Risks associated with poultry production systems

L.D. Sims
Asia Pacific Veterinary Information Services, PO Box 344, Palm Cove, Qld 4879, Australia.
E-mail: apvis@bigpond.net.au

SUMMARY

Every poultry farm has its own risk profile for the introduction of pathogens, subsequent development of disease, and spread of pathogens to other farms. This risk profile is determined by a complex interaction between the levels of infection in an area, the measures implemented on the farm to prevent disease, and other factors including the density of farms in the area and linkages with other farms and markets. Farm biosecurity measures reduce, but do not eliminate, the risk of introduction or onward transmission of pathogens; they include factors such as the location of farms, the physical facilities, and the operational procedures implemented. Investments in these measures are subject to the law of diminishing returns. The Food and Agriculture Organization of the United Nations (FAO) has defined four production systems based partly on the biosecurity measures implemented. Distinguishing between farms on the basis of the measures practised is important, as not all intensive poultry production units apply biosecurity measures appropriate to the level of risk of virus incursion. Experiences with highly pathogenic avian influenza viruses of the H5N1 subtype have shown that farms in all production systems have experienced outbreaks, of highly pathogenic avian influenza, and that it is not possible to blame one particular system for the genesis or spread of the disease. Nevertheless, farms that rear ducks outdoors or where poultry are sold through poorly regulated live poultry markets appear to be high-risk enterprises, especially in countries where infection is present. Enhancement of biosecurity measures is generally agreed to be the best way to minimize this risk, but not all farms are in a position to implement stringent biosecurity, especially those that rely on rearing poultry outdoors. Formal risk analysis has rarely been applied to individual farms, but would assist in determining the benefits of existing and proposed on-farm biosecurity measures and in highlighting gaps in our knowledge regarding the levels of hazard for farms.

Key words: poultry, production, systems, risks, H5N1

1 INTRODUCTION

Many different methods are used for rearing poultry. Production systems range from small, village-level scavenging poultry flocks (Kitalyi, in FAO, 1998) from which few poultry enter the formal market system, to integrated intensive operations in which large companies control all aspects of the production and marketing chain upstream and downstream from production units (see, for example, Tyson Foods, 2006). Between lies a range of systems...
Poultry in the 21st Century

– from individual farms practising industrial-type production (Sims et al., 2003) to flocks of ducks reared on paddy fields (Gilbert et al., 2006) which are often transported long distances to graze on recently harvested fields.

Each of these systems, and each individual farm or flock, has its own risk profile for the introduction of pathogens, subsequent development of disease, and spread of disease to other farms. This is influenced by a number of factors, including: the density of farms (Marangon et al., 2004), especially for agents in which rate of transmission is density dependent (e.g. airborne spread) (Truscott et al., 2007); and the linkages between different farms through production and market chains, which may lead to disease transmission that is density independent (e.g. spread via fomites) (ibid.).

This review examines the various production systems, discussing the risks they face and the risk they pose with regard to animal diseases, focusing on highly pathogenic avian influenza (HPAI) caused by viruses of the H5N1 subtype. It considers the systems’ key weaknesses and strengths in relation to disease prevention and spread, with special emphasis on biosecurity measures employed on farms. It reviews the interaction between the threat of infection and the different production systems, how the former varies over time, and the influence of this and other factors, such as farm density, on the overall risk of disease in different production systems. It also considers how these risks can be assessed and managed.

1.1 Production systems and biosecurity – some background and definitions

In 2004, the Food and Agriculture Organization of the United Nations (FAO) defined four production systems (originally referred to as “sectors”, but the term “system” is now preferred) based on the characteristics of the production methods, especially the biosecurity measures implemented, and the extent of involvement of the farm in the formal market chain (FAO, 2004b). The features of this classification system have been reviewed elsewhere (Sims and Narrod, in FAO, 2008) and are summarized in Table 1.

The term “biosecurity” has been used widely in the debate on avian influenza (FAO, 2004a; Thieme, in FAO, 2007a; Otte et al., in FAO, 2007b). In essence, it describes the sum of the measures taken to prevent incursion and spread of disease. In this paper, this term is applied specifically to farms, and refers to the hygiene and management measures taken to minimize the risk of incursion of pathogens onto individual farms (sometimes referred to as “bioexclusion”) and to minimize the risk of onward transmission to other farms if infection occurs (often referred to as “biocontainment”). Farm biosecurity practices cover a broad range of measures. These have been divided into three categories (Shane, 1997):

i) conceptual, including the choice of location for farms;

ii) structural, covering the physical facilities, such as netting to protect against entry of wild birds; and

iii) operational, covering the work procedures that farm staff and visitors are expected to follow.

Field experience suggests that breakdowns in biosecurity can occur if attention is not paid to any one of these three elements.

Farm biosecurity, in its broad sense, covers all measures used to prevent disease. There-
fore, other measures applied to individual poultry, such as vaccination, that reduce the risk of infection following virus incursion into a flock of poultry and the likelihood of onward transmission to other farms can also be regarded as biosecurity measures. However, as these are often treated separately, under the category of disease control and preventive measures (see, for example, FAO, 2004b), and are considered in detail in many other papers, they are not covered in depth here. The focus in this paper is worker behaviour and physical facilities (including farm location), which form the basis of most farm biosecurity plans and activities.

As with other measures used to control and prevent disease in poultry, farm biosecurity measures reduce, but do not eliminate, the risk of infection and disease. As a United Kingdom leaflet (DEFRA, 2006) on poultry-farm biosecurity states:

“Biosecurity means taking steps to ensure good hygiene practices are in place so that the risk of a disease occurring or spreading is minimized”.

Despite utilizing sophisticated biosecurity measures, the defences of some well-managed farms are sometimes breached by horizontally transmitted pathogens (East et al., 2006; Otte et al., in FAO, 2007b), including avian influenza viruses. This reaffirms that reliance on biosecurity measures alone will not prevent all cases of infection and disease.

In fact, there is no such thing as a totally biosecure farm – the investment required to achieve this would never make economic sense. Total biosecurity is restricted to high-

---

**TABLE 1**

**Summary of FAO production systems**

<table>
<thead>
<tr>
<th>Production system</th>
<th>Main characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 1</td>
<td>Integrated, industrialized enterprise with sophisticated, high-level farm biosecurity measures. Full control over all farm inputs and outputs (e.g. breeding stock, feed mill, slaughterhouse, processing, distribution, animal health services).</td>
</tr>
<tr>
<td>System 2</td>
<td>Commercial, intensive poultry production involving largely independent enterprises or contractors, practising moderate to high-level biosecurity. Distribution of poultry to slaughterhouses and/or to live poultry markets.</td>
</tr>
<tr>
<td>System 3</td>
<td>Commercial farms with relatively poor biosecurity. Sales are more likely to be through live poultry markets or to traders who on-sell through live bird markets. This system covers ducks and other poultry. Production may be intensive or extensive.</td>
</tr>
<tr>
<td>System 4</td>
<td>Village-level, scavenging chickens for local consumption. These small flocks are reared in village households. An occasional bird is sold locally, bartered, used as a gift or, occasionally, sold to a poultry trader for cash.</td>
</tr>
</tbody>
</table>

1 Village-level flocks from which poultry or products are sold regularly into markets outside the local district should be classified as system 3 farms.
security laboratories (and even these have, at times, failed to contain viruses).

The likelihood of incursion of a particular pathogen depends on the properties of the agent, including its means of spread and survival in the environment. This means that some agents can be kept out of farms more readily than others. For example, biosecurity measures to prevent campylobacter infections have a high failure rate (see Otte et al., in FAO, 2007b), which is probably linked to the agent’s biology and its high prevalence in nature. Other agents, especially certain parasites and agents that require close contact between infected animals for transmission, can be readily excluded.

1.2 Biosecurity and farm density

Modelling studies of outbreaks of H5N1 HPAI in Great Britain suggest that infection is likely to be extinguished if infected farms are relatively isolated, but can cause large clusters of disease in areas with high density of poultry flocks (Truscott et al., 2007). This matches field observations in earlier cases of HPAI in the United Kingdom, in which the disease was restricted to single farms or small clusters of neighbouring farms (Sims and Narrod, in FAO, 2008), and recent experiences in Italy, Canada and the Netherlands, where there was considerable local spread once virus gained access to a farm in areas with dense populations of poultry farms (Capua et al., 2003; Stegeman et al., 2004; Power, 2005).

Many of the areas with dense poultry production (so-called densely populated poultry areas) have developed without an overall master plan (Capua et al., 2003). Expansion of the poultry industry in specific locations usually occurred as a result of some economic or production advantage (such as easy access to markets, or ready availability of a supply of feed, land, etc), which then attracted other farm operators and increased the concentration of farms. A number of countries are contemplating the establishment of new livestock production zones. If designed and planned properly, these could reduce the likelihood of the spread of disease. However, it is also possible that they could increase risk if they lead to excessively high concentrations of farms (which may also emit excessive air, land and water pollutants if too concentrated and improperly regulated).

2 PRODUCTION SYSTEMS AND RISKS OF H5N1 HPAI

The current panzootic of H5N1 HPAI has focused attention on the risks associated with, and posed by, different poultry production systems. It has provided an opportunity to reflect on their role in the genesis, spread and prevention of HPAI, and has drawn a remarkably broad range of responses regarding the apparent contribution of the different production systems.

For example, many veterinarians and other poultry-industry experts regard enhancement of commercial farm biosecurity measures as the most appropriate response to this panzootic and to avian influenza generally (see, for example, TAES, 1995). Some have called for greater intensification of poultry production, or at least moves to enclosed production (Martin et al., in FAO/OIE, 2006), with a few countries even calling for the virtual elimination of “backyard” and free grazing poultry production (see, for example, MARD, 2006, cited by ACI, 2006). Others have proffered alternative, almost diametrically opposed, views suggesting that this disease is largely the result of industrialization of poultry production (see, for example, Grain, 2006; Greger, 2006). This view has also been promoted by
those opposed to so-called “factory farming” on welfare and environmental grounds (see, for example, Beyond Factory Farming, 2006).

In fact, blame for the current H5N1 HPAI panzootic cannot be attributed to any one production system, as farms in all systems have been affected and played some role in the persistence and spread of this disease (Sims and Narrod, in FAO, 2008). All production systems have their strengths and weaknesses, which are described below, although some specific production and marketing methods, notably free range rearing of commercial ducks and sale of poultry through poorly regulated live poultry markets, appear to have played a particularly important role in the genesis of this particular panzootic (Sims et al., 2005).

Despite calls by some for elimination of certain production methods, all of the current production systems are expected to persist for the foreseeable future. Even if there is an increase in intensification (as planned in some countries and likely to occur by evolution in others), smallholder and village/backyard flocks will still be present; although, based on experiences in developed countries, the proportion of poultry reared in such systems will likely diminish over time.

These flocks are most likely to persist in poorer countries, especially in places where they help to ensure financial stability for vulnerable groups and increase diversity of sources of income. In some countries, measures taken to control HPAI have already resulted in exclusion of some smaller producers from formal market chains (FAO/MARD, 2007). These households will need assistance to develop appropriate methods to prevent avian influenza and other diseases, and in some cases to retain or restore access to markets. The methods used to do this will probably differ from those used in larger-scale commercial farms, given the marked differences in production methods between the two. Small non-commercial flocks will also persist in rich countries, with some people choosing to rear poultry as a hobby, or to meet particular cultural or social needs and preferences such as rearing of game birds or desire to use freshly laid eggs.

Industrial production will also continue, although production methods will likely continue to evolve over time. Current trends suggest that this type of production will probably grow as long as demand for cheap and affordable poultry and traceability of food products increases. Free-range commercial production will also increase in places where consumers are prepared to pay a premium for poultry or eggs produced using these methods.

2.1 Biosecurity and intensive production

The use of intensive production methods does not mean that farms necessarily implement biosecurity measures appropriate to the level of risk. The outbreak of HPAI in western Canada in 2004 revealed many flaws in biosecurity practices in farms that were infected (Power, 2005). Outbreaks of HPAI in the Lao People’s Democratic Republic in 2004 were reported in commercial farms around Vientiane, but not in backyard flocks located away from the city. Several papers and articles (e.g. Grain, 2006) have suggested that this showed that intensive poultry rearing represents a higher risk than the rearing of scavenging poultry. However, such statements did not take into consideration the low level biosecurity measures practised on these commercial farms, which were deemed to be system 3 farms by several independent observers (see, for example, Rushton et al., in FAO, 2005a) and the possible occurrence of unreported disease in the village flocks.
Classifying all industrialized poultry farms together, without regard to the biosecurity measures implemented, is unhelpful and provides no indication of the likelihood of disease outbreaks on individual farms. This varies depending on the measures used to reduce the risk of infection on the farm, as well as other factors such as the presence of the agent in the area around the farm, the density of farms in the area and the measures taken to prevent infection by other farms.

For example, the risk of HPAI virus incursion into a farm is likely to be lower in infected areas where well-managed vaccine campaigns are implemented than in places where vaccination is not used. This occurs because vaccination, when applied correctly, reduces the levels of excretion in infected birds, therefore reducing the overall levels of virus in an area, and also increases the resistance of poultry to infection (van der Goot et al., 2005; Ellis et al., 2006).

2.2 Farm biosecurity and H5N1 HPAI

If a farm becomes infected with an H5N1 HPAI virus, it is an indication of a mismatch between the measures implemented and the risk of incursion. This does not necessarily indicate that the farmer has failed to implement appropriate biosecurity measures, as infection can sometimes occur even with well-designed and properly operated systems. However, in some outbreaks of H5N1 HPAI, specific deficiencies in biosecurity measures were identified (see for example DEFRA, 2007) which, had they been implemented properly, may have prevented viral entry. In others, the reason for the incursion of virus remains unknown.

Unfortunately, few field investigations of H5N1 HPAI in Asia provide sufficient detail on the biosecurity measures practised on infected farms to assess whether disease occurred as a result of poor management or whether the level of infection around the farm was such that it overwhelmed otherwise “reasonable” measures. If gains are to be made in understanding the role of different production systems with respect to this disease, future investigations should include better information on biosecurity measures, similar to that provided in investigations of the February 2007 outbreak in turkeys in the United Kingdom (DEFRA, 2007).

Only one small case-control study on H5N1 HPAI has been published (Kung et al., 2007), involving an outbreak in Hong Kong SAR. This study concluded that links to retail markets were a key factor in the outbreak, although the sample size was small and many of the cases were probably the result of local secondary spread due to proximity to infected premises. Biosecurity measures implemented at the time of this outbreak were deficient on all but a few farms (Sims, unpublished).

A study of outbreaks of HPAI in Israel in 2006 provided some general information on the biosecurity measures on infected farms. All had open sheds, but two of the affected farms (breeder farms) otherwise implemented higher-level biosecurity measures than the others. The precise means of introduction of infection to these farms was not determined, although close interactions between personnel and shared vehicles for deliveries may have played a role. The possibility of the introduction of virus by wild birds could not be ruled out (Balicer et al., 2007).

Results of case-control studies for other avian influenza viruses are also pertinent. A
study to evaluate risk factors for spread of low pathogenicity H7N2 avian influenza among commercial poultry in the United States of America (McQuiston et al., 2005) found that disposal of dead birds off-farm for rendering was a significant risk factor. Wild birds are well established as a source of avian influenza viruses, and a number of farms have been exposed due to inadequate bird-proofing, use of untreated drinking water, or contaminated feed and litter.

Studies in which an attempt was made to compare the number of cases of H5N1 HPAI in different farm types have not conclusively demonstrated relationships between the overall risk of infection with H5N1 viruses and specific farm production systems – due largely to problems of ascertainment bias. One study in Thailand (Tiensin et al., 2005) which suggested broiler farms may have been more likely to be infected acknowledged this possibility; when the study was conducted there was considerable under-reporting and non-recognition of infection, especially in subclinically infected ducks.

Recently, reported outbreaks in Viet Nam and Thailand have all been in small flocks reared under conditions of minimal biosecurity (therefore, largely production system 3), but, again, it is not known whether other outbreaks have occurred and gone unreported in farms in other systems.

Virtually all veterinarians working in the poultry industry and international agencies agree that farms practising high-level biosecurity are less likely to be infected than those with poor biosecurity, at least at the beginning of an outbreak in a particular area. Despite the larger number of inputs to industrial-style farms, the concurrent implementation of biosecurity measures can reduce the risk associated with these. There are exceptions to this rule. Minimally biosecure farms in remote locations, away from known sources of infection, are at low risk of being infected, whereas farms that purport to practise high-level biosecurity, but still engage in high-risk practices, such as sale of poultry through poorly controlled live poultry markets, are at a higher risk than would appear if only the farm facilities and management practices were examined. The rule is also less relevant in infected areas with a high density of farms – due to the potential for local transmission of virus over short distances. This can lead to the spread of infection to farms that otherwise implement appropriate biosecurity measures.

The following notes provide information on the biosecurity measures implemented in the different production systems, and factors affecting their vulnerability.

**System 1**

By definition, system 1 farms practise high-level biosecurity (if they don’t they should not be classified as system 1 farms).

System 1 operations are often large multifarm, multibarn enterprises, and as a consequence of their size, have more inputs (and outputs) than smaller farms (Otte et al., in FAO, 2007b). In addition, ownership of these farms is largely concentrated in the hands of a few large transnational companies. This allows greater control over inputs, and as these enterprises invest considerable sums in facilities and poultry, it is likely that appropriate biosecurity measures will be implemented to protect this investment.

Many of the companies operating system 1 farms work in multiple countries, and this can result in transborder movement of poultry, poultry products or equipment, which may
involve movement from infected countries to uninfected countries. The outbreak of H5N1 HPAI in a turkey flock in Sussex, United Kingdom, in 2007 (although not strictly a system 1 enterprise based on the biosecurity systems in use) demonstrated the extent of transborder trade in poultry meat through this one large company—and the risks that this can create if strict biosecurity measures are not maintained.

Risks to system 1 farms are offset by the biosecurity procedures in place and the controls these enterprises have over the source of inputs, many of which are derived from suppliers that form part of the integrated company.

System 1 farms have on occasions become infected with HPAI, but it has not always been possible to determine the reason for this. In one case, it is presumed that a combination of a high level of virus in the area around the farm and climatic conditions that facilitated dispersal of contaminated material may have played a role (Sims, unpublished).

In some countries, owners of integrated system 1 farms have strong political connections and it has been suggested (although not proven) that this may have led to collusion between government and industry and covering up of disease outbreaks (Davis, 2006). Regardless of the truth of these allegations, there is a segment of the community that remains suspicious of the motives of these companies and has lost faith in them, fearing that outbreaks in company farms may go unreported.

The only way to overcome this is to have independent, well-resourced veterinary services backed by appropriate legal powers to take action in the event of an outbreak of a disease such as HPAI. This must be coupled with strong open links between the private and public sectors.

Integrated farming operations often choose to locate their operations away from other farms, especially from farms at higher risk of infection. However, if another farmer also chooses to establish similar poultry operations in the same area, the benefits to both from isolation will be diminished. Some system 1 farms have also attempted to improve the biosecurity of system 3 and 4 flocks in the vicinity of their enterprises, to minimize the level of hazard in the area around their poultry houses.

**System 2**

Biosecurity measures for system 2 farms vary considerably, in line with the broad definition of this system (i.e. farms that practice “medium to high-level” biosecurity). Well-managed farms will have a similar risk profile to system 1 farms, whereas those at the lower end of the classification are likely to represent a greater risk. This is compounded if the farm sells poultry to multiple traders, does not practise all-in all-out management, or has direct links with poorly managed live poultry markets. The location of these farms plays an important role in the risk of infection.

Many supposed system 2 farms have been affected in the current panzootic of H5N1 HPAI. In some cases, breaches in biosecurity measures implemented on these farms contributed to the outbreaks, as was seen in outbreaks in Hong Kong SAR in 2002 where some farms had links to live poultry markets.
System 3

System 3 farms are generally considered to be the most vulnerable to virus incursion, especially large system 3 farms. Not only do these farms employ minimal biosecurity measures, they are also most likely to encounter virus through the marketing chain or potentially via contact with wild birds (e.g. grazing ducks in Asia).

Some of these farmers only rear poultry when they deem that it is likely to be profitable to do so or when they have surplus funds to invest. It appears that they are willing to take the risk that their flock may get infected (or do not have sufficient resources), and therefore invest less in facilities and biosecurity measures. In other cases, they do not own the building in which their poultry are housed and are, therefore, unwilling to invest in structural alterations that would enhance biosecurity (Pagani and Kilany, in FAO, 2007c). In so doing they potentially increase the risk for surrounding farms and those linked to the farm via the same marketing and supply chains.

Wild birds are recognized as a potential source of avian influenza viruses including H5N1 HPAI viruses. If poorly biosecure (system 3) farms are located in places that attract wild birds, the level of hazard is greater than for farms located elsewhere. This was the basis for interventions in Russia, in which poorly biosecure flocks near sites of congregation of wild water fowl were vaccinated after analysis of information from outbreaks in such farms in 2005/2006 (Irza, 2006).

System 3 farms are found in many locations – urban, peri-urban and rural. Some of these have developed from small, system 4 backyard flocks, and occupy the same site and use the same inappropriate facilities as the original flock. Often, these are located near to other poultry. In system 3 farms where poultry are allowed to range freely, the concentration of other poultry and wild birds in the area is an important factor that is likely to determine the risk of exposure.

Many outbreaks have occurred in system 3 farms, including grazing duck flocks, but a lack of denominator data prevents assessment of the relative susceptibility of these compared to farms using other production systems (Morris and Jackson, in FAO, 2005b).

System 4

System 4 farms differ little from system 3 farms except for the scale of the enterprises and the limited commercial sale of poultry in the former, most of which is conducted locally.

Although system 4 farms often implement few formal biosecurity measures, isolated system 4 farms can operate almost as a closed system, with few contacts with the commercial industry. Inputs are derived locally with minimal contact with traders. This means they can remain free from infection despite not implementing specific measures to prevent infection.

This was the case with backyard poultry in Hong Kong SAR in 1997 – very few, if any, of these birds were sold through commercial markets. This has also been described in isolated communities in Viet Nam (Edan et al., 2006). In HPAI outbreaks in the Netherlands and Canada very few “backyard” flocks were found to be infected (Halvorson and Hueston, 2006), suggesting that links between farms may be more important than proximity (unless airborne spread occurs).
Major risks for system 4 producers include human traffic in villages, wandering poultry and wild birds.

2.3 Combinations of farming systems
The mix of different farm types in a particular area is probably a more important factor than the concentration of farms in determining the overall risk for these farms. If all farms in an area practise high-level biosecurity, the risk of infection is reduced. However, if one or more farms in the area persist with high-risk practices, then the risk to all farms in the area is increased.

3 WHY DO FARMERS IMPLEMENT BIOSECURITY MEASURES?
For most large farms, commercial interest dictates that the farm owners implement biosecurity measures to reduce the risk of disease, especially if they believe that their flock is in danger of being infected and that the cost of outbreaks will outweigh the investment in biosecurity measures. To make informed decisions, farmers must understand the risks posed by their farming practices, the type of measures to implement, and the likely effectiveness of the biosecurity measures they implement. These are difficult to quantify, even for those with considerable animal health expertise.

Ultimately, the amount spent on biosecurity measures by individual farmers is an economic decision similar to other decisions relating to purchase of insurance. As with other similar decisions, it is subject to the law of diminishing returns. In addition, some farmers will choose to accept the risk of a disease outbreak and continue to engage in high-risk practices that provide few impediments to the incursion and subsequent onward spread of H5N1 HPAI viruses. This can occur if the farm owner does not have the resources to invest or cannot obtain credit, if there is no disincentive or regulation forcing biosecurity measures, or if the farmer perceives the overall risk (or cost of infection) as being low. By choosing not to invest in biosecurity measures, farmers make short-term savings, but these can be easily lost through poorer productivity resulting from the introduction and persistence of other pathogens and diseases. It can also lead to loss of entire flocks if an outbreak of H5N1 HPAI occurs.

In Australia, implementation of biosecurity measures is linked to co-funding agreements between government and industry for support in handling emergency animal diseases. This provides a strong incentive for farms to put in place appropriate measures and is supported by the various producer/poultry industry groups. Recent surveys suggest that this may be having a positive effect on farm management practices, with most commercial farms implementing the required biosecurity measures (East, 2007).

In other places, such as Hong Kong SAR, farm owners are not licensed to keep poultry unless they implement certain biosecurity measures such as bird-proofing. This is coupled with enforcement of these licence conditions.

For village-level producers, the incentives to implement biosecurity measures may differ from those of large producers. These may relate more to public health issues than to concerns about production, especially given that poultry die-offs occur regularly and in many communities are accepted as the norm in low-input systems. This is an area that warrants further research.
4 RISK ANALYSIS – RISK ASSESSMENT AND RISK MANAGEMENT RELATING TO FARMS AND FARM SYSTEMS

Most biosecurity programmes are based on some form of risk analysis, which involves identifying hazards, the pathways for their entry into farms, and the effect of existing measures taken at or outside the farm to reduce (or increase) these risks. However, most of these assessments, when they occur, are informal and probably not even identified as risk analyses by farm managers when developing and implementing farm procedures.

Generic biosecurity plans and guidelines are also available for farmers through government animal health services, universities and poultry industry associations, which are then adapted by farmers to local farm conditions (see for example University of Minnesota\textsuperscript{2}, University of California\textsuperscript{3}).

So far, there has been little use of formal risk analysis on farms, but if this technique were to be applied it could provide better information on the likelihood of breakdowns, based on existing or proposed practices. This would give farm operators and animal health authorities clear indications as to whether additional measures need to be taken to prevent disease, especially if the analysis suggests that existing procedures are associated with a high probability of disease breakdowns and spread.

The overall risk of incursion of H5N1 HPAI viruses (or other pathogens) into a specific farm is determined by a complex interaction between the levels of infection in the area (the level of hazard), which varies over time, and the likelihood of carriage of the virus into the farm.

The risk of virus incursion depends on the number of “contacts” with the world outside the farm, and the probability of each of these “contacts” involving infected or contaminated material. For example, larger farms tend to have more inputs (greater amounts of feed and greater movement of people such as catching crews and vaccination teams). However, these risks are modified by the biosecurity measures practised on-farm relating to these inputs.

Risk analysis for incursion of specific pathogens (such as H5N1 viruses) into farms in different production systems, if performed, should employ the same principles and techniques used by individual countries or states when performing import risk analysis – see OIE (2007) for details on import risk analyses. In these assessments, the farm can be considered as the “importing country” with the risk of “importing” virus depending on the level of infection in the area around the farm and the probability of virus entering the farm via each of the potential infection pathways – which in this case include animal feed, traders, wild birds, farm workers, water, day-old chicks, other items that are brought onto a farm, and direct spread of virus via dust and wind.

The risk analysis process includes hazard identification, risk assessment and risk management. The fourth component, risk communication, is used to inform farmers and workers of the need to implement appropriate biosecurity measures.

As a formal risk analysis can be costly, most enterprises would not normally opt to use this technique, even if available. The only exceptions would be large system 1 farms set-

\textsuperscript{2} http://www.ansci.umn.edu/poultry/resources/biosecurity.htm
ting up compartments for export, in which case importing countries would almost certainly demand a thorough and transparent risk analysis before accepting produce from the compartment. However, governments and industry groups would benefit from obtaining this type of information when devising control and preventive programmes.

Most veterinarians servicing the poultry industry have not been formally trained in risk analysis (Halvorson and Hueston, 2006), although they utilize the same scientific principles when developing biosecurity plans. To overcome this deficiency, and simplify the process of assessing risks, an exposure risk index has been developed that allows some comparison of the level of risk posed by different events and activities. This is based around the quantity of the hazardous material, the amount of pathogen in the hazardous material, the amount of this that is available (e.g. a mound of contaminated faeces versus faeces that is spread out over a field), the survival of the pathogen in the hazardous material, and the proximity of the material to susceptible poultry (ibid.). Use of this system correlates well with perceptions of veterinarians regarding the relative risk posed by various hazards, and could be an alternative to formal risk assessment.

4.1 Issues relating to hazard identification

Hazard identification is the process by which the potential threats to the area of interest (in this case, individual farms) are assessed. This is usually applied to specific pathogens, such as H5N1 HPAI viruses.

The best way to understand and identify hazards is to review the pathways that farms use for the introduction of items or people, and to assess where these come from and the likelihood of their being or becoming contaminated (fomites) or infected (poultry) along the supply chain. This assessment should also examine activities in the vicinity of the farm that might add to the risk, such as the presence of other farms or flocks of poultry, slaughter plants, processing plants or markets; the management procedures in place in these enterprises; and their sources of poultry or poultry meat. Market value chain analyses help to provide this information by identifying high-risk practices; this helps to overcome some of the constraints associated with disease surveillance discussed below.

Hazard identification for H5N1 HPAI in many infected developing countries is hampered by the limited availability of surveillance data. Generally speaking, these data do not provide accurate information on the infection status in any given place or area. Disease reports provide some indication of the levels of infection. However, active surveillance studies, when performed, have shown that “passive” disease reports underestimate the prevalence of infection, as clinically silent infection can occur (e.g. in ducks) and not all cases of disease suggestive of HPAI are reported to authorities. Even when active surveillance is done, it usually only gives an indication of presence of virus (if, in fact, virus is detected) in certain areas at a particular point in time.

Even when surveillance studies are undertaken, negative results do not necessarily prove the absence of infection. For example, serological studies in unvaccinated chickens are of limited value for detecting past exposure to H5N1 HPAI in a flock, due to the high case-fatality rate in infected poultry (Sims et al., 2003), and virological surveillance on apparently healthy chickens on farms is insensitive due to the limits on the number of samples that can be processed. Wild-bird surveillance on healthy live birds has failed to detect virus in
most places where this has been done, even in places where wild birds are known to have played a role in virus transmission. As a consequence, low-level infection, such as might occur in the early stages of an outbreak in a farm or in a flock of wild birds, can remain undetected.

Seasonal effects also need to be considered in assessing surveillance data. The levels of circulating virus can vary depending on the weather conditions (e.g. longer survival of virus in cool weather) and other factors such as the number of susceptible poultry being reared in the vicinity. Poultry numbers can increase prior to festivals as producers rear more poultry to take advantage of increased demand and prices. They can also increase dramatically just prior to rice harvests when additional ducks are bred to graze harvested rice paddies. Periods of wild-bird migration can also be associated with increased levels of influenza viruses in a given area.

The location and species affected are also crucial. If infection with influenza viruses is confined to wild birds, then those farms that prevent or limit direct and indirect contact between wild birds and poultry are less likely to become infected than those that do not practise these preventive measures. However, once infection is established in poultry, it is generally accepted that spread of virus is more likely to occur by contacts within the poultry industry.

In conducting a hazard analysis it needs to be recognized that infection with H5N1 HPAI will not normally persist in a flock of chickens for an extended period of time unless there is regular replenishment of susceptible poultry to the flock during the period it is infected. If there are no populations of birds in which the virus can persist, then the disease is relatively easy to contain and may even self-extinguish (at least until the next virus incursion to the area).

By contrast, live-poultry markets, where there is a constant inflow of poultry, and where a transient population of poultry is kept for more than 24 hours, provide ideal sites for perpetuation of avian influenza viruses (Kung et al., 2003). Similarly, duck flocks can probably remain infected for an extended period of time. Experimental studies suggest that individual ducks probably only excrete virus for several weeks (Hulse-Post et al., 2005), but the virus would likely take longer to transmit through an entire flock. Longevity of infection in a duck flock is also expected to increase if there is regular introduction of new susceptible birds.

As the level of threat varies over time, a two-level biosecurity system has been promoted in some places. This involves the use of a standard set of biosecurity measures under normal conditions, but enhanced biosecurity measures (in which farm inputs and visits are severely curtailed) when the threat increases, such as when new cases of infection have recently been diagnosed in the area around the farm (see, for example, OMAFRA, 2005). This works well when a disease is notified early, but in a number of cases in Asia, disease was already widespread before it was detected or reported, somewhat reducing the value of such a system.

4.2 Risk assessment
Risk assessment applied to farms should comprise a release assessment (i.e. what is the likelihood that virus outside the farm will get in to the farm?) and an exposure assessment
(what is the likelihood that virus once inside the farm will actually infect and cause disease in poultry?). Both are influenced by management systems employed on farms to reduce these risks. These are combined with an assessment of consequences to provide an overall assessment of risk. In the case of H5N1 HPAI in fully susceptible chickens, the consequences of infection are extremely serious due to the high rates of mortality produced and the losses arising from culling affected and in-contact poultry by veterinary authorities when the disease is reported.

The risk assessment should take account of existing risk-reduction measures as well as any proposed measures.

4.3 Release assessment

The main pathways that can lead to incursion of avian viruses into farms are well known (Halvorson and Hueston, 2006), and include: visitors, such as traders and work crews; manure haulage; dead-bird pick-up; off-farm labour; egg collection; allowing free ranging of poultry if this results in sharing areas with other poultry or wild birds; use of untreated water from ponds or rivers for drinking, cleaning or cooling; use of raw (not heat treated) animal feed and poor handling of feed; poor rodent control; introduction of new stock without appropriate quarantine and hygiene measures; and access of wild birds to poultry sheds, feed or water supplies.

Although it may not be possible to quantify all of these risks, several important principles apply. First, the level of risk is determined by the frequency of the event. Therefore, high-risk daily activities are often of greater consequence than similar activities that occur only a few times a year. In addition, the risks posed by these activities are influenced by the measures put in place to address them and the degree of compliance with these measures.

For example, if farm workers live off-site then they should be required to change their clothing and possibly shower when entering the farm. If this is done properly, the risk associated with this activity is lowered.

Another point to note is that the results of one survey, involving self-assessment of biosecurity measures and subsequent cross-checking by field observations, demonstrated marked differences between the perceptions of farmers regarding the biosecurity measures on farms, as recorded in a survey, and the situation on the ground (Nespeca et al., 1997). This suggests that independent audits of biosecurity procedures are valuable in ensuring that measures are being implemented.

A hazard profile can be developed for each individual farm (as shown in the hypothetical example in Table 2) based on the source of the inputs and the likelihood that these are contaminated. This uses a qualitative assessment of risk, but if appropriate data are available, a quantitative assessment should be conducted.

4.4 Exposure assessment

The effect of incursion of H5N1 HPAI virus into a flock of poultry depends on the susceptibility of the species reared (e.g. turkeys have been shown to be more susceptible than chickens), the method of rearing and the mode of introduction. For example, in the case of virus introduced to a poultry house on footwear, birds on litter are generally at higher risk of exposure to the pathogen than those in cages.
Risks associated with poultry production systems

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Factors affecting level of hazard</th>
<th>Release assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day-old chicks</td>
<td>No known infection in the province where the farm sources day-old chicks. All chicks are delivered in new cardboard containers. The vehicle used to transport the day-old chicks is fumigated daily and goes through a disinfectant bath before entering the farm.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Animal feed</td>
<td>Bulk heat-treated feed from a single company. No feed vehicle enters the premises – transfer of feed over boundary fence.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Wild birds</td>
<td>A few starlings and sparrows have been found within sheds two weeks previously. Repairs have been made to bird proofing. No major bodies of water on the farm to attract wild birds. Nearest permanent watercourse 2 km away.</td>
<td>Low</td>
</tr>
<tr>
<td>Water</td>
<td>Drinking and cooling water from a bore.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Tradespeople</td>
<td>Farm staff conduct all repairs.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Catching crews</td>
<td>All birds in one shed are sent to slaughter on a single day using own staff.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Vaccinators</td>
<td>No outside workers vaccinate.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Traders</td>
<td>All trading done by telephone. No company representatives allowed on premises.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Local spread</td>
<td>No farms within 1 km.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Dead bird disposal</td>
<td>Composted on site.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Links to live poultry markets</td>
<td>All sales direct to slaughterhouse in farm vehicles.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Farm workers</td>
<td>Farm workers are not allowed to keep poultry or visit places where poultry are kept. All staff must change clothing on entry to the farm.</td>
<td>Low</td>
</tr>
<tr>
<td>Veterinarian</td>
<td>One routine visit per month. Must change clothes and shower on entry. No contact with other poultry allowed within the previous 24 hours.</td>
<td>Low</td>
</tr>
<tr>
<td>Faeces</td>
<td>Composted on site.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Fencing/security</td>
<td>Farm securely fenced and entry gate locked at all times.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Rodents</td>
<td>Regular programme of rodent baiting. Grass kept low around barns.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Neighbouring farm</td>
<td>Nearest chicken farm is 3 km away. Village 1.5 km away with several non-commercial flocks of chickens.</td>
<td>Negligible</td>
</tr>
<tr>
<td>Other (markets roads, slaughterhouses, etc.)</td>
<td>One major road used by poultry vehicles approximately 1 km away. Nearest slaughterhouse 7 km away. No live poultry markets within 50 km.</td>
<td>Negligible</td>
</tr>
</tbody>
</table>
Consequences of exposure are modified by the use of vaccines, which can increase resistance to infection and also reduce Ro (case reproduction number) below 1 (van der Goot et al., 2005), preventing onward transmission in a flock. Vaccination has been the main method used in a number of places, including Hong Kong SAR, to increase resistance and reduce the effects if virus enters a farm, (Sims, 2007).

The stocking density of poultry in a farm can also influence the size of the outbreak. Infection can be self-limiting in scavenging poultry flocks kept at low density, and may not affect all poultry in the flock, especially if these are not housed close together at night.

Airborne spread (if it occurs) or introduction of virus via feed or water could result in a more rapid increase in the levels of disease if multiple poultry are exposed simultaneously compared with the slow onset associated with exposure of a single bird or small number of birds.

4.5 Risk management
Once the risk assessment is completed, the risk of infection is established, and the implications of various measures are determined, farmers and veterinarians should then make appropriate changes to existing biosecurity systems.

For some farms, the risk of virus incursion in the current location will be deemed to be so high that the only alternatives are to relocate the farm or to use other measures such as prophylactic vaccination to minimize the risk associated with exposure to virus once it enters the flock.

4.6 Farm biosecurity and Hazard Analysis and Critical Control Points (HACCP)-type procedures
Farm biosecurity measures lend themselves to methods based on HACCP-type management. HACCP is based around identification of key hazards, and determining critical control points along the production pathway, at which these hazards are monitored and corrective action taken if problems are detected (see, for example, Grimes and Jackson, 2001). Use of HACCP-type procedures when developing individual farm-biosecurity plans, also facilitates auditing by independent parties.

All commercial farms should have a biosecurity plan. This can range from a very simple plan for a system 3 farm to a full manual of procedures for a system 1 integrated operation.

5 BIOCONTAINMENT
So far, this paper has concentrated on measures used to limit the entry of pathogens onto farms, which reflects the view of most farmers when it comes to disease prevention. This focus on preventing pathogens from gaining entry to farms is probably based on the belief that there is more benefit to individual farmers in reducing the risk of introduction than in trying to deal with the consequences after it has occurred.

There is a public-good element in biocontainment which owners of individual units may choose to ignore. Once infection occurs on a farm, little direct benefit accrues to individual farm operators if they implement biocontainment measures. This benefit is a collective one distributed to all players in the industry (see the discussion on the Nash equilibrium presented by Otte et al., in FAO, 2007b).
Biocontainment is also imposed on farms by animal health authorities once disease is reported. This is usually achieved through combinations of movement restrictions and culling affected poultry.

Larger multi-barn farms are more likely to consider issues relating to biocontainment, as the effects of the transmission of infection from one shed to the other sheds can be significant. However, geographical and financial constraints and land-tenure issues often dictate the location and degree of separation of individual barns on farms, and distance from other farms, leading to compromises in biosecurity.

A study of poultry farms in Australia found that one of the key risk factors for seropositivity for Newcastle disease virus was proximity to other farms. This suggested that airborne spread may have been involved, although other horizontal links between these farms could not be ruled out (East et al., 2006).

Many modern enclosed poultry houses require forced ventilation to ensure the welfare of the housed poultry. The large extraction fans used can blow plumes of dust from inside sheds over considerable distances. It is still not clear whether avian influenza viruses survive in dispersed dust from farms, but this potential risk needs to be considered especially when farms are located close together (Power, 2005). Local spread of HPAI has been reported in some outbreaks (Brugh and Johnson 1986) even though avian influenza viruses are not normally considered to be spread over more than a few metres by air. Whether this local spread is due to airborne particles, flies, transfer by small birds (e.g. starlings) or local movement of people involved in control operations is yet to be determined.

When dealing with agents that can be spread by air, careful choice of the site of farms is required. Airborne spread cannot be prevented through adjustments to management on existing farms in areas with high concentrations of poultry farms (Shane, 1997).

Biocontainment depends on early diagnosis and action on infected farms. However, infection with H5N1 HPAI viruses can be present for seven days or more before being recognized in unvaccinated flocks (and possibly longer in vaccinated flocks, assuming only partial flock immunity) due to the lag phase between virus introduction and spread to sufficient numbers of poultry to cause a significant increase in mortality. This can lead to inadvertent transmission of infection if these poultry or products from them are sold. This is compounded by some farmers deliberately selling flocks that are known to be infected during the early stages of outbreaks (the short window between the first few fatal cases of disease and high rates of mortality has been exploited by observant farmers who, on detecting a slight increase in mortality, sell poultry before the disease spreads within their flock).

To overcome these problems, preventive biocontainment measures should be in place before infection occurs. This should cover issues such as farm density, direction of ventilation outputs, manure handling and dead-bird disposal. However, as these preventive measures may not be implemented voluntarily, it may be necessary to drive their implementation through the use of appropriate, enforceable regulations controlling density of farms (perhaps through a moratorium on building new farms within a certain distance of existing farms and closure (with compensation) of existing farms to reduce density) and rules for the disposal of waste material and carcasses.

In areas where the risk of incursion and subsequent transmission is high, it is reasonable to use prophylactic vaccination both to reduce the likelihood of infection and to reduce
excretion of virus if infection occurs. This approach has been applied in Italy and Hong Kong SAR.

Not surprisingly, larger farms have more outputs than smaller ones, including quantities of poultry and manure/litter (Otte et al., in FAO, 2007b). Therefore, large farms that do not implement appropriate biocontainment measures, such as on-site composting of manure before removal from the farm, can pose a high risk to other farms in the area, if they become infected.

6 METHODS FOR MINIMIZING RISK OF INFECTION INTO AND OUT OF FARMS

The general consensus, emerging from a UN technical workshop held in Rome in June 2007 (FAO, 2007d) was that many high-risk commercial practices, involving both marketing and production of poultry, exist in countries enzootically infected with H5N1 HPAI, and also in those at risk of becoming so. These practices are not restricted to any one production system.

When developing disease-control programmes, high-risk practices in all production systems should be identified and, where appropriate and feasible, modified over time. However, consideration should be given to the potential adverse effects (environmental, social, gender and economic) of any proposed changes before any significant modifications are made. Support should be provided to vulnerable members of communities disadvantaged by enforced changes. If changes to production and marketing practices are impractical, alternative disease-control measures will need to be implemented.

None of the above implies that all poultry must be housed or reared under intensive, industrial conditions.

The following section provides some suggestions on ways to enhance biosecurity in farms in each production system.

System 1

The best way to minimize risk to and from system 1 farms is to locate these away from other farms and to have clear, audited working procedures for ensuring high-level biosecurity.

Some biosecurity guides provide general guidance on appropriate separation for poultry farms and individual barns on farms (see Millar, 2004). These are of limited value for places with pre-existing farms, where the only way to apply these guidelines is through closing some of these farms. Nevertheless, if certain areas appear to have excessively high concentrations of poultry, bans on new farms in these areas are warranted, and provision of incentives for existing farms to close or relocate may be justified.

By definition, these farms already implement high-level biosecurity measures. However, these can be strengthened through compartmentalization, in which all inputs are tightly controlled and contacts with farms and suppliers outside the compartment are largely severed, so that all farms and related downstream and upstream units, such as feed suppliers and slaughterhouses in the compartment, can be defined as discrete epidemiological units.

To ensure biosecurity systems are operating properly, regular independent audits, daily compliance checks and implementation of HACCP systems will provide greater assurance of the measures implemented.
Most system 1 farms sell poultry through slaughterhouses rather than through live poultry markets; this reduces the risk of infection especially if the slaughterhouse does not receive poultry from other farms.

System 1 farms should implement regular targeted surveillance to demonstrate ongoing freedom from infection.

Often these farms self-regulate, and it is better for some overseeing of biosecurity measures to be provided by official veterinary services.

**System 2**

System 2 farms vary in the quality of their biosecurity measures. One option to strengthen these is to put in place specific standards that have to be met through farm licenses or permits, as is used in Hong Kong SAR. This must be backed by appropriate enforcement.

This can also be done through restrictions placed on access to markets, so as to only include farms meeting certain conditions, such as biosecurity standards.

Use of schemes such as that operating in Australia, where application of specific biosecurity measures is a requirement for participation in government cost-sharing arrangements in the event of serious disease outbreaks, also warrants consideration.

In places where system 2 farms sell poultry through poorly regulated live-poultry markets, attention should be paid to reducing the risk posed by these markets through improving management and hygiene and enhancing traceability and certification for poultry entering these markets (however, conditions for issuance of certificates must be scientifically sound and properly designed so as to actually reduce risk – this is not the case with much of the current certification in Asia).

As with system 1 farms, relocation may be required if the farm is located in an area where there are many other farms and the risk of infection is high. Independent biosecurity audits should be conducted to assess compliance with biosecurity plans and standards.

**System 3**

This paper has argued that system 3 farms are considered to be at high risk of virus incursion because of the lack of biosecurity measures and, in many cases, their links to poorly controlled live-bird market systems.

These farms often do not incorporate biosecurity measures appropriate to the level of risk of a breakdown. This raises a number of questions about these practices. First, increasing the size of a poultry flock from (system 4) backyard production to small-scale commercial production has allowed many disadvantaged people (especially women) to move out of poverty by taking advantage of the high returns potentially available from poultry rearing. However, this creates an externality if there is no regulation of biosecurity standards for these farms.

One solution is to modify production and biosecurity systems on these system 3 farms so that they become system 2 farms. However, this requires changes in management systems (full dependence on purchased feed) and, possibly, changes in the breed(s) reared to those amenable to intensive production. It also requires considerable investment in facilities. For many this is not economically or technically feasible.

This process can be driven by urban markets that demand “clean” certified produce.
At present this reduces opportunities for smallholders in system 3 to market their produce through legitimate channels. Small, independent system 3 farms will probably struggle to meet these market demands. Nevertheless, there is potential to develop “clean” villages or communes if all poultry-rearing households in these locations agree to restrictions on the entry of poultry and middlemen, and on methods of marketing; other disease control and preventive measures (such as vaccination); and submit to regular surveillance testing. This would require full cooperation from all poultry rearing households and community animal health workers in the commune as well as traders and others who visit. This is a relatively new concept that warrants further exploration.

Other options available for those farms that cannot upgrade are segregation of species (a major challenge in many rural areas), vaccination, small behavioural changes by poultry rearers (e.g. changing footwear before entering poultry enclosures, and not allowing visitors to enter premises) and indirect measures that reduce levels of infection in markets through better management, which reduces the likelihood of poultry traders inadvertently transporting virus from markets to farms.

Where changes to management cannot be implemented (e.g. grazing ducks in Viet Nam) there will likely be ongoing reliance on vaccination, coupled with movement controls.

**System 4**

Similar measures to those proposed for system 3 can also be adopted for system 4 flocks, in particular the behavioural changes that do not require investment in facilities. There has been a push towards confinement of scavenging poultry, but this may not be feasible for flocks in which the main advantage is the “free” feed obtained through scavenging.

Again, if husbandry methods can’t be changed, then other means to protect these poultry must be found, such as vaccination or better control of disease in production systems 1, 2, and 3, which will reduce the risk to these flocks (except in places where wild birds are playing a significant role in the spread of disease).

### 7 CONCLUSIONS

This paper has demonstrated that our knowledge of the role of different production systems in the persistence and spread of H5N1 HPAI viruses remains poor, due to a lack of detailed studies and investigations of outbreaks. This could be improved through use of formal risk assessments on a selection of farms in different production systems, and better case investigations.

Farms in all production systems have been affected by H5N1 HPAI, and appropriate measures need to be taken in all four systems to prevent infection and onward transmission of these viruses.

System 1 farms face risks because of their size, and sometimes their international trading practices, but these are mitigated by implementation of high-level biosecurity measures. System 2 farms vary markedly in their susceptibility to infection, depending on their location, the quality of their biosecurity measures and the method they use to sell poultry. Some lower-level system 2 farms represent a significant risk. If system 1 or system 2 farms are infected, there is a high probability of subsequent local spread of infection, depending on the density of farms in the vicinity. System 3 production is deemed to represent the highest
risk for incursion of H5N1 viruses, because in many parts of the world most sales from these farms are through live-poultry markets, and farm biosecurity measures are poor. System 3 production also includes grazing ducks, which are believed to have played a critical role in the genesis of the H5N1 HPAI panzootic. System 4 flocks are small and in some cases may already be largely segregated from the commercial sector – which offers some protection from infection.

If HPAI caused by Asian lineage viruses of the H5N1 subtype is to be contained, and perhaps even eliminated, all farms will be required to implement appropriate measures to minimize the risk of virus incursions and subsequent spread to other farms. This will require concerted efforts by animal health authorities and the private sector.

In many farms there is still a mismatch between the risk of infection and the biosecurity measures in place. This can be overcome by enhancing the biosecurity of farms using measures appropriate to the production system and/or by increasing resistance of poultry through vaccination and other control measures. Ultimately, this is a decision that has to be made by individual farm owners, but it can be guided by government regulations and quality information about the risks associated with different production systems and ways to overcome them.

REFERENCES


