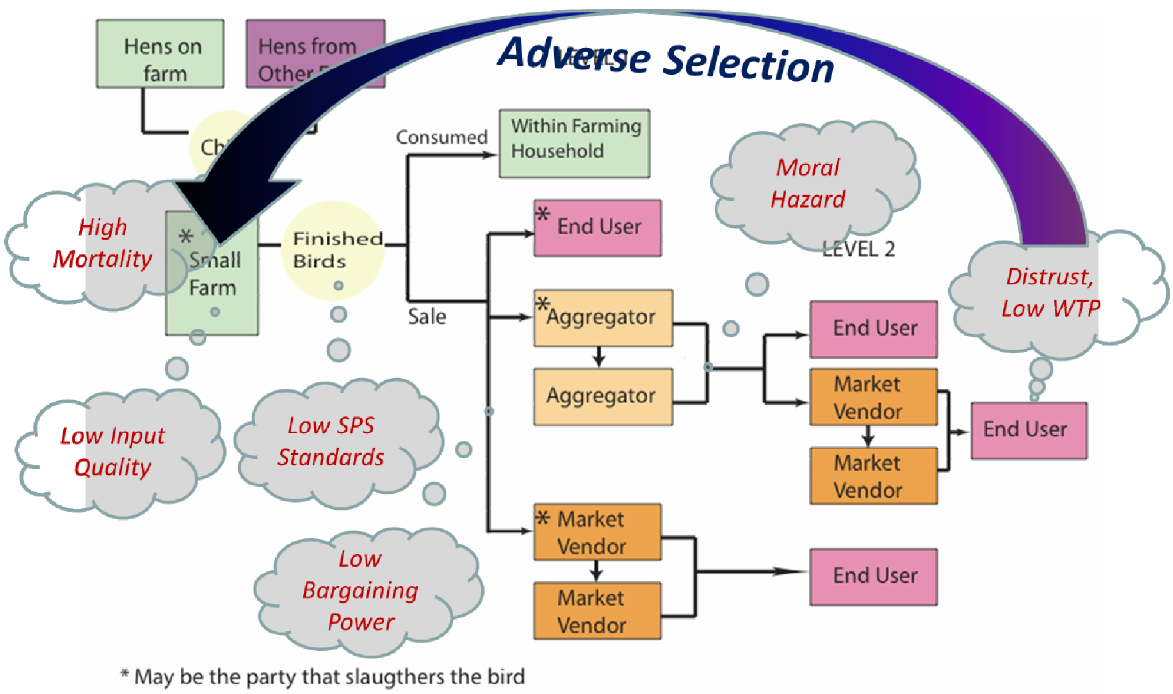
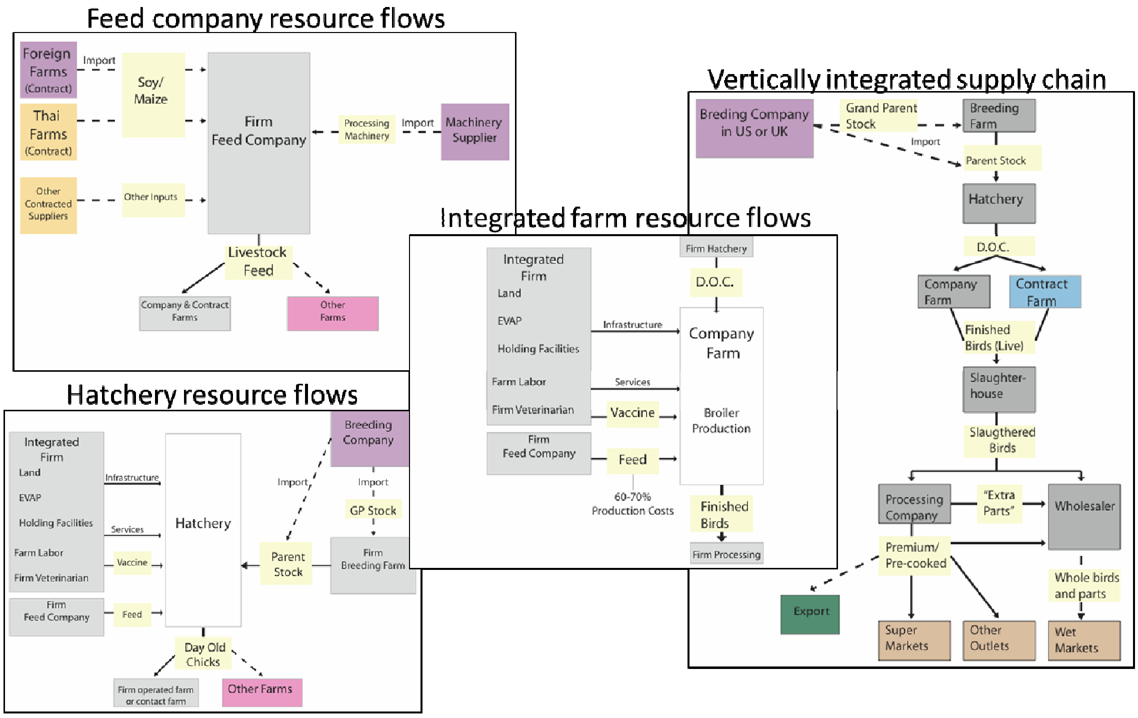


Figure 14: Examples of Supply Chain Audits



Poultry Networks in Cambodia: Implications for improving surveillance and control (*M. VanKerkhove*)

Background and methods

A series of studies was conducted to evaluate poultry movements and the extent of interaction between poultry and humans as measures of the risks of sustained transmission in poultry and onward transmission to humans in Cambodia (Van Kerkhove et al 2008 and 2009). A cross-sectional survey of rural Cambodians was conducted in 6 provinces to obtain quantitative data on poultry/trading and selling from heads of households (n=600) and village chiefs (n=115). In addition, a cross-sectional survey of market sellers (n=102) and middlemen (n=120) was conducted using the snowball sampling methods, as well as focus group discussions with Phnom Penh market veterinary inspectors and field visits at markets (n>100) and inspection points along national roads. A detailed questionnaire focused on market sellers and middlemen from Orussey, Chba Ampov, Deumkor Markets in Phnom Penh and Markets in District centres.

In addition, a gravity model was 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.

Findings

Live poultry networks in Cambodia are highly centralized, connected and unidirectional (see figures below). Poultry only for short time in the market chain so that silent amplification could be occuring. Most poultry movement occurs into Phnom Penh and wet markets in

Phnom Penh are a potential hub for the spread of HPAI H5N1. It was also found that poultry from Vietnam and Thailand enter Cambodia's market chain, e.g. half of the live ducks entering the Cambodian poultry trade network each week are from Viet Nam. A limitation of this study was that it did not capture localized cross-border trading activities, which is known to occur and at an increased rate around annual festivals.

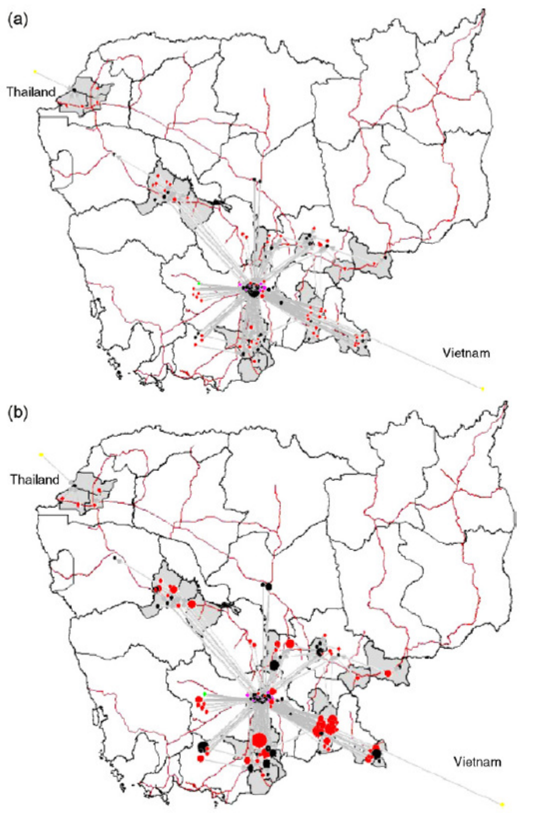


Fig. 2. Chicken trading network in Cambodia with nodes weighted by (a) in-degree and (b) out-degree. The figure illustrates node sizes weighted by in-degree (a) above and the same network weights nodes by OUT-degree (b) below. Node color indicates location type (black = market, purple = stock house, 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). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

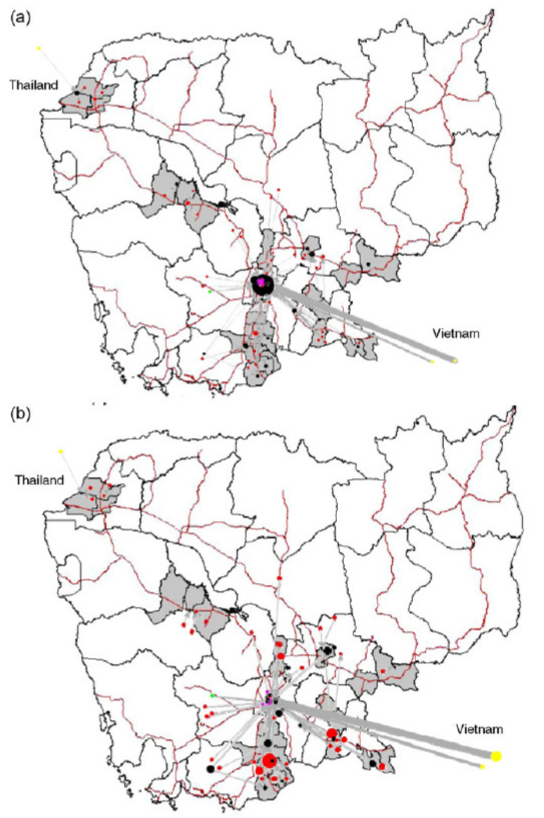


Fig. 3. Duck trading network in Cambodia with nodes weighted by (a) in-degree and (b) out-degree. The figure illustrates node sizes weighted by in-degree (a) above and the same network weights nodes by out-degree (b) below. Node color indicates location type (black = market, purple = stock house, red = 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). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

The gravity model indicates that poultry movement is best described using poultry population data at the source (supply of poultry) and human population at the destination (demand for poultry).

Implications

The study identified the need to improve the working conditions at wet markets. The results indicate the need for regular cleaning with disinfectant and the possible use of monthly market rest days to interrupt chains of infection. This study has identified critical points (i.e., wet markets) for active HPAI surveillance and has informed Cambodia's surveillance activities but does not replace the need for passive surveillance in rural areas.

The findings from the gravity model developed here suggest that poultry are bred primarily for local consumption with excess being traded and that the demand for poultry is proportional to population of the destination.

HPAI H5N1 Epidemiology and Disease Risk

Temporal and spatial patterns of HPAI H5N1 (*D. Pfeiffer*)

HPAI H5N1 outbreaks have been reported from the Greater Mekong Subregion (GMS) since late 2003. Both, Thailand and Viet Nam experienced major outbreaks resulting in the culling of hundreds of millions of poultry and severe economic losses to smallholder and commercial farmers, associated poultry as well as tourism industries. Figure 15a shows the magnitude of the outbreak numbers between 2004 and 2005 with Viet Nam experiencing outbreaks in association with the Tet holiday period. Since that time control measures have been able to effectively reduce the magnitude of outbreaks, but outbreaks still do occur in all GMS countries with Viet Nam having the highest frequency (see Figure 15b). This observed pattern suggests that the epidemiology of HPAI virus H5N1 in the GMS countries changed from an epidemic phase in 2004-05 to a current endemic phase, where there appear to be local reservoirs of infection in some countries. The control measures implemented in GMS countries vary significantly between and even within some countries. Large-scale vaccination campaigns of poultry populations were only implemented in Viet Nam, and are still on-going although the vaccination effort is now targeted at specific sub-sections of the poultry population. Thailand had decided early on not use any vaccination, and has been able to control the disease by relying on enhanced surveillance and targeted culling of infected populations. Both, Cambodia and Lao have much lower poultry population densities than Thailand and Viet Nam, and have experienced relatively small numbers of outbreaks, suggesting that they represent spill over from infection reservoirs elsewhere.

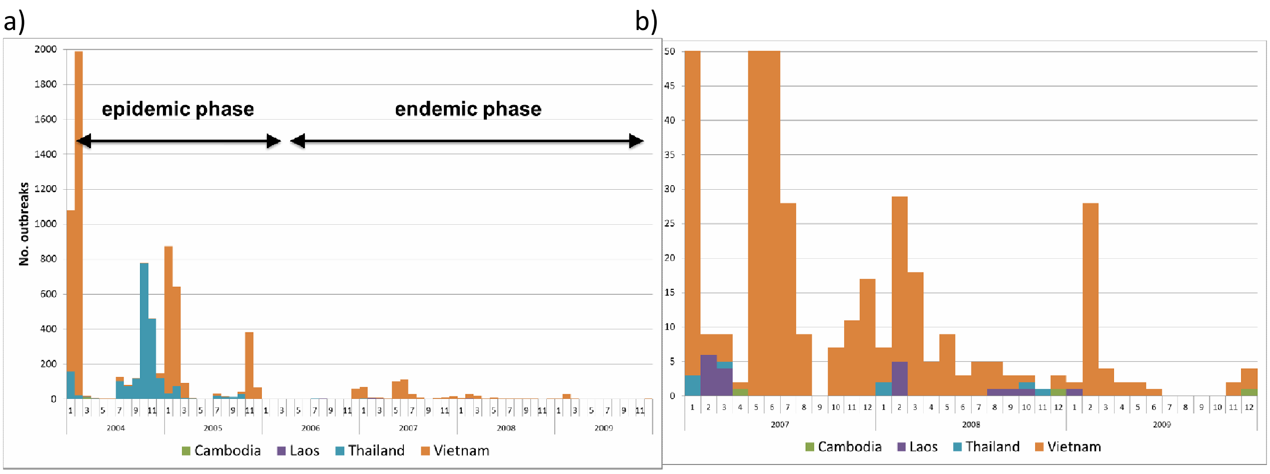


Figure 15: Temporal pattern of total number of reported monthly HPAI H5N1 poultry outbreaks in GMS countries

Table 3 shows the total of human cases and fatalities reported to WHO since 2003. It shows that over 75% of globally reported deaths due to HPAI virus H5N1 occurred in southeast Asia, and in the GMS countries about 30%. While probably significantly affected by underreporting bias, these figures demonstrate that the apparent potential for transmission to humans is higher in this region than in any others around the world (except for Egypt).

Table 3: Human HPAI H5N1 cases and deaths reported to WHO between 2003 and 2009 (http://www.who.int/csr/disease/avian_influenza/country/en/)

Country	Cases	Deaths
Cambodia	9 (1.9%)	7 (2.5%)
Indonesia	161 (34.5%)	134 (47.5%)
Lao	2 (0.4%)	2 (0.7%)
Myanmar	1 (0.2%)	0 (0%)
Thailand	25 (5.4%)	17 (6.0%)
Viet Nam	112 (24.0%)	57 (20.2%)
Other	157 (33.6%)	65 (23.0%)
Total	467 (100%)	282 (100%)

The continuing occurrence of outbreaks raises the question which are the underlying epidemiological mechanisms associated this locally endemic infection status. The main areas of interest in this respect are in the north and south of Viet Nam. The association between regional patterns of infection and risk factors has been examined on a national and regional scale, suggesting that higher density duck populations and/or free grazing duck production may be linked with increased risk of outbreaks (Pfeiffer et al 2007; Gilbert et al 2008). As shown in Figure 16, it appears that outbreaks in Viet Nam in the endemic phase occurred in areas of relatively high duck and aquaculture density. It is unclear though what the exact mechanism of local maintenance is, but likely that it is associated with human activity rather than potential presence of infected wild birds.

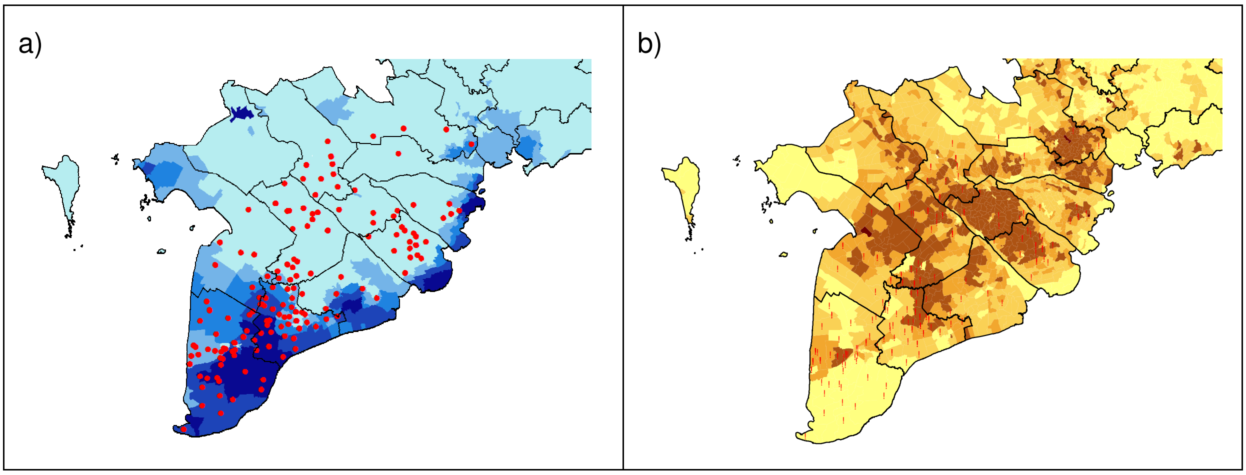


Figure 16: Locations of reported HPAI H5N1 outbreaks in poultry between 2006 and 2009 (red dots) in southern Viet Nam draped over density of aquaculture (a) and ducks (b) (darker color = higher density)

Assessment of the molecular evolution of HPAI virus H5N1 provides further insight into possible mechanisms behind re-occurrence of outbreaks, although it needs to be noted that the selection of virus isolates for gene sequencing was not done by a representative sampling process. As shown in Figure 17, it is notable that the highest variety of molecular clades has been reported from East Asia, with variety reducing with distance from that part of Eurasia. Interestingly, all outbreaks west of East and South-east Asia were caused by the same clade type, whereas the variety in the South-East Asia is higher. It is therefore possible that East Asia has a key role as a reservoir of HPAI virus H5N1, and outbreaks in other parts of parts of Eurasia and Africa were originally due to introductions from East Asia. The higher variety of clades in South-East Asia compared with South Asia and Africa/western Asia suggest a relatively intensive exchange of poultry (also possible through wild bird migration, but less likely) with East Asia, despite there being an official ban on trade.

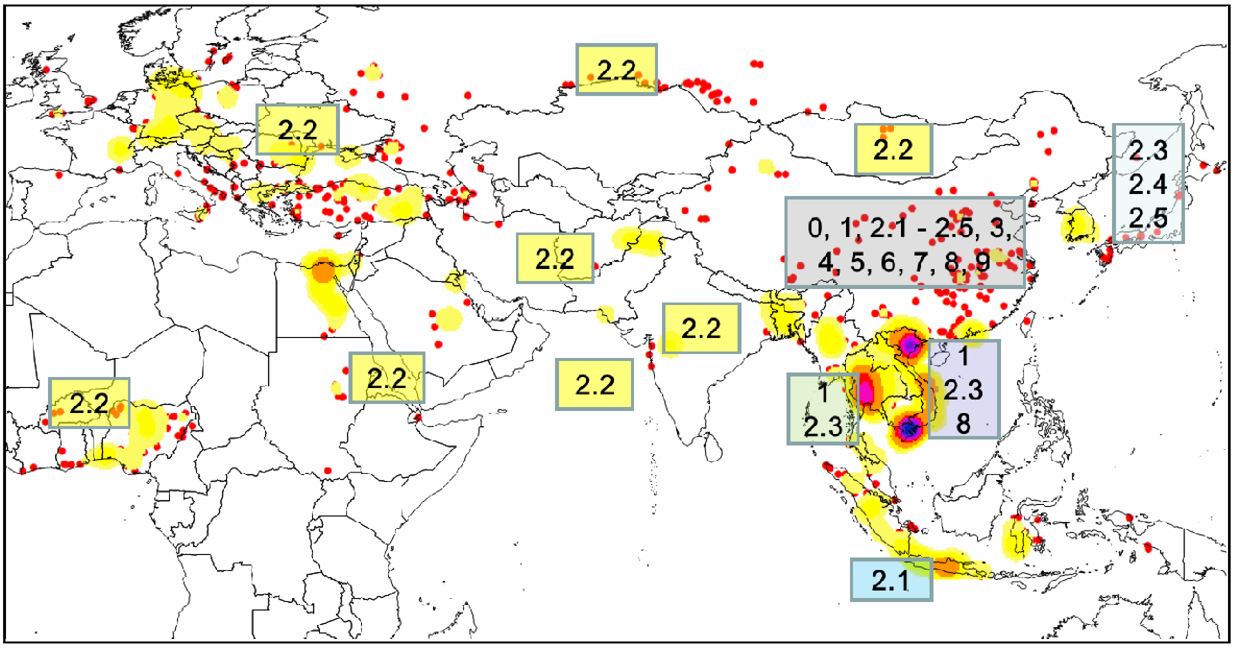


Figure 17: Global distribution of HPAI virus H5N1 clades identified in poultry based on nucleotide sequence variability of the HA gene (draped over density of poultry outbreaks – red dots = isolated outbreaks, yellow lower density – blue highest density)

Knowledge-driven mapping of relative likelihood of HPAI virus H5N1 occurrence in Indonesia (*S. Costard* & *W. de Glanville)*

Methods

Spatial analysis of the distribution of disease risk and its presentation through risk maps has been used in Indonesia with the objective of informing HPAI H5N1 surveillance. As data were only available on some aspects of the epidemiology of the disease, a knowledge-driven approach – multi-criteria decision modelling (MCDM) - was used to identify areas with a higher or lower likelihood of disease occurrence relative to other areas of the country, based on existing or hypothesized understanding of the causal relationships leading to the occurrence of HPAI virus H5N1. The approach involved identifying risk factors associated with occurrence of HPAI virus H5N1 in Indonesia, defining the relative importance of each risk factor in relation to the occurrence of disease, and developing a multi-criteria decision model to combine all risk factors to produce a weighted estimate of the relative likelihood of occurrence of HPAI virus H5N1 for each location in Indonesia. To obtain the risk factor weightings, pairs of risk factors were compared based not only on their importance (whether Factor A was more or less important than Factor B in the occurrence of HPAI H5N1 in Indonesia) but also on the degree of importance (whether Factor A was (i) equally, (ii) moderately, (iii) strongly or (iv) very strongly, more or less important than Factor B in the occurrence of HPAI virus H5N1 in Indonesia).

Findings

The map in Figure 18 illustrates the relative likelihood of occurrence of HPAIV H5N1 in Indonesia based on the risk factors and weights incorporated in the model. Areas of rice production, poultry density, and anthropogenic factors such as road and port density were considered to be most important for the occurrence of HPAIV H5N1 within Indonesia. Based on the results of the MCDM modelling, the relative likelihood of occurrence of HPAIV H5N1 in Indonesia is greatest on the island of Java, as well as some areas in the Banka-Belitung Islands and Sumatra.

Implications

The model produced seems to fit anecdotal evidence of high disease risk areas, but further validation with field data would be preferable. A recent publication by Paul et al (2010) highlighted the importance of anthropological factors for the occurrence of HPAIV H5N1 in addition to agro-environmental ones, which support the MCDM model developed in this study.

Advantages of such likelihood maps include the possibility to amend the MCDM model as knowledge on the disease increases, and the fact that they are not dependent on disease occurrence data, which can be difficult to obtain. But such maps also have limitations: their accuracy depends on the quality of the data – which may be out-of-date, incomplete or even incorrect - and current knowledge about the disease – which determines risk factors and weights to include in the MCDM model; and they only consider risk factors that can be mapped. Finally, they only represent a relative likelihood of disease spread, and not absolute probability or risk.

Despite these limitations, these MCDM likelihood maps can help policymakers target areas for strengthened surveillance and/or control activities. It would be possible to apply such approaches in the Mekong region and incorporate findings from recent studies on HPAI H5N1 in the region, to inform surveillance activities at the national and/or regional levels.

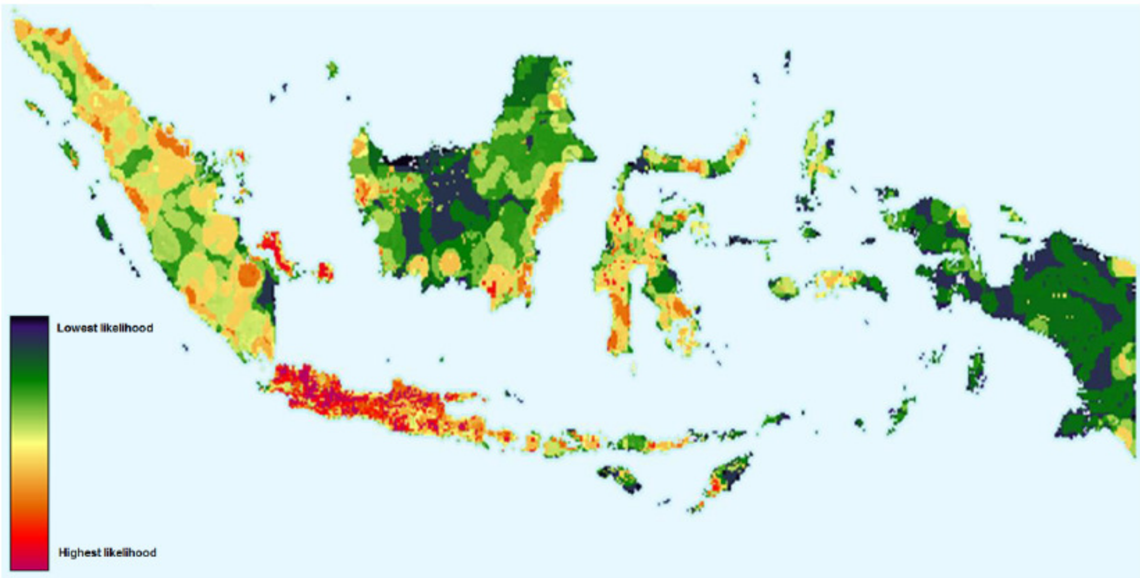


Figure 18: Map illustrating the relative likelihood of spread of highly pathogenic avian influenza H5N1 within Indonesia

Risk pathway diagrams for an assessment of the risk of transmission of HPAI virus H5N1 between semi-commercial and backyard poultry production systems in Indonesia (*W. de Glanville)*

Background and methods

This study will use a risk assessment framework to estimate the risk of transmission of HPAIV H5N1 between 1) semi-commercial broiler farms (i.e. those with 5000 birds or less) and 2) semi-commercial broiler farms and backyard poultry production systems. The quantitative assessment focuses on the province of Bogor, Indonesia and will quantify the risk of transmission of H5N1 between domestic poultry along all possible pathways that link these production systems. As a first step the relevant risk pathway diagrams were developed in consultation with stakeholders in Indonesia, and these results are presented here.

Findings

The risk pathway diagrams are presented in Figure 19.

a) b)

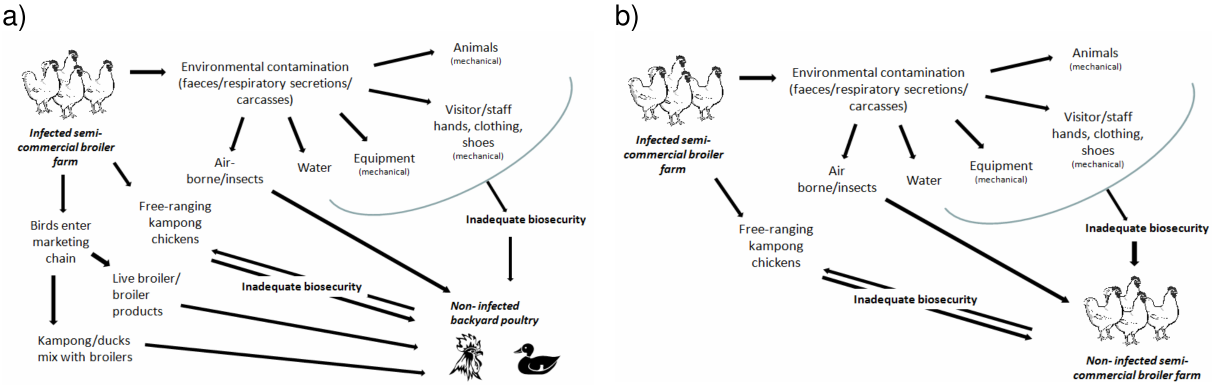


Figure 19: Risk pathway diagrams for the spread of HPAIV H5N1 from an infected small-scale broiler farm to a non-infected backyard (a) or small-scale broiler (b) farm in Bogor, Indonesia

It has become clear that environmental contamination with and persistence of HPAIV H5N1 are key parameters in these models. Survival of the virus will play a key role in the onward spread of H5N1 since it will determine the time over which exposure to virus can occur, and may therefore place strict limits on transmission pathways. Following the release of the virus, time dependent inactivation rates, estimated from laboratory based studies on virus survival together with estimates for abiotic parameters such as temperature, UV radiation and humidity that may influence virus survival, can be used to estimate the quantity, or dose, of virus present at the end of each identified transmission pathway.

The following data have estimated based on published data in relation to manure production and contamination with HPAIV H5N1. Each broiler chicken may produce ~ 1.7 kg of faecal waste over its lifespan resulting in around 40g/day. This means that a 5000 bird farm might produce 200 kg per day. On average, infected poultry might produce 5.8 $\log_{10}$ EID_{50} of virus in every gram of faeces. On average, infected poultry might produce 6.3 $\log_{10}$ EID_{50} of virus in every ml of respiratory secretion. Using published skeletal tissue contamination data, the predicted viral load can be $10^{8.3}$ to $10^{10.3}$ EID_{50} per carcass.

Implications

A detailed examination of the risk pathways associated with introduction of HPAIV H5N1 to poultry farms suggests that environmental contamination may have a very significant role in the spread of infection between poultry flocks. This means that visitors (e.g. traders, relatives, friends) to infected poultry flocks represent a high risk of becoming contaminated directly or indirectly, emphasizing the paramount importance of on-farm biosecurity. Similarly, any visitors to non-infected flocks that have been in contact with infected poultry populations may be able to introduce infection. It also emphasizes the importance of disinfection during any control operations, and the potential risk associated with inadequate hygiene during poultry vaccination campaigns.

Assessing the risk of HPAIV H5N1 for buffer zones around compartmentalized poultry farms in Thailand (*A. Prakarnkamanant & C. Poolkhet)*

Background and methods

Thailand has successfully controlled HPAI H5N1 since the early large-scale epidemic phases in 2004-05. The Department of Livestock Development (DLD) has established a system of intensive surveillance, so that any introductions of HPAI H5N1 can be detected as early as possible. Given importance of poultry export for the country, DLD has also encouraged poultry farmers to establish disease-free compartments for their farms. In this context, risk assessments were conducted to identify and estimate the risk of HPAI H5N1 entering and spreading in the buffer zone surrounding commercial compartmentalized poultry farms. Firstly, the risk of introducing HPAI H5N1 into the buffer zone was described using a qualitative risk assessment. As a second step, a quantitative risk assessment was used to determine the importance of activities associated with fighting cock competitions for these buffer zones. A comprehensive pathway diagram of the various mechanisms for introduction and spread of HPAI virus H5N1 for buffers zones around compartmentalised poultry farms was developed. Data needed for the analysis were obtained from scientific literature and expert opinion workshops with local experts. To collect additional data in relation to fighting cock activities, a field study consisting of face-to-face interview and the field observation was conducted in 2 provinces. The quantitative model was subjected to a sensitivity analysis.

Findings

In the qualitative risk assessment, it was found that the likelihood of introducing HPAI H5N1 into a buffer zone via wild birds and live poultry was very low with varying degrees of uncertainty. The overall risk estimates for other risk pathways were considered to be negligible. Considering the high degree of uncertainty of risk estimates particularly for pathways associated with wild birds and live poultry, the overall risk estimates from this assessment must be interpreted with caution.

In the quantitative risk assessment assessing the risk associated fighting cock activities, the probability of introducing at least one HPAI H5N1 into the buffer zone was very low. Human movement was considered to be associated with a higher risk of introduction than movement of fighting cocks, equipment or vehicles.

The models were highly sensitive to the risk of HPAI H5N1 infection in areas surrounding the buffer zones.

Implications

The main findings from this work are that the risk of infection is currently very low to negligible. But this is mainly a consequence of there being no infection in the areas around the buffer zones. It is therefore of paramount importance for Thailand to maintain freedom of infection in the country, since it will otherwise be difficult to prevent introduction into buffer zones around compartmentalised poultry farms. If disease freedom was not possible, biosecurity measures for compartmentalised poultry farms would have to be enhanced.

Transmission pathways from poultry to humans (*M. VanKerkhove*)

Background

HPAI virus H5N1 first crossed the species barrier in 1997 when an outbreak of 18 human cases resulting in six deaths was identified in Hong Kong. In late 2003, HPAIV H5N1 crossed the species barrier a second time infecting a family from Hong Kong that had recently travelled to Fujian Province in China. Since 2003, H5N1 has been confirmed in domestic poultry and/or wild birds in 61 countries throughout Asia, Africa and Europe. Until end 2009, HPAI/H5N1 has infected 467 individuals in 15 countries. The number of human cases is not evenly distributed throughout the world and the age/gender distribution varies by country. By far, the largest number of human cases reported has been from Indonesia and Viet Nam each having reported more than 100 cases. No human cases have yet been reported in Western Europe or the Americas. Although the apparent case fatality rate (CFR) of HPAIV H5N1 is high (>60%), this may be an overestimate of the true CFR since relatively few seroprevalence studies have been carried out in humans to determine the number of subclinical or asymptomatic cases in countries affected by HPAIV H5N1 outbreaks in domestic or wild poultry populations.

Findings

Several epidemiologic studies have evaluated the risk of transmission of HPAIV H5N1 from poultry to humans. These studies have identified several risk factors that may be associated with infection including close direct contact with poultry and indirect transmission via the environment. However, despite frequent and widespread contact with poultry, transmission of HPAIV H5N1 from poultry to humans is very rare.

Direct routes poultry-to-human infection of HPAIV H5N1 may include contact with aerosolized virus, infected blood or bodily fluids via food preparation practices (e.g., slaughtering, boiling, defeathering, cutting meat, cleaning meat, removing and/or cleaning internal organs of poultry); consuming uncooked poultry products (e.g., raw duck blood) or through the care of poultry (either commercially or domestically). Little is understood about HPAIV H5N1 transmission via indirect routes, though recent studies have suggested an association between exposure to a contaminated environment (e.g., water; cleaning poultry cages or their designated areas; using poultry faeces for fertilizer) and infection either through ingestion, conjuctival or intranasal inoculation of contaminated water, soil or via fomites on shared equipment or vehicles transporting products between farms. Other pathways may exist but are currently unknown.

Epidemiologic investigations of human HPAIV H5N1 cases have shown that transmission of HPAIV H5N1 from poultry-to-humans is currently limited to individuals who may have been contact with the highest potential concentrations of virus shed by poultry. This suggests that there may be threshold of virus concentration needed for effective transmission and that circulating HPAIV H5N1 strains have not yet mutated to transmit readily from either poultry-to-human or from human-to-human. The mode of transmission can be quite varied throughout different countries ranging from exposure to poultry during a visit to a wet market to preparing infected poultry to swimming or bathing in ponds, which are frequented by poultry.

It is likely that direct and indirect human-poultry contact patterns differ between countries. It has been shown that there is substantial variation in the frequency of different poultry contact practices amongst populations in rural Cambodia living in close proximity to poultry. Such differences demonstrate that the potential risk of transmission of HPAIV H5N1 from poultry-to-humans is not uniform across age and gender and therefore may not be uniform within or across countries. The demographic differences in human cases of HPAIV H5N1 to date between countries may be because contact patterns with poultry differ between countries. However, it is also suggestive that the variation in HPAIV H5N1 incidence by age may not be due to exposure alone and that there may be differences by age in intrinsic immunologic susceptibility to infection, pre-existing immunity against human influenza A virus and/or clinical presentation of disease.

Implications

Several important data gaps remain in the understanding of the epidemiology of HPAIV H5N1 in humans:

First, there remains considerable scope for underreporting of human cases and poultry outbreaks and we currently lack sufficient exposure data from the confirmed HPAIV H5N1 cases around the world to fully evaluate other potential risk factors (e.g., the environment) for infection.

Second, the influence of genetic and/or immunological factors on transmission is poorly understood. Although there have been several suspected clusters of HPAIV H5N1 infection (largely among blood relatives) where HPAIV H5N1 may have been transmitted between humans, the clusters are difficult to interpret because all suspected family members may not have been tested for HPAIV H5N1.

Third, improved knowledge is needed on all potential routes of transmission of HPAIV H5N1 from poultry-to-humans and the prevalence of risky practices in human populations. Studies to date have evaluated what are believed to be the main potential routes through which people can become infected with HPAIV H5N1, but we currently lack sufficient data from the confirmed HPAIV H5N1 cases around the world to fully evaluate other potential risk factors for infection such as the role of water and other environmental factors.

In order to fully evaluate the occurrence of human-to-human transmission, a detailed exposure history needs to be collected from all suspected cases and their contacts. Direct and indirect exposure to poultry by species should also be standardized across epidemiologic studies to facilitate pooled or meta-analyses.

Collaboration between human and animal health sectors is essential to understand the risk of transmission between domestic poultry and humans. Current exposure estimates remain too general to explain the current pattern or to predict future cases of HPAIV H5N1 infection in human populations; however the results of the available studies indicate that indirect exposure to poultry through the environment may play a role in transmission. Rapid, systematic and standardized collection of detailed information on poultry contact patterns in suspected human outbreaks of HPAIV H5N1 would improve our understanding of transmission from poultry to humans. Detailed exposure information detailing direct and indirect contact should be included in all future human outbreak investigations as well as sero-prevalence studies.

HPAI Control and Prevention Measures

Because they rely on changing well established patterns of daily human behaviour, measures to control and prevent HPAI implicate complex social and economic institutions and decisions. As a first step to designing effective policies, the objectives of control strategies, e.g. control (i.e. reduction of prevalence levels) or eradication (i.e. elimination of disease/infection in specific sections of the population at risk), need to be agreed and clearly explicated. As with other infectious diseases in humans and animals, most effective control and prevention of HPAIV H5N1 can be achieved by using combinations of measures, comprising vaccination, enhanced on-farm biosecurity, hygiene at live animal markets, traceability and certification of poultry, movement control and enhanced surveillance. The most cost-effective strategic mix will vary within countries or production systems depending on the most important risk pathways. It is also essential to subject the strategy to regular review (at least on an annual basis), as well as have some idea of the different phases that are needed over time. Risk assessment allows identification of the most important risk pathways, and dynamic models can be used to evaluate the impact of different control measures and their combination over time.

A range of studies were conducted to examine different aspects of controlling HPAI H5N1, and are discussed below together with a general review of the available measures.

Vaccination against HPAI - A literature review (*J. Hinrichs et al.*)

The available literature on field vaccination experiments with commercially available vaccine indicates that antibody titres considered as protective can develop within 13 days after the first vaccination. However, with the exception of Trovac, two injections at two-week intervals are required to achieve full protection and one of the few long-term serologic response studies indicates that immunity is lost in most chicken 20.5 weeks after vaccination. In general, vaccinated birds have been shown to shed less amounts of virus than unvaccinated controls at specific times post challenge. Thus, most commercial vaccines have the potential to reduce the level of circulating virus in infected chicken populations. However, a crucial factor for achieving significant reductions in circulating virus in poultry flocks are sufficiently high vaccination coverage levels (50% to 90% immunization of at least 50% of all flocks at risk of infection) with a vaccine that protects against the circulating virus(es).

Both theoretical considerations as well as field observations show that such high immunization rates are difficult to attain in large poultry populations through vaccination campaigns and that they are even more difficult to maintain over a longer time period due to the high population turn over in short-lived commercial broiler1 and mixed-age backyard poultry flocks. There are also problems of maintaining immunity levels in long-lived commercial layer and parent flocks as the currently available vaccines do not lead to lifetime immunity. The short to medium term gains in reducing the virus load with vaccination are not likely to result in a cost-effective long-term control approach, if no additional measures are in place, because infection chains are unlikely to be totally interrupted and virus will not be eliminated from the entire poultry population.

A major drawback of vaccination is that the probability of detecting outbreaks may decrease due to a lack or reduction of clinical signs, which could lead to the silent spread of virus

[1] Theoretically close to 50% of all vaccinated broilers have been replaced by non-vaccinated birds in the 60 days required by the Vietnamese animal health system to conduct one national vaccination campaign.

(Savill 2006). The main reason for this effect may be that farmers are less likely to be able to differentiate low levels of HPAI H5N1 mortality from other common causes of poultry mortality. Incentives for disease reporting are relatively low and masking disease signs through vaccination further depresses an already low level of reporting. For northern Viet Nam, Walker et al. (2009) estimated a 45% effective vaccination coverage achieved by mass vaccination campaigns, leading to a greatly reduced transmission of virus between communes but also to an increase in the commune-level infectious period due to outbreaks remaining unreported for a longer duration. The same authors estimated that, had detection levels been maintained at pre-vaccination levels, around two-thirds of outbreaks which occurred in the 2007 wave in northern Viet Nam would have been prevented. This highlights the fact that, regardless of the underlying reasons for less rapid reporting of outbreaks, in order to translate the reductions in disease transmission following vaccination into greater gains in disease control, more effective reporting and surveillance strategies are required.

Another drawback of the extensive use of vaccination is the increased likelihood of genetic drift as seen in Mexico and the US. Therefore close virus monitoring of circulating field strains, continuous vaccine testing via challenge trials, and subsequent development of new vaccines that protect from infection with evolving field strains are an inevitable component of any longer-term routine vaccination programme. This requires considerable financial resources and supporting activities have to be based on surveillance systems that have a high probability of detecting circulating HPAI viruses even in the absence of significant clinical disease. It also requires the sharing of isolates with laboratories capable assessing the suitability of the vaccines used. At present these significant 'collateral' investments to vaccination are rarely found in countries with problems of HPAI endemicity.

Short-lived broilers, mainly chicken but also ducks, constitute a relatively large share of the standing poultry population of most countries, which, due to their rapid turnover, provide a constant and ample supply of susceptible avian hosts. Campaign-based vaccination programmes can only achieve a very low coverage in these systems, particularly if two injections are required to achieve immunity. An age-based vaccination schedule for broilers would be an option to achieve higher vaccination coverage and its maintenance over time, but the logistical requirements for age-based vaccine delivery and associated costs differ significantly from those of vaccination campaigns. The private incentives for owners of broiler flocks to regularly vaccinate replacements are low and even if owners do vaccinate, broiler flocks will remain at least partially susceptible for two to three weeks, i.e. most of their lifespan (unless Trovac is used and protects against circulating virus strains). Broilers thus represent the 'Achilles heel' of any HPAI control strategy that relies, at least to some extent, on the use of vaccination.

Although vaccination of more valuable breeder and layer flocks is generally more 'profitable' from the flock owners' perspective, the incentives to vaccinate are not constant over the production cycle and immunity of birds might have waned towards the end of their productive life. Also, as breeder and layer flocks have relatively high contact rates with other flocks and as HPAI vaccination is frequently used in these production systems, postponed detection of infection due to potential masking of symptoms by vaccination may undermine the success of a vaccination strategy in these systems. Upgrading of bio-security is likely to be safer and more cost-effective in these production systems than vaccination.

From a public health and national health security perspective the reduction of human cases of avian influenza as a means of reducing the risk of a national panic and global pandemic is most important. Human cases of avian influenza receive high media attention and the political pressure to act is high. The impact of poultry vaccination on human health risk is controversially debated in the scientific community. Human cases of H5N1 infections in China in January 2009 raised concerns about the role of vaccination in increasing the virulence of HPAI virus and masking its symptoms in poultry. Hygiene practices and awareness of risk factors for poultry to human transmission are possibly as important for preventing human infections as reducing virus shedding by vaccination.

The cost-effectiveness of national vaccination efforts need to be weighed against those of alternative measures to reduce disease spread in the national flock. In Viet Nam for example the culling strategy employed during the first wave of outbreaks led to the destruction of about 44 million birds (20% of the standing poultry population) and caused major losses to poultry owners and costs to the government. However, even this extensive depopulation of poultry flocks was not sufficient to break the chain of infection in all locations (Tuan 2007). As a consequence, the government decided to use vaccination as an additional control measure, which, in combination with a modified culling policy, reduced the number of culled poultry, but added substantial vaccination costs. On the other hand, Thailand managed to very significantly reduce or even eliminate the circulation of H5N1 virus in its domestic poultry population within 2 years without resorting to vaccination, largely through intensive active and passive surveillance combined with, progressively restricted, culling in case of outbreaks.

The high and recurrent costs, technical difficulties, and epidemiological drawbacks of large-scale, open-ended blanket vaccination programmes in national efforts to control HPAI call for careful targeting of vaccination in national control strategies, which ‘intelligently’ combine available disease control measures. In principle, vaccination can be targeted spatially, temporally, and / or by production system to maximise its impact and cost-effectiveness. Effective targeting however requires sound risk assessments, for which data and expertise are often lacking. Strengthening of the epidemiological capacity of national animal health systems would thus be a major prerequisite for large-scale use of vaccination in the control of HPAI.

Two modelling investigations were conducted in Thailand and Viet Nam, and are presented below.

Modelling the impact of control measures on the spread of HPAI virus H5N1 in Viet Nam and Thailand (*P. Walker*)

Background and methods

In late 2005 Viet Nam implemented a mass poultry vaccination campaign in an attempt to control the spread of H5N1 whilst avoiding the high socio-economic costs associated with the “stamping out” of outbreaks using mass culling around the location of an outbreak. Quantifying the changes in the dynamics of transmission around this shift in policy provides an indication of how effective vaccination has been in preventing infection and what further needs to be achieved in order to control the disease.

Only the dates at which an outbreak within a commune was reported are available. As a consequence, we it was attempted to simultaneously estimate the infectious period and the reproductive number for each infected commune. To do this a Bayesian Monte Carlo Markov technique was used to fit a spatio-temporal transmission model to the outbreak report data.

In northern Viet Nam, three waves of infection were defined for Viet Nam occurring before (late 2004-early 2005), during (mid 2005) and after (mid 2007) the initial implementation of the vaccination campaign.

Findings

Using the model for all three waves in the North of Viet Nam, the fitted model was able to highlight the areas close to the Red River Delta as being at high risk of infection but could not explain the transmission which occurred in more remote border areas based upon poultry numbers alone. A large reduction in between-commune infectivity during the wave which occurred in 2007, following the implementation of vaccination was found. Assuming this is a result of the vaccination campaign the size of the reduction this provides an estimate of a 45% effective vaccination coverage and demonstrates the potential for mass vaccination to prevent the sustained transmission of outbreaks. However, an increase in the commune-level infectious period due to outbreaks remaining unreported for a longer duration was found. This could be the result of the "silent spread of disease" where outbreaks in vaccinated flocks are more difficult to detect, a consequence of less rigorous surveillance or a reduction in the willingness to report disease. As the proportion of outbreaks occurring in ducks has increased it may also be partly attributable to differential pathogenicity in chickens and ducks. Combining the estimated reduction in infectivity (potentially due to vaccination) with the increased time taken to report an outbreak following initial infection resulted in only a minor reduction in overall risk. Thus sustained transmission in the Red River Delta was able to reoccur, producing a less intense but more prolonged wave of outbreaks.

Fitting a similar model to the spread of HPAI virus H5N1 in Thailand it was found that the model accurately highlighted the central region of Thailand as an area at high risk of sustained transmission in 2004/5 and the Khorat Plateau as a region at risk of sporadic transmission. Despite the large number of outbreaks, relative to those occurring concurrently in Viet Nam, it was found that outbreaks were being reported at approximately the same rate following the introduction of infection. It was also found that to reduce the geographical scope of transmission to the level observed required a substantial reduction in spatial transmissibility suggesting that significant progress has been made in controlling the spread of infection.

Implications

The findings for Viet Nam highlight the need for more effectively targeted surveillance in order to help ensure that the effective coverage achieved by mass vaccination is converted into a reduction in the likelihood of outbreaks occurring which is sufficient to control the spread of H5N1 in Viet Nam and suggest that more work needs to be done in order to assess the mechanisms behind the spread in the less densely populated northern provinces.
The application of the model to Thailand illustrated the importance of the highly effective surveillance conducted subsequent to the first outbreak wave.

Modelling the impact of vaccination on silent spread of HPAI virus H5N1 during the final stages of the small-holder production cycle in northern Viet Nam (*G. Fournie & D. Do)*

Background and methods

Farm visits by traders are considered to be one of the main risk factors for introduction of HPAI virus H5N1 to poultry flocks. Therefore, the end of the poultry batch production cycle is a high risk period for the introduction of disease into a farm due to potential contact with potentially infected birds bought elsewhere by the trader or contamination associated with the trader. The risk is further increased for small-scale producers as it can take several days to sell an entire batch. Thus, if the virus is introduced into the flock during this period, it may spread silently within the batch, birds being sold before significant increases in clinical disease or mortality are observed. This may result in multiplication of the virus on the farm, before the batch is sold, and potentially multiple introductions into the market chain through the movement of multiple batches of infected birds.

A study on the feasibility of a tracing system for poultry was carried out in Northern Viet Nam in 2008. Trade practices were recorded for 68 small-scale commercial farms (i.e. <2000 birds/batch). This data was used to develop a stochastic model at the flock level. The analysis is restricted to broiler chickens. The end of the batch production cycle is characterized by the number of baskets needed to sell the entire production batch, and the time needed to sell all these baskets.

Findings

For at least 50% of farms, it took between 2 to 5 days to sell batch. This proportion may have been underestimated as all baskets sold at farm gate were not recorded. Our model predicts that morbidity and mortality will remain low up to a week after disease introduction. For a flock of 2000 birds, on average less than 5% and 2% of birds will show disease signs or die from the disease at the farm, respectively. The number of infected baskets released at the farm gate will increase as the time needed to sell the batch becomes longer. The slope increases with the total number of released baskets (Figure 20). Vaccination of 50% of the flock will be sufficient to achieve a significant reduction (up to 70% reduction) in the proportion of infected baskets released at the farm gate (Figure 20). However, if the disease is introduced at any time during the batch production cycle, incomplete protection at the flock level can lead to silent spread of infection, and thus to an extended infectious period. Therefore, the number of infected baskets released at the farm gate will increase up to 350% compared with an unvaccinated flock (Figure 21).

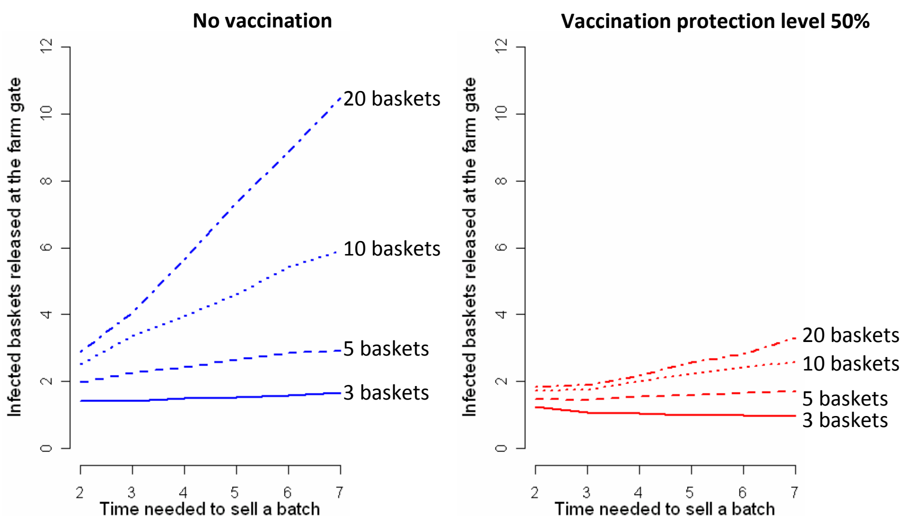


Figure 20: Number of infected baskets released at the farm gate as a function of time needed to sell a batch and total number of baskets sold (blue - unvaccinated flocks, red - vaccinated flocks)

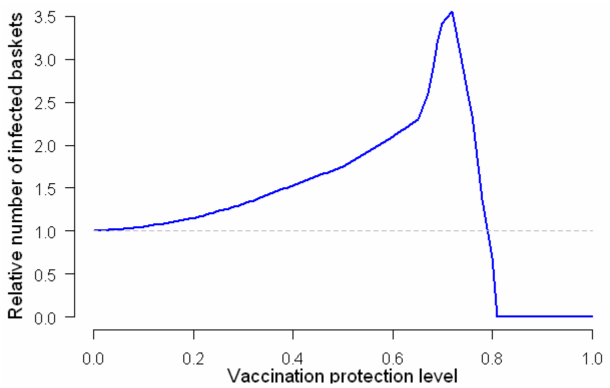


Figure 21: Relative number of infected baskets released at the farm gate as a function of the vaccination protection level

Implications

Poultry traders represent an increased risk for introduction of HPAI virus H5N1 to poultry flocks during the final stages of the poultry production cycle. This can then lead to silent amplification of the virus during the short period until all birds from a particular batch have been sold, which in turn may result in further amplification by the trader spreading the virus to other poultry flocks when purchasing birds or through contact at the live bird market. The impact of vaccination on the movement of infected animals will depend on the 'at risk period' for disease introduction into a farm. Therefore, the risk of disease introduction and the production system characteristics of poultry farms should be investigated and taken into account when designing vaccination programmes.

Biosecurity – some general considerations (*J. Otte*)

Biosecurity does not come in 'black or white' but in shades of grey, that is an operation is not either biosecure or bio-insecure. Biosecurity is incremental, i.e. one measure can be put on top of another, and sensibly should address the biggest risk(s) first. This, however, means that biosecurity is to a large extent context-specific and a number of interventions have made the point that although in qualitative terms we know how the HPAI H5N1 virus may move, there are no hard figures as to the relative importance of different pathways in different production systems. Everything else being equal, 'tighter' biosecurity measures should lead to decreased disease risk, but everything else is never equal. Thus there is no strict correlation between apparent and real biosecurity.

As all investments, investing in biosecurity is subject to the law of diminishing returns and it is neither economically efficient, nor biologically feasible, to reach 100% biosecurity. But this is also not necessary: the combined effect of all disease control measures should lead to the interruption of flock-to-flock transmission, and thereby gradual elimination of infection from domestic poultry. For privately funded investment in biosecurity the benefit to the individual needs to at least cover the cost over the lifetime of the investment. Given that investing in biosecurity has a fixed cost component, cost per bird protected will be lower for larger production units than for smaller production units, hence economic incentives are different (in addition to the fact that larger flocks have more transactions and therefore often more risky contacts than small flocks).

Unlike vaccination, biosecurity 'kills several birds with one stone' and returns at the beginning of the 'biosecurity function' are high. If context-specific (i.e. proven to work and not requiring radical changes in a given environment and production system), the introduction / improvement of biosecurity is potentially pro-poor rather than anti-poor, provided producers have access to the required capital and knowledge, and are given sufficient time and support to adapt.

The above transition should be ‘subsidized’ to some extent by the international donor community. After all the international donor community is investing in HPAI control for the benefit of its own human (and poultry) populations (else why not target diseases of higher priority to poor poultry producers such as ND?) and has a history of providing subsidies to its own agriculture, much of which go to firms rather than farms. The most important issue is how to ensure that these ‘subsidies’ go to where they should go to do what they are intended to do. It is unrealistic to expect the large integrators to pick up the bill of upgrading somebody else’s biosecurity – it is much easier (and cheaper) to raise the barrier to entry into / stay in the poultry business.

‘Carrots need to be complemented by sticks’, so ‘bad’ behaviour should be punished and ‘good’ behaviour rewarded. It is difficult to devise incentive schemes along these lines, particularly as a negative side-effect may be disease concealment, but nevertheless it should be an underlying principle. These ‘rules’ need to be clear at the outset and ‘top-down changes as the epidemic unfolds’ clearly undermine any confidence producers may have (and that is normally not very much) in their animal health authorities. Currently, it seems that large offenders get compensated while bureaucratic hurdles prevent compensation from reaching smallholder producers.

Enhanced biosecurity has been used by Thailand as a key measure from protecting commercial poultry farms from infection with HPAIV H5N1. Risk assessments were conducted to assess the effectiveness of these measures. In Indonesia, risk assessments are being conducted to examine the risk pathways for transmission between semi-commercial flocks and from these to backyard flocks. It is likely that the mechanisms are broadly similar between both countries.

A poultry tracing scheme for smallholders in Viet Nam: Results of a feasibility study (*R. Metras et al.)*

A key tool in effective disease control is the tracing of infection during an outbreak. In addition, it will provide incentives to the various actors in the poultry production and marketing chain to take responsibility for minimising the risk of infection. Some findings of a unique traceability study are presented here.

Background and methods

A longitudinal study was conducted between July and October 2008, recruiting 68 semi-intensive (FAO sector 3) farms within Ha Noi, Ha Tay and Ha Nam provinces in northern Viet Nam. Four live poultry markets (LPMs), identified as the principal suppliers of Ha Noi city with live poultry, were selected, and all communes within the three provinces known to contain at least three farms trading with these LPMs comprised the sample frame. 14 of these were randomly selected and a random sample of farms was made based on the numbers of farms identified as coming from that commune in a previous study. Selection of farms was based on poultry type. The locations of the LPMs and communes under study are shown in Figure 22. 50% of the farms raised 425 birds or less. Of the 39 chicken farms selected, all were solely chicken farms, whereas 8 of the 29 duck farms were mixed duck and chicken farms. The median number of traders used was 1, and 32% of farms consistently used the same traders.

When a ‘batch’ of birds (defined as a group of birds transported by one trader at one point in time) was due to be released from any of the farms of study, a veterinarian attached a plastic tag to a leg of each bird. The batch was weighed and this was recorded this along with the date and farm identification code to a radio frequency identification (RFID) tag, which was attached to the batch. 315 ‘batches’ of poultry were released from 64 farms over the study period. At each of the study markets, market inspectors monitored batches for RFID tags. When found, the batch was weighed again and a visual inspection made for untagged poultry. A batch was classified as non-traceable if it either contained untagged birds or experienced a weight change of more than 10% of the farm weight. Finally, a mixed effects logistic regression model including farm as a random effect was used to evaluate possible risk factors for batch traceability.

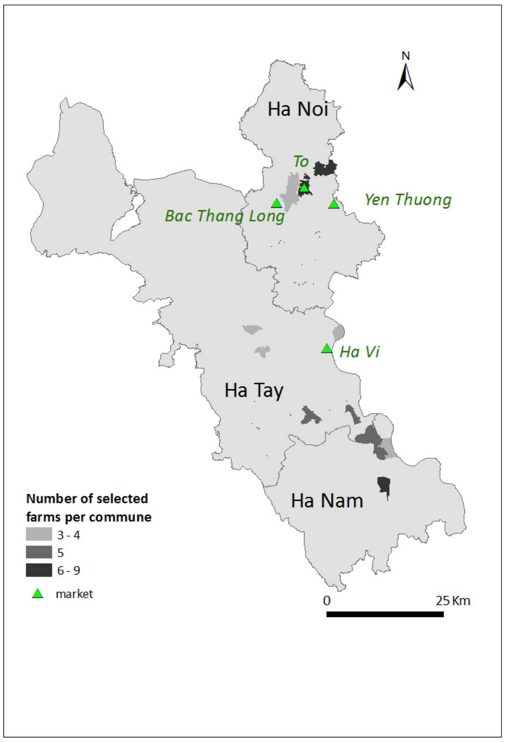


Figure 22: Map of Ha Noi, Ha Tay and Ha Nam provinces at the time of the study

Findings

The number of batches released ranged from 0 to 32, with a median of 4, and these were released on an average of two days over the study period (range: 0-7). The median batch weight was 210kg, although this ranged from 30 to 985kg. A total of 117 batches (35% of the batches released) from 48 farms arrived at one of the study markets over the study period. Yen Thuong market did not receive any batches. Of those batches arriving at the market, 50% arrived on the day of farm release, although the maximum duration of travel was recorded as 98 days. 21 batches (18%) contained birds without tags, and the median number of untagged birds was 70. 44 batches (37%) underwent a change in weight of more than 10% (32 batches lost weight, 12 batches gained weight). 67 (57%) of the batches arriving at the markets were classified as ‘traceable’. Assuming that addition of untagged birds without a change in weight represented both addition and removal of birds, batch changes between farm and market can be summarised as shown in Figure 23. Both arriving at the market on the same day as farm departure and trading with 2 or less traders were found to be associated with a batch being traceable (odds ratios 4.9 [1.6-15.6] and 7.0 [1.7-28.1] respectively).

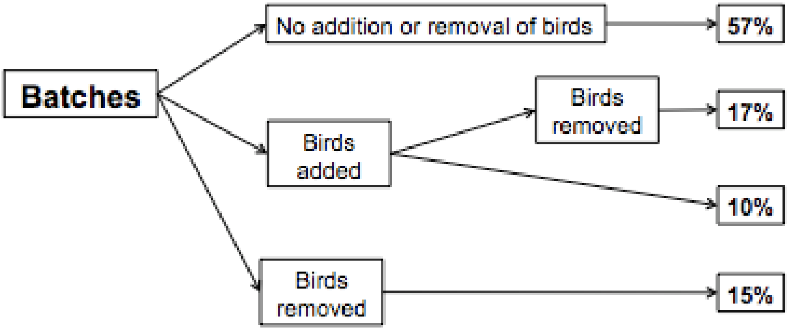


Figure 23: Flow chart demonstrating suspected batch changes between farm and market

Implications

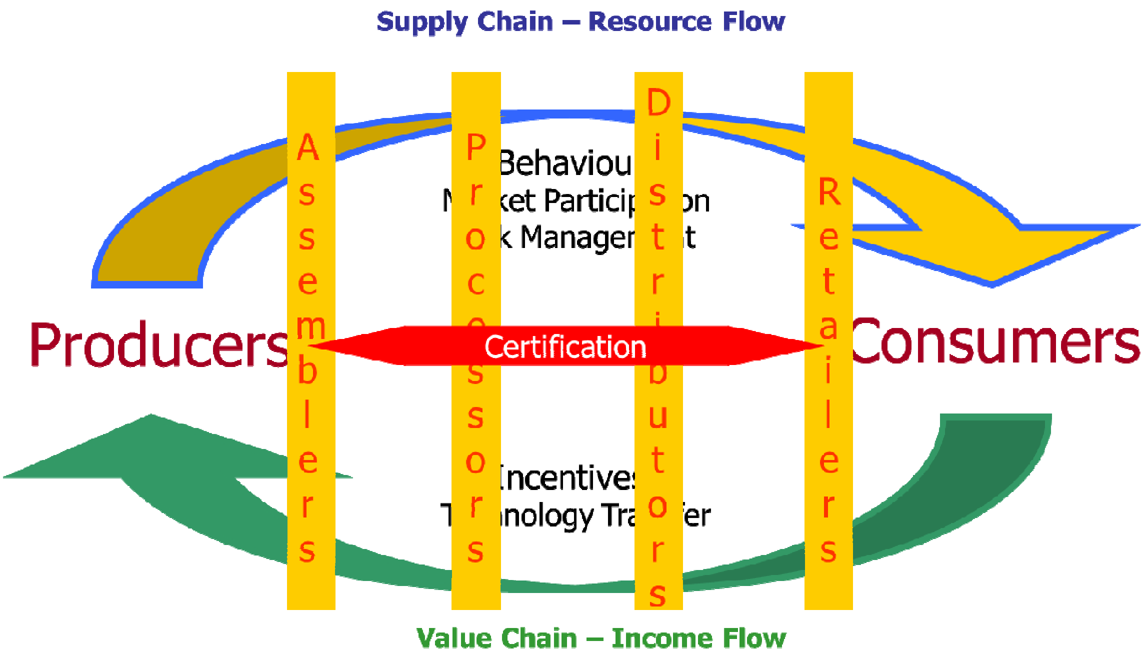
This is the first study to investigate poultry traceability in Viet Nam, and details a tracing system which could potentially be employed at a larger scale. Our results suggest that traceability of those batches arriving at the markets of study was quite high, even in the absence of incentives for this. Addition and removal of birds from batches between farm and market appeared to occur at similar frequencies. It is not known why this occurs, but it is possible that it is performed in order to ensure a suitable number of birds to justify paying to enter the market. The type of trader used (wholesaler, assembler or retailer) was not found to be associated with batch traceability, although other trader-associated factors were. This suggests that traders (or farmers' use of traders) may present a 'control point' for improving traceability. There are two main caveats to the interpretation of these findings – firstly, the selection process used means that the descriptive findings cannot be extrapolated to all farms in the provinces under investigation. Secondly, no inference was made relating to those batches which never arrived at market. It is possible that these batches were sent to other markets (the selection process meant that although the communes chosen were known to trade with the markets, the individual farms chosen may not, and so may have sent their birds to other markets in the area). However, another likely possibility is that those batches which were missing included those from which all the birds were removed en route (i.e. non-traceable batches), resulting in considerable selection bias. Further investigation, possibly incorporating questions directed to the trader relating to intended market destination, would be required to investigate this further.

Certification – Results of a pilot study in Ha Noi (*J Ifft et al.*)

Highly pathogenic avian influenza (HPAI) associated with the H5N1 virus strain first occurred in the GMS in Viet Nam in late 2003, causing severe mortality in affected flocks. Given that the virus has crossed the species barrier between poultry and humans and caused human fatalities, national governments and international agencies are intensively studying measures to control the spread of the disease. The strategic options considered included 'restructuring' the poultry industry in ways that could threaten the livelihoods of smallholder backyard producers.

This project undertook a pilot study for an alternative approach, promoting pro-poor H5N1 risk reduction, using the demand side of the poultry market to achieve higher food safety standards. In this approach, smallholders contribute voluntarily to the global commons of disease prevention, improve their livelihoods, and displace costly and inefficient government intervention in disease surveillance and control. Modelled on organic, fair-trade, and other specialist product marketing strategies, this product certification pilot was intended to combine risk management with product quality development, correcting for negative surveillance/control effects and opening the potential for private incentives to improve product quality and incomes for all participants in food value chains.

Figure 24: Overcoming Market Uncertainty



Methods

The pilot study targeted markets in the inner districts of Ha Noi, as well as Bac Thang Long wholesale market. A questionnaire survey provided detailed information about the dynamics and key actors in the local live poultry supply chain. A second component of the study assessed the feasibility of establishing a private certification system for individual birds in the Vietnamese poultry value chain.

- Pilot Project to test market free range chicken from a certified supply chain in 4 markets (cho) in the inner districts of Ha Noi
- Household survey of Ha Noi residents living near the markets
- Economic experiment with survey participants
- Coordination with project market vendors

Findings

Our general findings suggest that certification can promote virtuous quality cycles that combine risk reduction with higher product value and incomes along supply chains of low income market participants, including smallholder farmers, individual traders, and market vendors. Salient findings of the pilot study were:

- Ha Noi households exhibit significant willingness to pay for chicken 'traceability'
- Taste (breed) is also very important, i.e. a premium chicken product in Viet Nam, in addition to having a credible safety guarantee, must be free range
- We find no evidence that better-off households are moving away from local chicken, a traditional product

Implications

It is important to emphasize that this approach addresses not only the HPAI risk issue, but three larger priorities for the Government of Viet Nam. Conceptually, the pilot was situated at the intersection of economy-wide goals: Public Health Enhancement, Privatization, and Trade Policy as reflected in WTO global and bilateral SPS standards. Three general implications follow from the supply chain activities carried out for this project.

- Local chicken production systems should be included in policies and initiatives to improve biosecurity
- Biosecurity and poverty reduction can be advanced with incentive compatible, privately financed quality schemes like certification
- Field experiments are a promising way to estimate consumer valuation of traceability, especially when a market does not exist

On the basis of this pilot project, it is recommended that the Government of Viet Nam consider scaling up activities to promote certification of smallholder poultry. to the national level.

Market Hygiene and Rest Days - Impact of implementation of control strategies in live bird markets on dynamics of HPAI virus H5N1 (*G. Fournie*)

Trade with live poultry in South-East Asia involves a complex network linking poultry farms mainly through poultry traders and through live poultry markets. Markets are considered to have a very significant role in the amplification and spatial spread of infectious disease outbreaks, as was demonstrated during the FMD outbreak in UK in 2001 where ruminant livestock traded through the Longtown market within the first week following the first case resulted in spread of infection across large parts of the country. It seems logical that measures need to be applied that reduce the risk of spread through a live poultry market, and possible measures are increased market hygiene and disinfection, combined with rest days, as has been implemented successfully in Hong Kong.

Here, we describe the results from a theoretical model examining possible control strategies at live bird markets in Viet Nam.

Background and methods

Live bird markets (LBMs) are suspected to play a crucial role in the endemicity of H5N1 avian influenza in south-east Asia. They may be able to sustain silent circulation of avian influenza viruses and be a source of infection for poultry farms. Thus their role in the transmission cycle should be considered in the design and implementation of control strategies.

Two models were developed. A stochastic market model was developed to assess if factors related to management of poultry can produce conditions for silent perpetuation of HPAI virus H5N1 in a population of highly susceptible poultry. The disease is transmitted directly by contact and indirectly by the contaminated environment. Using a stochastic meta-population model, the potential effect of rest days during which LBMs are emptied and disinfected was investigated to modulate the dynamics of HPAI virus H5N1 within the poultry sector. A vertical production system was assumed with a unidirectional flow of poultry comparable to the one in use in Hong Kong where poultry are moved from farms to a single wholesale market, and then on to retail markets. The infection can spread by commercial poultry movements, and by indirect contacts between farms, between farms and retail markets, and between retail markets.

Findings

In the market model, the introduction of a single infected bird followed by daily introduction of susceptible birds and virus amplification can lead to high prevalence of infection in LBMs. For a low turn-over period (i.e. poultry spend short time at market), the model predicts that infected birds will be sold and slaughtered before showing disease signs or dying due to the disease, independent of prevalence level. With the meta-population model, when market-to-farm transmission dominates, frequent rest days will be more effective than interventions applied on farms (i.e stamping out, vaccination) for reducing disease transmission within the poultry sector. In all scenarios in which market closure (i.e. banning of live bird market trade) results in flock reproduction numbers being reduced below the threshold value of one, weekly rest days achieve this same level of reduction.

Implications

HPAI virus H5N1 can be sustained silently within LBMs depending on the time spent by poultry in markets and the frequency of introduction of new susceptible birds. Therefore, these features need to be taken into account when identifying “at risk” markets and designing surveillance programs. Furthermore, rest days seem to be an effective strategy for controlling the disease, patterns of contacts and risk of transmission between farms and markets being important for determining which interventions are best suited for local circumstances and at which levels they should be applied. The rationale behind banning of LBMs needs to be well justified, particularly where live bird trade is an important part of local culture, and in such cases rest days may be a more appropriate intervention.

Financing Disease Control and Pandemic Preparedness

Animal disease as an externality (*D. Zilberman et al.*)

To support more socially effective HPAI policy, this project seeks to strengthen the public economics perspective on control the spread of zoonotic diseases like Avian Flu. The human activities that affect the spread of disease and can be affected by policy interventions do not conform to conventional policy prescriptions from standard public economics. Contagious diseases have features of negative externalities, actions that unintentionally may hurt others, since their spread is largely determined by choices individual farmers make without regard to collective risk. However, these are also stochastic externalities – low probability, high impact events. This contrasts with most externality problems, which have higher degrees of predictability. Secondly, most externalities result from situations that benefit farmers, while activities that lead to the spread of zoonotic diseases arise under distress: farmers have their own flock infected, and their response to infection may induce further spread of the disease. For these reasons, the traditional remedies to externality problems – taxes or payment for environmental services, do not apply to our problem and we need different solutions. Furthermore, the concerns for distributional effects of policies may prevent implementation of harsh policies like severe penalties on risk contribution (to disease spread), even when they may enhance efficiency.

Developing an economic model of farmer response to stochastic externalities under distress, we have been able to derive properties of an optimal policy intervention, one that reduces the likelihood and damage of pandemics, while sustaining the livelihoods of smallholders. This model also recognizes that the policymakers operate under uncertainty about farmers' choices and that available disease control technologies, including diagnostic tools, vaccination and precautionary efforts, are limited in their efficacy.

A useful policy package will lead to more efficient resource allocation. To reduce the magnitude of pandemics and protecting livelihoods of farmers, a mandatory insurance program may be needed, where farmers pay a certain premium to be reimbursed for disease control damage. The payments affect and are affected by farmers' behavior, i.e. farmers may lose the right to being compensated if certain protective actions were not taken. In some cases, farmers may be taxed for some of the externalities that they cause, but the insurance payments can also serve this purpose by covering losses of culling programs and other side effects of the disease.

Given the apparent weakness of information currently available to policymakers on these issues, we recommend more intensive data development on risk perceptions and willingness to pay for livestock insurance. This evidence will support public good research to develop improved disease control and monitoring technologies will be worthwhile. Creating the right financial incentives for farmers to internalize their risk externality will more effectively decentralize collective risk management more effectively than conventional control measures, that are perceived as adversarial by farmers. Moreover, these policies can be readily extended from domestic to multilateral policy, with concomitant efficiency gains and reduced re-infection risk.

Multilateral perspective on HPAI prevention (*D. Zilberman et al.*)

Influenza virus is a perennial companion of human society, posing substantial direct threats to human lives and livelihoods as well as animal populations. Realistic investments to manage pandemic risk, including spending on research, public health, and agro-food practices, may seem large as individual commitments, but they are small relative to the cost of averted morbidity, mortality and economic damages. It is important to recognize that prevention of highly contagious disease is a global commons, with economic benefits to each nation commensurate to their living standards and population size. Even in countries with high per capita health expenditure, however, domestic investments can only reduce a fraction of pandemic risk. At the same time, financial constraints in lower income countries limit their ability to reduce domestic and therefore global risk. This reasoning supports a strong case for significant and sustained multilateral coordination to combat highly contagious diseases, with cost sharing based on economic loss aversion and targeting based on cost-effective risk reduction. Such an approach would, among other things, entail significant investments by high income countries to reduce disease risk and incidence in lower income countries.

To support more evidenced-based approaches to global health strategy, we developed an economic model of the expected value of pandemic disease prevention. Based on best available outbreak, mortality, and actuarial data, our results suggest that present commitments to research and public health practice related to influenza prevention and management are far below the value that could be realized by higher investments. In particular, we estimate that the current cost of saving a life from increasing such spending is a fraction of the statistical value of human life in most countries, but dramatically smaller for OECD actuarial values. Moreover, in very populous countries like China and India, lower per capita loss estimates are offset by enormous numerical incidence at comparable mortality rates. For these reasons, both the high income and high population countries have a strong justification to spend more on flu prevention and mitigation.

The second challenge is to target increased spending. In the age of globalization, highly contagious diseases pose risks everywhere, regardless of where they originate. For this reason, countries that have already achieved high levels of disease suppression may remain vulnerable to infection from areas with higher incidence or ambient outbreak risk. The economic benefits that individual nations draw from a commons of global disease prevention are roughly proportional to their current living standards, as this is a proxy for the magnitude of damages that would arise from worker disability, mortality, and other economic disruptions. Thus, regardless of the geographic origin of such diseases, wealthier countries have a greater economic stake in protecting this commons, and should thereby be willing to make greater investments to conserve it, regardless of where those investments are made. It is in everyone's interest that preventative investments be allocated most efficiently, and to economists this means the place where one dollar yields the largest reduction in risk of pandemic origination. In the case of HPAI, for example, most experts believe that the most cost-effective risk reductions can currently be concentrated in the so-called 'epicentre' countries of Southeast Asia, where there dense human and livestock populations live in close daily proximity.

To inform general policy insights into this question, we developed a model to estimate the expected benefits from additional investment, assessing performance in terms of the implied statistical value of lives saved. Under alternative assumptions, we estimated the cost of a statistical life saved to be roughly US$450,000 - US$1.67 million in low mortality pandemic scenarios and US$41,700 - US$66,700 under high mortality. To provide context for these numbers, the United States Environmental Protection Agency (USEPA) uses US$6.9 million as the statistical value of a life saved. The US per capita GDP is roughly US$47,000, while the worldwide per capita GDP is US$10,400, implying a heuristic worldwide statistical value of a life saved (based on the US standard) of roughly US$1.53 million. This figure suggests that a billion dollar annual investment in safety is justified if it saves, on average, only 654 people per year.[2] If our assumptions are reasonable, and a US$10 billion annual influenza risk management investment reduces expected fatalities of a pandemic by 10%, then the cost of a statistical life saved is commensurate with the worldwide value, relying on more conservative WHO mortality estimates. Thus, if a ten billion dollar annual investment instead reduces fatalities by 20% under low mortality or just 10% under higher mortality, then it is a real bargain for humanity.

While these results are only indicative, it is clear from this analysis that higher investment in pandemic aversion can be worthwhile from a global perspective, the value to individual players depends on the costs they incur and the benefits they gain. However, the stakes for high income countries in the global commons of disease prevention are clearly greater, and so therefore would be their optimal investment levels. The reasoning laid out above suggests a strong rationale of self-interest for significant and sustained commitments to coordinate multilateral investment. This would follow a two stage process. First, individual countries could assess their financial commitment based on the value of averted economic losses. Second, effective institutional coordination would be needed to allocate these combined resources most risk-effectively around the world.

[2] By comparison, about 35,000 people die from pneumonia each year in the US alone.

Conclusions and Policy Implications

Poultry industries in the GMS

- Poultry production in the GMS is heterogeneous, with the use of different species, different production and marketing systems and the provision of a range of products and services. Typically, poultry are an integral feature of smallholder agriculture, where the majority of households keep a small flock of 'indigenous', dual-purpose birds to meet household consumption needs, social obligations and minor cash expenses, the latter by sales through informal, live bird marketing channels. This traditional, extensive poultry production system is virtually ubiquitous and comprises by far the majority of poultry producers.
- Smallholder poultry keepers tend to specialize in traditional bird varieties, which command higher prices for their taste and are raised in traditional low-input systems.
- Simultaneously, however, intensive, industrial poultry production systems have been established, particularly in Thailand. The traditional extensive and the industrial poultry production systems are extremes, between which 'hybrid'/'intermediate', systems exist, combining characteristics of the other two (e.g. partial scavenging with feed supplementation, indigenous birds crossed with industrial poultry lines, thereby relying on 'formal' input supply systems), operating at intermediate scales (hundreds of birds), and mostly relying on 'traditional', informal live bird marketing networks. Each production model has advantages and disadvantages and none is likely to disappear completely.
- In Thailand, large-scale industrial poultry production is one of the economy's most important sources of animal-derived food, employment, and income. In Cambodia and Lao PDR, the 'formal', industrial poultry sector occupies a minor share in national poultry production, while the situation in Viet Nam is intermediate between that of Thailand and Cambodia / Lao PDR.
- Conditions for smallholder poultry production have not significantly changed in Cambodia (or Lao PDR?) while the situation in Viet Nam is somewhat intermediate with 'erratic' application and lifting of poultry production (and sales) bans and plans (of plans) for livestock production zones.

Poultry supply chains

- Traditional, low-volume poultry supply chains support livelihoods across extended networks of low-income people through production, distribution, processing, and marketing.
- In Thailand, investigations of the smallholder poultry supply chain, suggests that recent changes in market conditions, as an indirect result of the HPAI outbreaks, are making it very difficult for small-scale poultry farmers to sustain their rural enterprises. Despite the absence of large outbreaks since mid 2004, there have been significant movements out of the native chicken sector during 2006 and 2007. Households who grew chicken in the past continue to do so for own consumption, but they presently see sharply diminished prospects of a livelihood from this form of livestock.
- With respect to industrial poultry production, it will be difficult for many independent commercial farmers to remain in the 'business'. The high fixed costs of processing, controlled primarily by the integrators, are one example of the barriers prohibiting entry of independent farms into the system. Moreover, there are obstacles to entering into contracts with integrators. The high costs required to build the necessary infrastructure and difficulty of securing loans without collateral, make it unlikely that low-income

households would be able to enter into any stage of industrial poultry production. Even farmers that presently have contracts may have difficulty adapting to the current hyper-competitive conditions if they are required to make expensive upgrades to farm infrastructure.

- Consumer perception of ‘quality’ is continuously evolving and these consumer reactions in turn influence which supply models will prevail. The industrial sector has adapted to HPAI by exerting increasing control over every stage of production and emphasizing their safety standards in their marketing campaigns. Additionally, in Thailand, because of export restrictions and changing consumer demands, processing plays an increasingly important role in the organization of poultry production.
- In Viet Nam (Ha Noi) over half of survey respondents report never visiting a supermarket, whereas nine out of ten are within 15 minutes of a wet market. These wet markets sell live and whole fresh local chickens, while supermarkets sell frozen birds and fresh cuts of industrial chickens. Live birds are cheaper than slaughtered ones and live chickens are preferred because customers believe they can determine their quality and health.
- Although the market share of smallholder poultry production is diminishing, market-oriented smallholder producers still constitute the vast majority of ‘commercial’ poultry production units. In the GMS, as elsewhere, their market interactions are governed by verbal agreements and informal contracts - smallholders and small enterprise downstream intermediaries are deeply embedded in networks of customary trading and mutual insurance. Trust, reliability, credit, conflict resolution, and contract enforcement are main components of these relationships.
- Results from Ha Noi consumer surveys reveal consistent preference for traditional poultry varieties as well as significant concern about and willingness to pay for food safety. Together, these represent a price premium that could finance HPAI risk reduction and higher producer incomes.
- Close to two-fifths of respondents regularly buy chickens that had government certification stamps, but these are not seen as a credible certification.
- As in Viet Nam, Thai consumers also still exhibit clear preferences for local chicken varieties. But, although there is a distinct preference for local chicken, three-quarters of all purchases were other types of chicken. Initially, it was hypothesized that the high price of local breeds limited their demand. However, consumers rated price as the third or fourth most important attribute, while safety was rated the most desirable attribute in every province. Half of respondents said that they were not satisfied with the safety of the chicken they regularly purchased. When asked why they were concerned about the safety of the chicken, the most common response in every province was unsanitary market conditions.

HPAI H5N1 disease risk and control measures

- In the initial epidemic waves, HPAI risk in Thailand and Viet Nam was statistically associated with duck abundance, human population and rice cropping intensity but less strongly with chicken numbers.
- In Viet Nam, the two main HPAI risk clusters (Red and Mekong River Deltas – RRD & MRD) not only coincide with irrigated rice areas in the lowlands, but also with areas of good market access and high poultry transaction frequency.
- Traditional small-scale backyard poultry producers do not appear to have been the main spreader of HPAI H5N1 virus in the initial waves of infection, and there is no conclusive evidence that smallholder poultry present HPAI outbreak risks that are commensurate with the control resources that have been targeted at them. Indeed, on a headcount

basis it appears that smallholders present much lower national risk than larger scale producers.

- A striking feature of the different epidemic waves in Thailand and Viet Nam is that they did not appear to be synchronous, which raises questions about the underlying factors that may define 'hot' periods during which increased virus circulation can be expected.
- Thailand has experienced only a very small number of outbreaks since the major outbreak waves in 2004. The very small number of outbreaks that have occurred since then are believed to be associated with live poultry trade and cock fighting activities of backyard farmers.
- In Viet Nam, the poultry trading network has an important role in the spatial spread of infection. The direct or indirect contact potential resulting from the overlap through visiting the same communes between individual poultry traders' contact networks can provide effective spread of HPAIV H5N1 over a well defined geographical space.
- A significant amount of HPAI risk seems to arise from information failures and incentive failures in poultry supply chains, such as inadequate compensation and extensive preventive culling. This has been recognised by Thailand's DLD and largely rectified by a combination of measures including increasing awareness about risk factors, adequate compensation, introduction of compartmentalisation and more focussed culling, thereby contributing to the highly reduced risk of outbreak occurrence since the first outbreak wave in 2004.
- In the RRD the predominant virus clade(s) have changed over time while the original clade still dominates in the MRD. This suggests different mechanisms of introduction and maintenance between the RRD and MRD. Northern Viet Nam seems to be subject to more frequent introductions of virus from southern China, whereas the MRD may have a local reservoir of circulating virus.
- In Viet Nam the within-flock reproductive number of infection (R0) has been significantly reduced in the fourth epidemic wave (vaccination-based control policy) when compared to the second epidemic wave (depopulation-based control policy). However, the mean within-flock R0 of the fourth epidemic wave was still not significantly below unity.
- A transmission model for the North of Viet Nam confirmed the RRD as a hotspot for sustained onward transmission. A similar model in Thailand highlighted areas around and to the North of Bangkok and, to a far lesser extent the Khorat Plateau in the east of Thailand as areas at risk of onward transmission given epidemiological conditions such as those leading to the 2004 wave.
- The occurrence of smaller outbreaks between larger epidemic waves supports the hypothesis of the presence of fairly widespread and endemic infection in Viet Nam, possibly among domestic and wild water birds.
- Thailand has not used poultry vaccination, but instead focused national control efforts on detection (x-ray surveys), culling, prohibition of grazing duck production, information campaigns targeted towards increased awareness and bio-security. Thailand has managed to achieve and maintain a very low risk of outbreak occurrence for several years now, with only sporadic outbreaks being reported.
- As demonstrated by the continued occurrence of outbreaks in Viet Nam, 'modern' industrialized country approaches to transboundary animal disease (TAD) control (ring culling, movement bans, etc) did not fulfil the objective of HPAI eradication, despite massive cost to the national government, commercial poultry producers, and, above all, 'subsistence' household poultry keepers.
- During the 2007 wave of outbreaks, control measures, including vaccination, appear to have been successful in significantly reducing the daily level of transmissibility between communes. However, this was offset, to a certain extent, by an increase in the time it

took for outbreaks to be reported within a commune. This gave rise to an extended commune-level infectious period, in comparison to previous waves in both Viet Nam and Thailand and resulted in a less intense but longer lasting wave of outbreaks.

- By reconstructing the ‘epidemic tree’ (i.e. the network of which commune infected which) it was possible to examine the role this increase in the commune-level infectious period had upon the 2007 wave. Had the rate of detection matched that observed during the preceding 2005 wave, the analysis found that an expected 80% of the outbreaks would have been averted and the wave would have been controlled 70% more quickly, with a 40% probability that the wave would have died out within the first ten outbreaks. This highlights the potentially large gains in control which can be achieved by improving detection and suggests it may be worthwhile exploring more targeted surveillance strategies.
- Mass vaccination, as used by Viet Nam, undoubtedly contributed to reducing HPAIV spread and human exposure but did not eliminate virus circulation. The achievable coverage with mass vaccination campaigns is not sufficient to break infection chains. Without concomitant efforts to improve disease detection, mass vaccination campaigns are an unsustainable HPAI control instrument in situations where backyard chicken, broilers, and ducks represent a large share of the national poultry flock.
- The high level of temporal and spatial dispersion observed in outbreaks in Viet Nam since introduction of large-scale vaccination in 2005 suggests that significant changes in the mechanisms of transmission and spread have occurred. Possible factors involved are an increase in the proportion of outbreaks which are not being detected or in the relative importance of ducks.
- The continued occurrence of outbreaks in the GMS is likely to be caused by different mechanisms across the region, largely dependent on the distance to the border of southern China. The closer that border, the greater is the phylo-genetic variation amongst isolates over time which suggests relatively frequent introductions from China.
- Mechanisms for local maintenance of virus presence are unclear, but are particularly important in southern Viet Nam (and bordering areas of Cambodia) since introductions from outside the region seem to be less common. In official OIE reports, unvaccinated ducks have been implicated on various occasions as the cause of outbreaks in that region. The area within the MRD where the outbreaks occurred is known for a high duck density.
- Overall, geographic areas with high density of poultry production appear to be able to maintain virus infection, whereas outbreaks in low poultry density areas are either not detected or do not occur.
- Domestic duck production (linked to paddy rice growing) is probably one of the key mechanisms for maintenance of infection.
- There appears to be a non-negligible risk of continued introductions of HPAIV H5N1 into the GMS from southern China, particularly in northern Viet Nam and possibly Lao PDR.
- Transmission models, whilst able to capture the dynamics in the RRD well, are unable to account for the level of risk of outbreaks in communes near these borders based upon poultry populations alone, suggesting the existence of other risk factors.
- The estimated interval between time of infection and report in Thailand was comparable to that during outbreaks in Viet Nam pre-vaccination (2004/5 wave). As the Thai wave involved approximately six times the number of outbreaks than in Viet Nam, this suggests that the impact of surveillance efforts upon the size and scale of spread is likely to vary between regions and different waves of outbreaks.
- Large-scale vaccination does not eliminate infection (e.g. Viet Nam), whereas a control strategy without vaccination involving a combination of activities including targeted

surveillance such as practiced in Thailand around compartmentalised poultry production units appears to be able to almost eliminate infection. Compared to vaccination, market hygiene improvements appear to be more cost-effective.

- Overall, control measures in place during the 2007 wave of outbreaks in Viet Nam reduced the number of communes capable of spreading infection by an estimated 11%. This was achieved at a far lower social and economic cost than during previous waves. However these gains have to be balanced against the cost of maintaining levels of effective protection in an endemic situation. As estimates suggest that the infectious period has increased following vaccination, the impact of waning levels of immunity as the initial impetus to vaccinate is lost, coupled with the effects these changes may have upon the ability to detect outbreaks, remains an issue which needs to be addressed.
- Gains in detection would have had a large impact upon the scale and duration of both the 2007 wave and any which may occur in the future supporting the notion that more targeted surveillance may be necessary for effective control.
- HPAIV H5N1 now appears to be endemic parts of the GMS and domestic and (especially) external public resources for control measures will be difficult to sustain at the previous levels. For this reason, privately financed animal health strategies, such as certification and contracting, may provide more effective long term risk reduction.
- Transboundary transmission risk within the GMS appears to be high and Thailand, Lao PDR and Viet Nam are exposed to the risk of HPAIV introduction from southern China, suggesting an urgent need for more determined multilateral policy coordination. It will be difficult to effectively utilize domestic or external resources in individual countries in the absence of such coordination.
- Even if each country within the GMS would conduct highly effective control programmes, eradication of HPAIV H5N1 from the GMS seems impossible as a result of the risk of re-introduction from southern China.

Policy implications

- Disease control authorities need to recognize that the risk of disease is a combined result of biological processes and economic behaviour of livestock keepers, their input suppliers, their downstream market partners, and of agents within the disease control system itself. ‘Conventional’ HPAI control strategies pose adverse incentive problems and significant long term fiscal obligations.
- Policies that disrupt livelihoods may drive production and trade underground and thereby unintendedly increase disease risk. On the other hand, allowing the regional poultry trade, in its current form, poses risks to public health and large-scale producers, in addition to the risks posed to small-holders’ poultry and their own health.
- Given the structure of current market incentives, smallholder poultry keepers are unlikely to adopt compulsory bio-security measures. Diseases are part and parcel of their everyday experience and local responses are determined by local cultural rather then by imposed technical rationales.
- Any attempt to formalize markets without maintaining low transactions costs will displace low income participants.
- Consumers (from both lower and higher income groups) continue to exhibit a preference for local poultry breeds and are willing to pay significant premia for this preference.
- It appears that ‘certification’ can promote virtuous quality cycles that combine risk reduction with higher product value and incomes along supply chains of low income market participants, including smallholder farmers, individual traders, and market vendors.

- There is potential for introducing a tracing scheme for poultry, as was demonstrated with a pilot study in Northern Viet Nam.
- Research and investment to enhance monitoring / surveillance efficiency at low cost is a major priority.
- Mitigation of collateral impacts through supporting coping mechanisms is likely to enhance social effectiveness of public and private HPAI risk management programmes.
- There is a direct link between the perceived value of poultry and the optimum disease management approach. Higher valuation of live poultry will increase the care taken, possibly enhancing monitoring efforts and thereby reducing the culling radius. Enhancing the value of poultry, via improved marketing and safety, would ultimately result in less drastic HPAI control policies.
- Development of incentive-compatible policies critically depends on information technologies. The time lag between infection and detection, both at the bird and flock level, will affect policy design and the impact of these policies. When, in an ideal situation, detection is low-cost and immediate, one can introduce incentives like penalties for not reporting sick animals and having them culled. A penalty that is equal to the ‘social cost’ of not culling is ‘optimal’, and is superior to a subsidy for culling (compensation for sick birds) because the subsidy will result in over-production and under-investment in prevention. Also, when information is imperfect, ‘ring’ culling is a crucial disease control measure. Earlier (and more accurate) information will reduce the optimum radius of culling and thereby spare resources and livelihoods.
- In the absence of ‘perfect’ information, systems of ‘carrots and sticks’ need to be introduced. The sticks include heavy penalties for knowingly contributing to the spread of disease (i.e., knowingly exposing other flocks to infection). At the same time, awards should be given for self-reporting of infection. Compensation should not make having one’s own flock culled profitable, but should allow farmers to maintain their livelihood.
- The need for improved disease surveillance is global, willingness to pay at each location may be small, but gains may be substantial. Based on a simple statistical value of life calculation, we estimate that the gain from reduced pandemic risk is in the billions of dollars, annually. The private sector is unlikely to invest optimally in development of improved surveillance and risk reduction measures. Therefore, development of disease surveillance technologies has a global public good element, and their development should be supported by public sources.
- To deal with distributional issues within and across countries and regions, a regime of penalties should be accompanied by fixed transfers, including from third countries which benefit from reduced disease risk.

Annex 1 Workshop Programme

Avian Influenza, Public Health, and Smallholder Livelihoods

Economic, Epidemiological, and Veterinary Modelling of
Alternative Solutions

Kantary Hills Hotel
Chiang Mai, Thailand
January 8-10, 2010

Friday, January 8

13:00 Welcome
Joachim Otte, FAO

Part I – Economic Assessment: Tools, Results, and Implications

13:30 Overview of Economic Research
Roland-Holst, UC Berkeley
14:00 Economics of Risk Management from National and Global Perspectives
David Zilberman, UC Berkeley
15:00 Break
15:30 Survey Work in the GMS: Techniques, General Findings, and Policy Insights

Viet Nam – *Jenny Ifft and Ahn Tuan* (40 min)
Thailand – *Sam Heft-Neal (*30 min)
Cambodia – *Sam Heft-Neal* (30 min)
Lao PDR – *Drew Behnke and Phinseng Channgakham* (40 min)
Wrap-up – *David Roland-Holst* (10 min)

18:00 Adjourn

Saturday, January 9

Part II – Epidemiological Assessment: Tools, Results, and Implications

09:00 Overview of Epidemiology Research
Dirk Pfeiffer, RVC London
09:30 Assessing risks of H5N1 in buffer zones around compartmentalised poultry farms in Thailand
Apisit Prakarnkamanant / Chaithep Poolkhet
10:00 Quantitative risk assessment of HPAI H5N1 in Indonesia
Solenne Costard / *Will de Glanville*
10:30 Break
11:00 Modelling the impact of vaccination on silent spread of Highly Pathogenic Avian Influenza H5N1 during the final stages of the small-holder production cycle in Northern Viet Nam
Guillaume Fournie / Dung Do

11:30 Impact of the implementation of control strategies in live bird markets on the dynamics of H5N1 HPAI
Guillaume Fournie

12:15 Lunch

13:45 Mathematical models for Viet Nam and Thailand to explore the impact of potential control measures to reduce the risk of outbreaks of H5N1 in poultry
Patrick Walker

14:15 Knowledge-driven risk mapping of HPAI H5N1 in Indonesia
Solenne Costard / Will de Glanville

14:30 Poultry trade networks in Cambodia
Maria van Kerkhove

15:15 Break

15:30 Poultry trade networks and pilot study on traceability of poultry in northern Viet Nam
Alex Mastin / Raphaelle Metras

16:00 H5N1 animal human interface
Maria van Kerkhove

16:45 Working group assignment

- Technical ‘options’ for HPAI control in relation to poultry production systems and different poultry sector composition in Mekong countries
- Institutional ‘mechanisms’ to support implementation of technical ‘solutions’
- Political economy considerations / issues that determine acceptability / success of 1 & 2

18:00 Adjourn

Sunday, January 10

09:00 Working groups

12:15 Lunch

13:45 Report of working groups to plenary
14:15 Group Discussion
15:15 Break
15:30 Workshop wrap-up and closure

Annex 2 List of Participants

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