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HPAI PRO-POOR HPAI RISK REDUCTION

Qualitative Release and Exposure Assessment on the risk of HPAI transmission between sector 4 farms and between sector 3 and sector 4 farms in Kenya

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Preface

Since its re-emergence, highly pathogenic avian influenza (**HPAI**) H5N1 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 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, multidisciplinary 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.

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Disclaimer

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More information

For more information about the project please refer to www.hpai-research.net.

Executive Summary

This study assessed the risk of transmission of highly pathogenic avian influenza (HPAI) between backyard poultry (S4) farms and between S4 and semi-commercial (S3) farms in Kenya. It was designed to complement findings of a study that had been conducted in 2007 by the DVS and FAO to evaluate the risk of introduction of the disease into the country. It followed the OIE risk analysis framework where release, exposure and consequence assessments are done successively and their risk parameter estimates combined to obtain an overall risk estimate for a given pathway. Risk questions were formulated in a stakeholder workshop that was convened at ILRI in Nairobi on 2-3 October 2008. These included:

1. What is the risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm (S4-S4) via:
    i. live birds (poultry),
    ii. fomites associated with poultry (such as cages, sacks, trucks, egg-trays),
    iii. farm staff or visitors (such as traders, vets), or
    iv. farm-bridge species (such as wild birds, dogs, vultures and vermin)?

2. What is the risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm (S4-S3) via:
    v. fomites associated with poultry,
    vi. farm staff or visitors, or
    vii. farm-bridge species?

3. What is the risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm (S3 – S4) via:
    viii. live birds (poultry) or
    ix. fomites associated with poultry?

A total of nine risk pathways were formulated (4 for the first question, 3 for the second and 2 for the third as indicated by the roman numerals above). Risk parameters were estimated using qualitative methods because data needed for quantitative analyses were not available. Data and information used in the analysis were obtained from an expert elicitation survey, project reports or published literature. The expert elicitation survey used structured questionnaires. For each question raised, respondents were expected to give the most likely answer, its minimum and maximum value, the level of confidence on the answer given (in a scale of 1 to 5 with 1= not confident, 5= very confident) and the source of the information used for reference. Risk estimates were determined as very high, high, medium, low, very low or negligible. Overall risk estimates for each pathway were obtained by combining estimates for each step of the pathway using a combination matrix described by Zepeda (1998). The level of uncertainty for each risk parameter estimate was described as low, medium or high.

The main challenges encountered in the study comprised lack of reliable data and information on the poultry sector in the country as well as the small sample size used for the expert elicitation survey. Keeping in mind these caveats, the study found that movement of infected or contaminated farm-bridge species poses a very high risk of HPAI transmission from infected to uninfected S4 farms. All

the pathways that considered an S4 farm as the source of infection exhibit high or very high levels of risk, while those based on S3 as the source of infection have either low or medium level of risk. This may be attributed to the fact that S4 farms lack capacity and incentives to implement bio-containment measures to curtail onward disease transmission. The risk of release of HPAI from S4 farms (in S4 – S4 and S4 – S3 transmission pathways) is always very high while the risk of release from S3 farms (in S3 – S4 transmission) is always medium. Equipment moved from S3 to S4 farms is the main pathway through which susceptible S4 farms could get exposed to the disease from infected S3 farms.

Although the capacity of S4 farms to implement improved biosecurity measures is low, there is a need to sensitize S4 farmers on a few bio-containment measures that they can implement to reduce the risk of release of the disease when their farm gets exposed. These include proper disposal of carcasses and confinement of poultry when there is an active disease outbreak in the village to prevent further exposure. The DVS will also need to enhance its surveillance efforts and attempt to identify and impose penalties on farms that sell off poultry in the face of an outbreak. S3 farms, on the other hand, should implement a range of biosecurity measures including provision of protective clothing to their staff, limiting visitors from coming into contact with poultry by enclosing poultry in pens or houses, prompt disposal of contaminated material, cleaning and disinfection of farm tools and equipment before and after use, and provision of disinfection baths.

To improve the quality of HPAI risk assessment for Kenya, further research will be needed in the following areas:

- identifying risk factors for disease occurrence and persistence;
- characterizing susceptibility of farm-bridge animals and bird species to HPAI so that their involvement in the transmission of the disease can be accurately determined;
- evaluating effectiveness of the various biosecurity measures;
- assessing potential for the use of risk analysis as a component of an early warning system for a risk-based surveillance strategy;
- exploring the potential for using risk analysis together with value chain analysis to determine critical control points for targeting interventions.

Abbreviations

CDC	Centers for Disease Control
DFID	Department for International Development
DVS	Department of Veterinary Services
FAO	Food and Agriculture Organization of the United Nations
HPAI	Highly pathogenic avian influenza
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
KWS	Kenya Wildlife Services
MoLD	Ministry of Livestock Development
NMK	National Museums of Kenya
NGO	Non governmental organization
OIE	World Organization for Animal Health (*Office International des Epizooties*)
PAHSP	Private animal health service provider
RVC	Royal Veterinary College (UK)
S3	Sector 3 poultry production system (see Glossary and definitions)
S4	Sector 4 poultry production system (see Glossary and definitions)
VILS	Veterinary Investigation Laboratory Services

Glossary and definitions

Source: OIE (World Animal Health Organization) 2004: Handbook on Import Risk Analysis for Animals and Animal Products: Introduction and qualitative risk analysis. Vol. I. OIE Publications, Paris.

Commodity: Animals, products of animal origin intended for human consumption, for animal feeding, for pharmaceutical or surgical use or for agricultural or industrial use, semen, embryo, ova, biological products and pathological material.

Consequence assessment: A description of the consequences of an exposure to a given hazard and the estimation of the likelihood of occurrence and magnitude of these consequences (including biological, environmental or economic effects). A causal process must exist through which exposures produce adverse health or environmental impacts which may in turn lead to socio-economic consequences.

Exposure: The condition of being subjected to a source of risk.

Exposure assessment: Identification of biological pathways necessary for an exposure of a defined susceptible population to a hazard and estimation of the probability of this event occurring. In this assessment, exposure assessment identified pathways through which a susceptible farm would be exposed to the HPAI.

Fomite: Any inanimate object or substance capable of absorbing, retaining, and transporting contagious or infectious organisms (from germs to parasites) from one individual to another.

Hazard: Any pathogenic agent that could produce adverse consequences.

Hazard identification: The process of identifying the pathogenic agents.

Poultry production sectors: Poultry production sectors can be described according to production and marketing systems:

Sector 1	Industrial integrated system with high-level biosecurity and birds/products marketed commercially (e.g. farms that are part of an integrated broiler production enterprise with clearly defined and implemented standard operating procedures for biosecurity).
Sector 2	Commercial non-integrated poultry production system with moderate to high biosecurity and birds/products usually marketed commercially (e.g. farms with birds kept indoors continuously; strictly preventing contact with other poultry or wildlife).
Sector 3	Commercial poultry production system with low to minimal biosecurity and birds/products entering live-bird markets (e.g. a caged-layer farm with birds in open sheds; a farm with poultry spending time outside the shed; a farm producing chickens and waterfowl).
Sector 4	Village or backyard production with no or minimal biosecurity and birds/products marketed through informal systems and consumed locally.

Adapted from: FAO (2010).

Poultry: Poultry include fowls, turkeys, guinea fowls, ducks, geese, quails, pigeons, pheasants, partridges and ratites reared or kept in captivity for breeding, production of meat or eggs for human consumption, or for restocking game birds, as defined by Council Directive 90/539/EEC (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1990L0539:20070101:EN:PDF).

According to the World Animal Health Organization (OIE) (and in line with the European Union's revised legislation for the control of avian influenza) poultry is defined as all birds reared or kept in captivity for the production of meat or eggs for human consumption, production of other commercial products, restocking game or breeding.

Game birds for release are legally considered as 'poultry'.

Qualitative risk assessment: An assessment where outputs of risk assessments are described using words (i.e., natural language expressions such as negligible, low, moderate, high or very high).

Quantitative risk assessment: An assessment where outputs of risk assessments are expressed numerically.

Release assessment: Identification of pathways necessary for the release of a hazard from an infected population and the estimation of the probability of this event occurring. In this assessment, release assessment evaluated pathways that would lead to the discharge of the highly pathogenic avian influenza virus from infected farms.

Risk: The likelihood of occurrence and the magnitude of the consequences of an adverse event in a susceptible population over a specified time period.

Risk assessment: The process of evaluating the likelihood of an adverse event occurring and the estimation of the magnitude of the consequences associated with it.

Risk estimation: The process of integrating results from release assessment, exposure assessment, and consequence assessment to produce overall measures of risks associated with the hazards identified at the outset.

Transparency: Comprehensive documentation of all data, information, assumptions, methods, results, discussion and conclusion used in the risk analysis. Conclusions should be supported by an objective and logical discussion and the documents should be fully referenced.

Uncertainty: Lack of precise knowledge on input data used in the risk analysis. This may also arise from poor data quality.

1 Introduction

1.1 Context

Highly pathogenic avian influenza (**HPAI**) is a viral disease of birds that affects all poultry species and wild birds (Sims et al. 2005). The recent outbreak of the Asian-lineage of HPAI was first reported in China in 1997. It then spread rapidly across Asia, Europe, Middle East and Africa and by June 2007, a total of 64 countries had reported outbreaks in poultry or wild birds (CAST 2007). Countries that were affected in Africa include Egypt, Nigeria, Niger, Cameroon, Burkina Faso, Côte d'Ivoire, Sudan, Djibouti, Ghana, Togo and Benin. The disease might have been carried along migration routes of wild water birds to densely populated areas in the South Asian subcontinent or through illegal importation of birds or poultry products from infected countries (Sims 2007).

The Department of Veterinary Services (**DVS**) in collaboration with the Food and Agriculture Organization of the United Nations (**FAO**) assessed the risk of introduction of the disease into Kenya in 2007 when neighbouring countries such as Sudan, Djibouti, Egypt and Nigeria were reporting outbreaks. That assessment indicated that the country had a high risk of being infected (Okuthe and Munyua 2008). This finding supported previous observations indicating that the country was highly vulnerable to HPAI infection because it is located under the migratory route of wild birds and that some of the commercial farms imported day-old chicks and other poultry products from France, United Kingdom, the Netherlands and Germany which had experienced limited outbreaks (Omiti and Okuthe 2008).

The present study assessed the risk of transmission of HPAI between backyard flocks as well as between semi-commercial and backyard flocks after introduction of the disease. It therefore complements the DVS/FAO study (referred to above). It was implemented as one of the activities of a multi-disciplinary project funded by the Department for International Development (**DFID**) to identify and promote pro-poor HPAI risk reduction strategies. The project is implemented by IFPRI, ILRI and RVC in collaboration with local partners, including the DVS in Kenya.

1.2 Background information on Kenya's poultry industry

Kenya has about 37.3 million poultry (MoLD 2006). A high proportion (98.2%) of this population consists of chickens. Ducks, turkeys, pigeons, ostriches, guinea fowl and quails make up the remaining 1.8% of the population. The proportions of free-ranging, layer and broiler chickens are reported as 84.1%, 8.4% and 5.7%, respectively. Up to 65% of households keep chickens; households with chickens keep, on average, about 12 birds (Omiti and Okuthe 2008).

Poultry production systems in Kenya are generally classified into three categories based on scale of production, level of productivity, functions, breeds kept and husbandry practices. These systems are conventionally referred to as commercial, semi-commercial and free-range (or backyard) production systems. FAO has classified poultry production systems into four operational sectors as defined in Glossary and Definitions. The number of poultry farms that can be classified under each of these four sectors is given in Table 1 while poultry population by province and type is given in Table 2. Rift Valley Province has the highest population of poultry followed by Nyanza and Central Provinces in that order.

Table 1. Number of poultry farms falling under commercial, semi-commercial and village production systems in Kenya

Province	Commercial (Sector 2)	Semi-commercial (Sector 3)		Village Poultry (Sector 4)	Others	TOTAL
		Layers	Broilers			
Rift Valley	1	1,975	1,132	559,266	393	562,767
Coast	1	1,088	1,030	131,457	213	133,789
Western	1	523	88	176,905	105	177,622
Nyanza	1	1,072	639	252,076	217	254,005
Central	1	4,902	10,750	115,252	980	131,885
Eastern	0	783	558	255,281	0	256,622
N/Eastern	0	6	0	9,493	0	9,499
Nairobi	2	962	9,464	7,833	192	18,453
Total	7	11,311	23,661	1,507,563	2,100	1,544,642

Note: Sectors are defined in the Glossary and Definitions.
Source: MoLD (2005); MoLD (2007).

Table 2. Estimated poultry population in Kenya in 2005 – 2006 by type and province

Province	Layers	Broilers	Indigenous	Others	Total
Rift Valley	392,353	225,979	5,617,020	92,604	6,327,956
Coast	213,200	205,700	1,972,000	185,600	2,576,500
Western	114,865	18,450	2,669,819	219,165	3,022,299
Nyanza	215,630	127,400	5,416,148	108,875	5,868,053
Central	980,314	2,149,870	1,728,763	60,849	4,919,796
Eastern	156,300	111,300	3,829,200	29,301	4,126,101
N/Eastern	1,100	-	142,400	-	143,500
Nairobi	192,400	692,700	117,500	4,600	2,207,200
TOTAL	2,266,162	4,731,399	21,492,850	700,994	29,191,405

Source: MoLD (2005); MoLD (2007).

Kenya is nearly self-sufficient in poultry egg and meat production. A consumer scare that occurred in Kenya in September 2005 related to HPAI is estimated to have caused a loss of about Ksh. 2.3 billion mainly due to reduced demand for poultry products (Kimani et al. 2006)[1].

[1] In September 2005, the Kenya Shilling exchanged at approximately Ksh. 76/US$ 1.

1.3 Approach

This study assessed the risk of transmission of HPAI between backyard farms—referred to as sector 4 (**S4**)—and between semi-commercial farms—referred to as sector 3 (**S3**)—and S4 farms when one of them is infected. The assessment focused on specific routes of transmission which had not been studied in the previous risk assessment conducted by Okuthe and Munyua (2008). These pathways include:

- movement of staff or visitors, live poultry, fomites (materials associated with live poultry such as cages, crates, sacks, veterinary equipment), or farm-bridge species (wild birds such as vultures, vermin, dogs and other scavengers) from infected to susceptible backyard farms (S4 farms);
- movement of staff or visitors, live poultry, fomites, or farm-bridge species from infected backyard farms (S4) to susceptible semi-commercial farms (S3);
- movement of live poultry or visitors from infected semi-commercial farms (S3) to susceptible backyard farms (S4).

Qualitative risk analysis was conducted due to limited resources and data required for quantitative analysis. In qualitative risk analysis, risk parameters are described in words on an ordinal scale ranging from negligible to very high (Table 3). This methodology has been described by the World Organization for Animal Health (**OIE**) (OIE 2004) and Zepeda (1998). This study focused only on release and exposure assessments and the data used to estimate some of the risk parameters were obtained from an expert elicitation survey. This survey is described in section 1.7.

1.4 Qualitative risk parameters

Table 3 presents qualitative risk parameters used in the study and their interpretations.

Table 3. **Definition of the qualitative risk parameters used in the study**

Probability category	Interpretation
Negligible	Event is so rare that it does not merit to be considered
Very low	Event is very rare but it cannot be excluded
Low	Event is rare but it does occur
Medium	Event occurs regularly
High	Event occurs very often
Very high	Even occurs almost at certainly

Source: Pfeiffer et al. (2006)

1.5 Combination matrix

Individual risk parameters estimated at each step of each pathway were combined in two successive stages using the matrix illustrated in Tables 4. The first stage involved combining risk parameters under the release and exposure assessments to obtain separate overall risk estimates for release and

exposure pathways. In the second stage, release and exposure risk estimates were combined to obtain a global risk estimate for a given pathway.

Table 4. **Combination matrix for release and exposure risk parameters**

		Parameter 2 Exposure risk category					
		Negligible	Very Low	Low	Medium	High	Very High
Parameter 1 Release risk category	Very High	N	VL	L	M	H	VH
	High	N	VL	L	M	H	H
	Medium	N	VL	VL	L	M	M
	Low	N	N	VL	VL	L	L
	Very Low	N	N	VL	VL	VL	VL
	Negligible	N	N	N	N	N	N

Source: Zepeda (1998)

1.6 Uncertainty

Each risk parameter estimate was associated with some level of uncertainty. It was not, however, possible to differentiate variability from uncertainty; both of these parameters were therefore presented as uncertainty. The different levels of uncertainties considered are described in Table 5.

Table 5. Uncertainty categories and their interpretation

Uncertainty category	**Interpretation**
Low	There are solid and complete data available; strong evidence is provided in multiple references; authors report similar conclusions
Medium	There are some but incomplete data available; evidence is provided in small number of references; authors report conclusions that vary from one another
High	There are scarce or no data available; evidence is not provided in references but rather in unpublished reports or based observations, or personal communication; authors report conclusions that vary considerably between them

Source: Pfeiffer et al. (2006)

1.7 Data sources

Data obtained from an expert opinion elicitation survey were used to estimate a number of the risk parameters. Experts were identified during the inception workshop that was held at ILRI, Nairobi on 2-3 October 2008. Participants included poultry production and disease control professionals from the Ministry of Livestock Development (**MoLD**), representatives of S3 and S4 farmers, experts from the Kenya Wildlife Services (**KWS**), National Museums of Kenya (**NMK**), Centers for Disease Control (**CDC**) and FAO. A structured questionnaire was used in the survey. The questionnaire had 3 sections covering (i) S3 farms, (ii) market operators who traded in live poultry and (iii) S4 farms. Each question required the respondents to give the most likely answer, a minimum and maximum values for

quantitative responses, the level of confidence on the information given (scored from 1: not confident, through 5: very confident) and the source of information used for reference (whether personal opinion, observation or data). For those cases in which existing data were used for reference, respondents were expected to provide the title of the project or report from which the data were obtained, authors or principal investigators, year when the data were collected or the report published. Experts from the same institution were asked to fill out one questionnaire that combined their individual opinions.

Questionnaires were sent to 15 experts via email and follow-up interviews were conducted by phone. Seven respondents returned completed questionnaires. Data collected were entered into a Microsoft Excel database and analyzed using @Risk software for risk analysis. Opinions from the experts who participated in the survey were weighted based on their levels of expertise. Any quantitative data obtained from this survey were converted into the probability categories described earlier using the outline shown in Table 6.

Table 6. Probability ranges used to convert numerical data obtained from the expert opinion survey into qualitative risk categories

Probability range	Probability value used for calculations (combined expert opinion)	Qualitative risk categories
0% through 5%	5%	Very Low
6% through 15%	15%	Low
16% through 25%	25%	Medium
26% through 54%	54%	High
55% through 100%	92%	Very High

2 Risk questions

This section outlines risk questions and pathways that were analysed. These questions were formulated in the inception workshop that was held at ILRI, Nairobi on 2-3 October 2008.

2.1 Risk question 1

What is the risk of transmission of HPAI from an infected backyard poultry farm (S4) to a susceptible S4 farm via live poultry, fomites, staff or visitors, or farm-bridge species (i.e. S4-S4 transmission)?

2.1.1 Release assessment

Pathway 1: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via live poultry traded or exchanged for breeding

Steps in the pathway:

a. What is the probability that an outbreak of HPAI in an S4 farm will be reported promptly and that clinical diagnosis made will be verified with appropriate laboratory tests?

b. What is the probability that poultry and poultry products that are destined for market from an S4 farm (either through traders or directly by a producer) or those exchanged with fellow producers will be infected or contaminated?

c. What is the probability that contaminated or infected live birds (poultry) will be sold (or given out) by an S4 farm?

Pathway 2: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via fomites associated with live poultry

Steps:

a. What is the probability that there will be contaminated materials in an S4 farm (such as faecal material or carcasses) given that the farm is infected?

b. What is the probability that feed, water and fomites (such as crates, feeding utensils, trucks and cages) will be contaminated on an S4 farm given that the farm is infected?

c. What is the probability that H5N1 virus will remain viable on inanimate objects for an appreciable length of time for it to be transmitted between farms?

Pathway 3: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via movement of farm staff or visitors

Steps:

a. What is the probability that there are contaminated materials on an S4 farm given that the farm is infected?

b. What is the probability that staff or visitors of an infected S4 farm will get contaminated while at the farm?

Pathway 4: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via farm-bridge species

Steps:

a. What is the probability that an S4 farm will have contaminated material on the farm given that the farm is infected?

b. What is the probability that farm-bridge species will come into contact with contaminated material present on an infected S4 farm?

c. What is the probability that farm-bridge species will get contaminated or infected following contact with contaminated material present on an infected S4 farm?

2.1.2 Exposure Assessment

Pathway 1: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via live poultry (traded or exchanged for breeding purposes)

Steps:

a. What is the probability that infected or contaminated spent hens or cockerels are exchanged for breeding or sold from an infected S4 farm to a susceptible one?

b. What is the probability that new birds that are introduced into a susceptible S4 farm (from markets or neighboring farms) will be allowed to join resident birds immediately without any quarantine measures?

c. What is the probability that contact between infected and susceptible birds in an S4 farm will result in an infection?

Pathway 2: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via fomites associated with live poultry

Steps:

a. What is the probability that contaminated poultry equipment (such as trays and cages) will be exchanged between infected and susceptible S4 farms?

b. What is the probability that contact between poultry and contaminated poultry equipment (fomites) will result in an infection in a susceptible S4 farm?

Pathway 3: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via movement of farm staff or visitors

Steps:

a. What is the probability that contaminated staff or visitors from an infected S4 farm will visit a susceptible S4 farm?

b. What is the probability that contaminated staff or visitors of a susceptible S4 farm will come into contact with poultry, poultry feed or equipment in the farm?

c. What is the probability that contact between poultry and contaminated staff or visitors of a susceptible S4 farm will result in infection in poultry?

Pathway 4: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via farm-bridge species

Steps:

a. What is the probability that infected or contaminated farm-bridge species will directly or indirectly come into contact with poultry in a susceptible S4 farm?

b. What is the probability that the contact between infected or contaminated farm-bridge species and poultry from a susceptible S4 farm will results in an infection?

2.2 Risk question 2

What is the risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm via fomites associated with live birds, movement of farm staff or visitors or farm-bridge species (i.e. S4 – S3 transmission)?

Live poultry was not considered here because the stakeholder workshop indicated that S3 farms were unlikely to purchase live poultry from S4 farms. Fomites associated with live birds were however considered because S3 farms might use cages or crates to deliver poultry or poultry products to S4 farms. These materials might act as fomites when moved between the farms.

2.2.1 Release assessment

Pathway 5: Risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm via fomites associated with live birds

Risk steps considered here are similar to those that have been described under release assessment of Pathway No. 2 (Risk question No. 1).

Pathway 6: Risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm via movement of farm staff or visitors

Risk steps considered here are similar to those that have been described under release assessment of Pathway No. 3 (Risk question No. 1).

Pathway 7: Risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm via farm-bridge species

Risk steps considered here are similar to those that have been described under release assessment for Pathway No. 4 (Risk question No. 1).

2.2.2 Exposure Assessment

Pathway 5: Risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm via fomites associated with live birds

Steps:

a. What is the probability that fomites associated with live birds (such as cages, crates) originating from an infected S4 farm will reach a susceptible S3 farm?

b. What is the probability that the fomites described in point (a) above will come into direct or indirect contact with poultry in a susceptible S3 farm?

c. What is the probability that the contact between fomites (with H5N1 virus) and susceptible poultry in an S3 farm will lead to infection of poultry on the farm?

Pathway 6: Risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm via movement of staff or visitors

Steps:

a. What is the probability that staff and visitors (such as veterinarians) contaminated in an S4 farm will be allowed to access an uninfected S3 farm?

b. What is the probability that the staff and visitors contaminated in an infected S4 farm will have direct or indirect contact with poultry in an uninfected S3 farm?

c. What is the probability that the contact described in step (b) will result in an infection of poultry in a susceptible S3 farm?

Pathway 7: Risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm via farm-bridge species

Steps:

a. What is the probability that farm-bridge species contaminated or infected by coming into contact with infective material in an S4 farm will come into contact, directly or indirectly, with poultry in a susceptible S3 farm?

b. What is the probability that contact described in step (a) will result in an infection in poultry in a susceptible S3 farm?

2.3 Risk question 3

What is the risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm via live birds or fomites associated with live birds (i.e. an S3-S4 transmission)?

Other possible pathways for HPAI transmission between S3 and S4 farms were not considered because the inception workshop prioritized the pathways for live birds and formites associated with live birds for assessment.

2.3.1 Release assessment

Pathway 8: Risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm via live birds (purchased directly or indirectly through markets)

Steps:

a. What is the probability that an outbreak of HPAI in an S3 farm will be reported promptly and that appropriate laboratory tests will be used to verify clinical diagnosis?

b. What is the probability that poultry or poultry products that are intended for market sale (or disposal to other farms) from an S3 farm will be infected or contaminated?

c. What is the probability that contaminated or infected live birds (poultry) will be sold out by an S3 farm?

Pathway 9: Risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm via fomites associated with live birds

Steps:

a. What is the probability that there are contaminated materials in an S3 farm (such as faecal material or carcasses) given that the farm is infected?

b. What is the probability that poultry equipment (such as trays and cages) of an S3 farm will be contaminated with H5N1 virus given that the farm is infected?

c. What is the probability that H5N1 virus will remain viable on inanimate objects for it to be transmitted from an infected S3 farm?

2.3.2 Exposure Assessment

Pathway 8: Risk of transmission of HPAI from an infected S3 to a susceptible S4 farm via live birds

Steps:

a. What is the probability that infected or contaminated spent hens or cockerels from an exposed S3 farm will be purchased by an uninfected S4 farm?

b. What is the probability that infected live birds from an S3 farm, once purchased by an uninfected S4 farm, will be allowed to come into close contact with resident birds?

c. What is the probability that the contact described in step (b) above will result in an infection of poultry in an S4 farm?

Pathway 9: Risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm via fomites associated with live birds

a. What is the probability that contaminated poultry equipment (fomites such as trays, cages) will be carried from an infected S3 farm to an uninfected S4 farm?

b. What is the probability that the contaminated materials referred to in step (a) above will come into contact with poultry in an uninfected S4 farm?

c. What is the probability that the contact referred to in step (b) will result in an infection of poultry in an S4 farm?

3 Overview of Risk Pathways

3.1 Overview

Figure 1 presents the pathways that were evaluated in the study with their release, exposure and consequences components marked with unique colour-bands. Only release and exposure assessments were covered in the study. Table 7 shows how these pathways were numbered depending on the types of farms involved in the transmission of the disease.

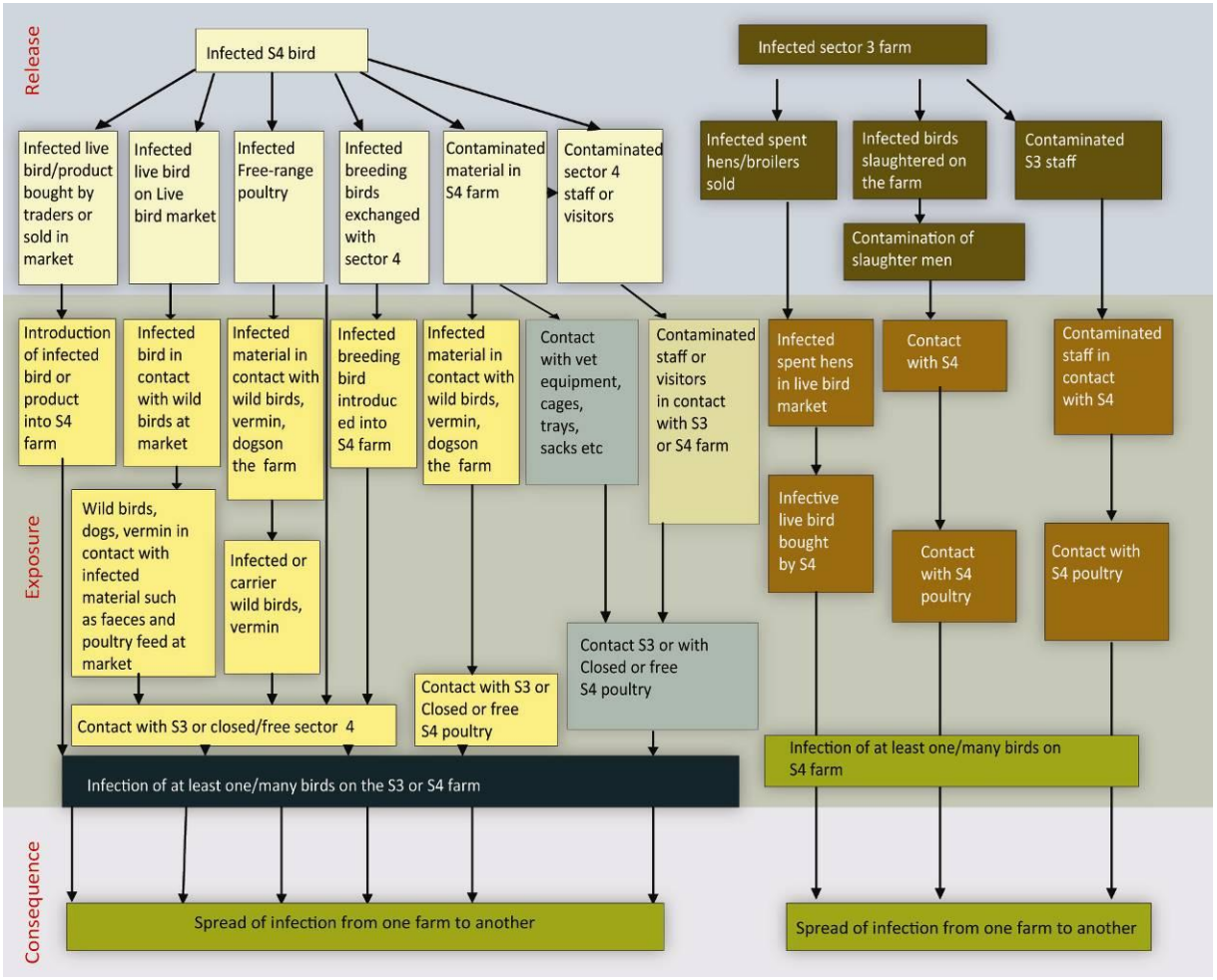

Figure 1. Risk pathways with their respective release, exposure and consequence components marked with unique colour-bands

Table 7. Numbering of the pathways assessed in the study by the types of farms involved in the transmission of the disease

Pathway	Risk question No.1: HPAI transmission between S4 farms	Risk question No. 2: HPAI transmission from S4 to S3 farm	Risk question No. 3: HPAI transmission from S3 to S4 farm
Live birds (traded or exchanged for breeding, etc)	Pathway No. 1	-	Pathway No. 8
Fomites associated with live birds moved between farms	Pathway No. 2	Pathway No. 5	Pathway No. 9
Movement of farm staff or visitors between farms	Pathway No. 3	Pathway No. 6	-
Movement of farm-bridge species from a farm to another	Pathway No. 4	Pathway No. 7	-

3.2 Release pathways

Factors that might influence the release of infection from an infected S3 or S4 farm include:

- delayed detection of infection, reporting and implementation of interventions;
- poor methods of disposal of contaminated biological material such as dead birds or faecal matter that might contaminate staff, visitors or equipment;
- sale of infected or contaminated live birds;
- movement of contaminated staff, poultry and other animals out of exposed farms.

3.3 Exposure pathways

Exposure pathways evaluate mechanisms through which uninfected farms get exposed to the HPAI virus. Farm staff, farm-bridge species and equipment (acting as fomites) get contaminated when they come in contact with infected material. Mechanisms leading to exposure of uninfected farms include:

- movement of contaminated staff or visitors into uninfected farms and a lack of effective biosecurity measures to prevent contact with poultry in such farms;
- exchange of contaminated equipment such as veterinary tools, cages, sacks or egg trays between infected and uninfected farms;
- contact between infected or contaminated farm-bridge species with poultry, feed, or equipment of an uninfected farm.

4 Release Assessment

This section reports the findings of release assessments for each of the pathways considered.

4.1 Release assessment: Risk of transmission of HPAI from an exposed to a susceptible S4 farm (S4 – S4)

4.1.1 Pathway 1: Risk of release of HPAI from an infected S4 farm via live poultry

The parameters required for this assessment are:

- probability that outbreaks of infectious diseases or significant mortality events will be reported promptly and that clinical diagnosis will be verified using appropriate diagnostic tests (most of the time, official interventions are implemented after verification of diagnosis);
- time interval between reports of an outbreak of an infectious disease being given by a farmer and implementation of response measures such as diagnosis, sampling, testing and awareness campaigns by the DVS;
- proportion of S4 farms that directly or indirectly sell off their poultry or poultry products in the face of an outbreak of an infectious disease in their farms;
- proportion of S4 farms that are likely to cull their live birds following an outbreak of an infectious disease in their farms.
- proportion of S4 farms that dispose dead birds and poultry waste material by burying or incineration;

Steps required for this release assessment are outlined in Table 8.

Table 8. Steps considered for the release assessment of HPAI from an infected S4 farm via live birds

Risk step	Data Needed	Data Sources
Probability that outbreaks of infectious diseases will be reported promptly and accurately Probability that a diagnostic test will confirm infection	- Response time (reporting to implementation of response activities) - Proportion of farms reporting significant mortality events to the DVS, private animal health service providers (**PAHSP**)	- Veterinary Inspection Laboratory Service (**VILS**), DVS Kabete: past reports of clinical disease - PAHSP
Probability that an S4 farm will sell out poultry and poultry products that might be contaminated in the course of a disease outbreak	- Farm practice and levels of hygiene and whether cleaning, disinfection or disposal practices are implemented - Volume and frequency of sales of poultry and poultry products	- S3 and S4 producers - Traders and other market actors - FAO - CDC - Value chain studies

4.1.1.1 Probability that outbreaks of infectious diseases will be reported promptly and their diagnoses verified using appropriate diagnostic tests

Description of information available

The expert elicitation survey indicated that only 16% of S4 farms would report significant mortality events in their poultry to the local public or private veterinarians. Most animal health service providers would be able to visit such a farm for clinical investigation, verification of diagnosis and provision of advice on appropriate interventions within a period of 7 days. The survey also revealed that only 14% of S4 farms cull their poultry. Very few bury or incinerate infected poultry; in fact in some areas birds that die from Newcastle disease are usually consumed. These findings suggest that the probability that outbreaks of an infectious disease will be promptly reported and its diagnosis verified using diagnostic tests is very low.

Interpretation

A majority of S4 farms rarely report outbreaks of infectious diseases to the local public or private veterinarians even if such cases caused significant mortalities. Instead, most of them sell off or consume apparently healthy chickens in an attempt to avoid mortality losses. Moreover, the DVS lacks capacity for effective HPAI surveillance and control. There is limited surveillance and documentation of infectious disease outbreaks. A majority of field veterinarians do not have access to laboratory facilities; it would be difficult for them, therefore, to verify diagnoses of most of the cases they encountered in backyard or semi-commercial farms as these farms do not have access to private laboratory facilities.

Conclusion

The probability that outbreaks of infectious diseases or any other significant mortality events will be reported promptly and a confirmatory test done to verify provisional diagnosis is low. This estimate is associated with a high uncertainty because of lack of corroboration of the information used.

4.1.1.2 Probability that poultry and poultry products that are to be sold by an infected S4 farm are contaminated with HPAI virus

Description of information available

A small proportion (6%) of S4 farms implement recommended disposal procedures for culled birds and contaminated biological materials such as feathers and faeces (Nyagah 2007). Most of these farms, if exposed to HPAI, would not be able to supply clean poultry and poultry products to their clients. This is because most S4 producers do not have capacity to implement effective biosecurity interventions that would allow for the production of clean poultry products, especially when their farms have been exposed to an infectious disease.

Interpretation

There is a very high likelihood that poultry and poultry products obtained from an S4 farm that has had an HPAI outbreak would either be infected or contaminated with the HPAI virus.

Conclusion

The likelihood of poultry or poultry products getting infected or contaminated with HPAI virus in an S4 farm following an outbreak of the disease is very high. There is a high uncertainty on the value of this estimate because of lack of adequate reference data.

4.1.1.3 Probability that live birds contaminated or infected with HPAI virus would be offered for sale by an infected S4 farm

Description of information available

According to the expert opinion elicitation survey, 60% of S4 producers would sell off their poultry in the face of an infectious disease outbreak to prevent mortality losses. Forty-seven percent of such producers sell their birds through traders. This practice is usually observed during Newcastle disease outbreaks.

Interpretation

The sale of sick or apparently healthy poultry in the face of an outbreak of an infectious disease is a common practice that has been reported in many countries. This practice has not been fully assessed but it is likely that both producers and traders have high and complementary incentives for engaging in this practice. Producers seek to avoid disease-related mortality losses whereas traders would be hoping to capitalize on frantic efforts by the producers to purchase live or dressed birds at much reduced prices. This practice encourages the dissemination of infectious diseases.

Conclusion

The probability that infected or contaminated live birds are sold off from an S4 farm that is experiencing an infectious disease outbreak is very high. This estimate is also associated with a high uncertainty.

4.1.1.4 Overall risk of release for pathway No. 1

The risk of release of the virus from an infected S4 farm through live birds is very high with high uncertainty. A summary of the information analyzed in this section is given in Table 9.

Table 9. Assessment of the risk of release of HPAI from an infected S4 farm via live birds

Risk parameter	Source	Risk Category	Uncertainty
Probability that clinical cases will not be reported promptly and their diagnosis will not be verified with appropriate diagnostic test	- Expert opinion	Very High	High
Probability that poultry and poultry products from S4 earmarked for sale in the market directly or indirectly through traders are infected or contaminated on-farm	- Expert opinion - Okuthe and Munyua (2008) - Omiti and Okuthe (2008)	Very High	High
Probability that contaminated or infected live birds (poultry) will be sold by an S4 farm	- Expert opinion - Omiti and Okuthe (2008)	Very High	High

4.1.2 Pathway 2: Risk of release of HPAI from an S4 farm via fomites associated with live birds (cages, trays, feeding utensils, etc.)

Information required:

- proportion of S4 farms that properly dispose of contaminated materials;
- proportion of S4 farms that disinfect poultry equipment such as cages, trays, etc.;
- proportion of S4 farms that lend contaminated equipment (fomites) to other farms.

4.1.2.1 Probability that poultry equipment (such as cages, egg-trays) of an S4 farm are contaminated given that the farm is infected

Description of information available
As described earlier, the expert opinion survey indicated that a large proportion (84%) of S4 farms do not observe standard disposal or decontamination procedures for biological materials such as carcasses or faeces, even when such farms are infected with an infectious disease. The risk of contamination of farm or poultry equipment such as trays, cages and other fomites in these farms would therefore be very high. These materials are also unlikely to be cleaned and disinfected before and after use (Nyagah 2007).

Interpretation
Equipment such as trays and cages can act as fomites for HPAI virus. The type of material used for making this equipment (e.g. plastic, bamboo, aluminium, other metal) influences the extent to which they can retain infectious agents. Cages made of bamboo stems, for example, are more difficult to clean than those made of metal or plastic.

Conclusion
The risk of having farm equipment being contaminated with infective material following an outbreak of HPAI in an S4 farm is very high.

4.1.2.2 Probability that the virus will remain viable on fomites for an appreciable length of time

Description of information available
H5N1 virus is mainly excreted via faeces and respiratory excretions which may contaminate the environment as well as equipment used on-farm. The survival of the virus on such fomites influences the risk of transmission: the more resilient the virus, the higher the risk of transmission. Different factors influence the viability of the virus in the environment: viral strain, temperature, humidity, pH and solar UV. As indicated in the work by de Glanville et al. (2010), because of the relatively few experiments conducted under variable conditions, a lot of uncertainty on the virus survival and the factors influencing it remains. It is thought that faecal material, as well as any other contaminated organic matter, protects the virus from being rapidly inactivated by direct sunlight, heat, detergents or disinfectants (such as calcium or sodium hypochloride) (Songserm et al. 2006). In addition, various studies show that HPAI H5N1 can persist and retain infectivity for several days, and that the conditions most favorable to virus survival are low temperatures (<17°C), slightly basic pH (7.4– 8.2) and fresh to brackish salinities (0–20,000 ppm) (de Glanville et al. 2010).

Interpretation

The length of time that HPAI virus can remain viable on fomites would allow the release of HPAI infection when farms share contaminated equipment or feeding utensils. Fomites can also be moved over large distances, particularly when farmers use them to transport live birds or products such as eggs to the market. Regions with high densities of poultry in Kenya, such as the Central Province, central Rift Valley and the outskirts of Nairobi have mean maximum temperatures of <25^{o}C that favour survival of the virus.

Conclusion

The probability that H5N1 virus would remain viable for an appreciable length of time on fomites is very high.

4.1.2.3 Overall risk of release for pathway 2

The risk of release of the virus from an S4 farm via fomites associated with live birds (cages, trays) is very high with high uncertainty.

4.1.3 Pathway 3: Risk of release of HPAI from an infected S4 farm via movement of farm staff or visitors

The types of staff and visitors referred to include employees of S4 farms, veterinarians, traders or neighbors. This pathway considers frequency of movement between farms, probability that staff and visitors come into contact with poultry, presence of infectious material on-farm and infectiousness of such materials.

Information required:

- proportion of S4 farms that properly dispose of contaminated biological material such as dead birds by burying or incineration;
- proportion of S4 farms that are likely to cull live birds in case of a contagious disease outbreak in the farm;
- proportion of S4 farms that provide footbaths for visitors and protective clothing to farm staff.

A summary of the steps considered for the release assessment are given in Table 10.

4.1.3.1 Probability that staff or visitors of an infected S4 farm will get contaminated by HPAI virus-laden material

Description of information available

The results described earlier indicated that an infected S4 farm would have contaminated material (manure and water, feeds, poultry equipment, trade equipment) on the farm. Visitors of such farms such as veterinarians, traders and neighbors would have a high chance of getting contaminated through direct or indirect contact, either with infected birds or the contaminated material. In addition, HPAI virus can survive in manure or faeces for a few hours to a few days (see section 4.1.2.2). Faecal material can be easily carried on staff/visitors' clothes, shoes, tools or vehicle tyres.

Interpretation

The probability that staff, owners or visitors of an infected S4 farm will get contaminated by infected biological material is very high.

Table 10. Risk steps used in the risk assessment for release of HPAI from an S4 farm via farm staff or visitors

Steps	Data Needed	Data Sources
S4 infected		
Probability that there is contaminated material on an infected S4 farm and that staff/visitors will get contaminated.	- Proportion of farms that dispose of contaminated biological material - Proportion of farms where visitors/staff get in contact with poultry or contaminated materials (e.g. faeces, feathers) and level of biosecurity - Proportion of farms where visitors/staff clean or change clothes and shoes before leaving the farm	- S4 representatives - FAO and CDC data
Probability of contact of staff/visitors (traders, veterinarians) with poultry	- Number and type of visitors, purpose of visit, frequency of movement between S4 farms	- S4 representatives

Conclusion

There will be a very high risk of staff, owners or visitors of an infected S4 farm getting contaminated with material containing infective virus.

4.1.3.2 Overall risk of release for pathway 3

The risk of release of HPAI from an infected S4 farm via farm staff or visitors was estimated to be very high. This estimate was associated with high uncertainty due to lack of reference data.

4.1.4 Pathway 4: Risk of release of HPAI from an S4 farm via farm-bridge species given that the farm is infected

Table 11 summarises steps considered in this assessment.

4.1.4.1 Probability that farm-bridge species (wild birds, vermin, dogs, vultures and other scavengers) will come into contact with contaminated material or infected poultry in an S4 farm when the farm is infected

Description of information available

The expert opinion survey indicated that wild birds come into close contact with poultry and poultry feed in 92% of S4 farms. It further reported that 63% of these farms keep dogs, and only 26% treat their facilities against vermin. The experts also indicated that vermin, particularly rodents, would be present in feed stores in most of S4 poultry farms and would be able to access poultry feeding troughs. Given the lack of adequate biosecurity practices in such farms, it is highly probable that if an S4 farm is infected, farm-bridge species would come into direct or indirect contact with

contaminated material. The poor methods of disposing carcasses in such farms would allow vultures and other scavengers to retrieve the carcasses from dumping sites.

Table 11. **Risk steps used in the release assessment of HPAI transmission from an infected S4 farm via farm-bridge species**

Step	Data Needed	Data Sources
Probability of finding material contaminated with HPAI H5N1 virus in an S4 farm that has been exposed to the disease	Level of hygiene and sanitation determined by: - Disposal of faecal material; - Drainage systems; - Cleaning and disinfection of equipment such as crates.	- Farms - FAO - CDC
Probability that farm-bridge species will directly or indirectly come into contact with contaminated material in an S4 farm	- Types of farm-bridge animal and bird species and their susceptibility to H5N1 virus; - Type and frequency of contact between the farm-bridge species and contaminated material or infected poultry in S4 farms; - Biosecurity practices in S4 farms.	- Farm representatives - NMK and KWS - PAHSP - Literature - Farm staff - MoLD or DVS

Interpretation

A majority of S4 producers do not bury compost or incinerate carcasses or any other biological material that could be contaminated with an infectious agent. This allows farm-bridge species, particularly vultures, to access them in dumping sites which are usually not covered. This would lead to contamination of both the environment and farm-bridge birds/animals that scavenge on disposed carcasses. Vultures might also carry such infected carcasses over long distances, leading to the dissemination of the disease across a wider area.

Conclusion

The likelihood of farm-bridge species coming into contact with contaminated material or infected birds in an S4 farm that has been exposed to the disease is very high with high uncertainty.

4.1.4.2 Probability that farm-bridge species will get contaminated or infected following contact with material contaminated with H5N1 HPAI virus

Description of information available

There is scanty information on the susceptibility of farm-bridge species to HPAI virus. At least two cases of wild birds getting infected from poultry have been reported. One of these involved large-billed crows (*Corvus macrorhynchos*) in Japan in 2004 that died possibly from scavenging on chicken carcasses that had been exposed to H5N1 infection (Nishiguchi et al. 2005). The other involved hooded vultures (*Necrosyrtes monachus*) in Burkina Faso in 2006 (Ducatez et al. 2007). House sparrows are also highly susceptible to H5N1. They excrete the virus through oro-pharyngeal and cloacal routes several days before clinical signs develop (Brown et al. 2009). Cases of HPAI H5N1 have

also been reported in cats in areas where outbreaks of the disease had occurred in poultry (Kuiken et al. 2004; Rimmelzwaan et al. 2006). Other animals that have developed the infection from either experimental or natural exposure include laboratory mice and ferrets (Maines et al. 2005) and dogs (Thiry et al. 2007).

In general, wild birds and other farm-bridge species that are commonly associated with poultry farms are considered to be potential vectors for H5N1 (Brown et al. 2009; Alexander 2007).

Interpretation
The likelihood of farm-bridge species getting contaminated through exposure to infective material is very high. The susceptibility of some of these animals to H5N1 virus is not clear, although some of them have been shown to become infected. They also have a potential of shedding and mechanically transmitting the virus.

Conclusion
The probability that farm-bridge species will get contaminated or infected following contact with infective material containing HPAI virus is very high.

4.1.4.3 Overall risk of release for pathway 4

The overall release risk estimate for pathway 4 is very high with high uncertainty.

4.2 Release assessment: Risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm (S4 – S3 transmission)

This section presents results of release assessments for the three pathways through which HPAI might be transmitted from a backyard poultry farm (S4) to a semi-commercial farm (S3) (risk question No. 2). Pathways considered include movement of fomites associated with live birds, staff or visitors (such as traders, veterinarians, etc.) or farm-bridge species between farms. HPAI transmission via live birds was not considered because it was considered highly unlikely that S3 producers would purchase live birds from S4 farms.

4.2.1 Pathway 5: Risk of release of HPAI from an infected S4 farm via fomites associated with live poultry

This assessment is similar to that of pathway No. 2 described in section 4.1.2. The risk of release of HPAI from an S4 farm via fomites associated with live birds was found to be very high with high uncertainty.

4.2.2 Pathway 6: Risk of release of HPAI from an infected S4 farm via farm staff or visitors

This release assessment is identical to that of pathway No. 3 described in section 4.1.3. The overall risk estimate was found to be very high with high uncertainty.

4.2.3 Pathway 7: Risk of release of HPAI from an infected S4 via farm-bridge species

This assessment is equivalent to that of pathway 4 described in section 4.1.4 where the overall risk estimate was found to be very high with high uncertainty.

4.3 Release assessment: Risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm (S3 – S4 transmission)

Pathways through which HPAI might be released from an infected S3 farm that were evaluated include sale or exchange of spent hens or broilers directly or indirectly through traders, movement of contaminated staff or visitors and exchange of contaminated equipment and vehicles.

4.3.1 Pathway 8: Risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm via live birds (through sales, gifts)

Information required:

- proportion of S3 farms that report disease outbreaks and significant mortalities to the local veterinary authorities;
- the time interval between provision of reports on disease outbreak, confirmation of diagnosis and implementation of mitigation measures.

Steps considered for the release pathway are outlined in Table 12.

Table 12. Risk steps used in the release assessment of HPAI transmission from an infected S3 farm to a susceptible S4 farm via live birds

Steps	Data Needed	Data Sources
Probability that disease outbreaks will be promptly reported by an S3 farm and that response activities will be implemented on time	- Proportion of farms reporting clinical cases; - Response lead time (reporting to sampling, sampling to VILS to results, results to communication)	- VILS DVS Kabete: past reports of clinical disease - PAHSP
Frequency of sale of live poultry including spent hens or exchange of cockerels for breeding by an S3 farm	- Volume and frequency of sales; - Cockerel exchange practices	- S3 farmers - Traders, brokers staff/owners - FAO, CDC - Value chain studies
Risk of contamination of equipment, staff, following on-farm slaughter in an S3 farm Methods of disposal of dead birds and other waste material by S3 farms.	- Biosecurity level in an S3 farm - Frequency of movement of staff between S3 and S4 farms	- Farms - PAHSP, private vet clinics - VILS, DVS (licensing inspection reports)

4.3.1.1 Probability that live poultry or poultry products will be sold or given out by an S3 farm given that the farm is infected

Description of information available

The expert opinion survey indicated that 68% and 65% of semi-commercial farms are likely to report outbreaks of a contagious disease and significant mortality events to local veterinarians. The survey also indicated these veterinarians would respond to such cases within a period of 7 days. Response activities would include confirmation of diagnosis and provision of advice on appropriate control measures. The survey further revealed that most of S3 producers report disease events as soon as they observe one or two cases in their farms, although 51% of them would sell off their birds in the event of an outbreak to avoid mortality losses. Up to 52% of such sales would be made through traders.

Interpretation

Although a majority of S3 farms are likely to report disease events in their farms to local veterinarians, especially if the disease causes heavy mortalities, half of them would sell off their birds in the face of an outbreak to avoid mortality losses. This is further complicated by the fact that veterinarians take an average of 7 days to respond to infectious diseases outbreaks.

Conclusion

The probability of release of HPAI from an S3 farm through live birds was estimated to be medium.

4.3.2 Pathway 9: Risk of transmission of HPAI from an infected S3 farm to an S4 farm via fomites associated with live birds

Information required:

- proportion of S3 farms that have contaminated material on the farm given that the farm is infected;
- proportion of S3 farms that routinely clean or disinfect farm equipment and vehicles before they leave the farm;
- viability of the H5N1 virus on inanimate objects.

4.3.2.1 Probability that there is contaminated material in an S3 farm given that the farm is infected and that equipment such as cages, crates and trucks will be contaminated

Description of information available

Virus excretion by infected animals and survival in the environment has been briefly discussed in section 4.1.2.2. S3 farms (particularly broiler farms) clean their premises once only at the end of a production cycle. Bedding materials such as saw dust are periodically spread on the floor to cover faecal material and other dirt such as spilt feed. Such practices may increase the survival of the virus, as suggested by a study conducted in Hong Kong (Shortridge et al. 1998). The prolonged survival of the virus in faeces increases the chance of equipment such as cages, crates and veterinary equipment getting contaminated on an infected farm.

Interpretation

Most S3 farms lack capacity to implement effective biosecurity measures, yet they raise poultry under intensive production systems. Because of the modes of excretion of HPAIV H5N1 by infected birds and the ability of the virus to survive, it is thought that on farm equipment would easily get contaminated.

Conclusion

The probability that there will be infectious material on an S3 farm when the farm gets infected and that equipment such as cages, crates or trucks will be contaminated with virus-laden material is medium (with high uncertainty). This analysis assumes that there would be minimal reactive interventions such as farm closure, etc. In such a case, it would still be possible to transport contaminated equipment out of the farm.

5 Exposure Assessment

Results of exposure assessments for all the risk pathways considered in the study are presented in this section.

5.1 Exposure assessment: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm (S4 – S4 transmission)

5.1.1 Pathway 1: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via live poultry

Information required:

- proportion of S4 farms that obtain live poultry (breeding or replacement stock) from live markets either directly or indirectly through traders;
- proportion of S4 farms that obtain replacement or breeding stock from other S4 farms.

5.1.1.1 Probability that a susceptible S4 farm obtains live birds for breeding from an infected backyard farm directly or indirectly via traders

Description of information available

The expert opinion survey revealed that 53% of backyard chicken farms are likely to obtain poultry such as cockerels and spent hens for breeding from other farms, 23% from open markets and 60% from traders. The practice is more common in the western parts of Kenya than elsewhere. Birds obtained from mobile traders or live-bird markets are likely to have been mixed with those from multiple sources/farms while in transit. Mixing birds from various sources increases the risk of being exposed to a number of infectious agents (Li et al. 2004).

Interpretation

The exchange of breeding birds between S4 farms is a common practice. Live birds are also presented as gifts in social functions such as weddings, fund raising, etc. Such practices aid the transmission of infectious disease, especially at the early stages of the disease when clinical signs are not apparent.

Conclusion

The likelihood of S4 farms obtaining live birds such as breeding cockerels, spent hens or replacement flocks from other backyard poultry farms is high. This is one of the methods through which HPAI can be introduced into uninfected farms.

5.1.1.2 Probability that birds acquired by an S4 farm are immediately mixed with the resident birds without any quarantine measures

Description of information available

It is a common practice for S4 farmers to mix newly acquired birds with the resident ones because such farmers usually lack capacity to implement quarantine measures. If infected, newly acquired birds would contaminate the farm as they would shed the virus in faeces and respiratory excretions.

H5N1 virus would also persist in the feathers detached from such infected birds. Yamamoto et al. (2010) have shown that viral infectivity persists in the feathers for 160 days at 4°C and for 15 days at 20°C.

Interpretation
The level of interaction between newly introduced birds and resident flocks in an S4 farm is expected to be intense; this would facilitate disease transmission if newly introduced birds are infected.

Conclusion
The probability that newly introduced birds are not quarantined at the time of introduction is very high. This increases the risk of the farm acquiring an infection if newly introduced birds are infected or contaminated with HPAI virus.

5.1.1.3 Overall risk of exposure for pathway 1

The probability of an uninfected S4 farm being exposed to HPAI through live birds obtained from an infected S4 farm is high with a high uncertainty.

A summary of the exposure assessment described here is given in Table 13.

Table 13. Risk of exposure of an S4 farm to HPAI via infected live birds acquired from an infected S4 farm

Step of pathway	Source	Risk Category	Uncertainty
Probability that infected spent hens or cockerels are acquired by an S4 farm for breeding or as replacement stock	Expert opinion	High	High
Probability that newly purchased or acquired birds will be mixed directly with resident birds in an S4 farms with no quarantine measures	Expert opinion	Very High	High

5.1.2 Pathway 2: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via fomites associated with live birds

Information required:

- probability that farm equipment such as poultry crates, cages, etc. contaminated with H5N1 virus is transported from an infected S4 farm to a susceptible one;
- probability that fomites referred to above will come into direct or indirect contact with poultry in a susceptible S4 farm and that this contact will lead to an infection in the farm.

5.1.2.1 Probability that farm equipment such as poultry crates, cages, etc. contaminated with H5N1 virus is transported from an infected S4 farm to a susceptible one, and that fomites referred to above will come into direct or indirect contact with poultry in a susceptible S4 farm and that this contact will lead to an infection in the farm

Description of information available

Equipment such as cages, trays, feeding utensils is often shared between S4 farms. These types of equipment can act as fomites (Boone and Gerba 2007) and might be effective in H5N1 transmission because they come into close contact with poultry. S4 farms do not have the capacity to implement effective biosecurity measures that would allow safe use of such equipment (Mubareka et al. 2009). Commercially available disinfectants such as soaps and detergents used at recommended concentrations can inactivate the virus (e.g. Songserm et al. 2006; Shahid et al. 2009), but such disinfectants are rarely used by S4 farms.

Interpretation

S4 farms do not have adequate biosecurity measures to prevent contaminated poultry equipment such as cages, trucks from transmitting infectious diseases such as HPAI between farms.

Conclusion

The risk of introduction of contaminated equipment associated with live poultry into susceptible S4 farms and the probability that this would result in an infection in the farm is high.

5.1.2.2 Overall risk of exposure for pathway 2

The probability of introducing H5N1 infection to a susceptible S4 farm via fomites associated with live birds was assessed as high, with high uncertainty.

Table 14. Risk of exposure of a susceptible S4 farm to H5N1 infection via fomites associated with live birds obtained from an infected S4 farm

Parameter of pathway	Source	Risk Category	Uncertainty
Probability that S4 farms will get exposed to contaminated equipment associated with live poultry	Expert opinion (n=7)	Very High	High
Probability of contact between contaminated equipment (cages, trucks) and poultry	Expert opinion (n=7)	High	High
Probability that contact between poultry in a susceptible S4 farm and contaminated equipment will result in an infection of S4 farm	Expert opinion (n=7)	High	High

5.1.3 Pathway 3: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via movement of farm staff or visitors

Information required:

- proportion of people working in S4 farms who visit other S4 farms at least once in a week;

- proportion of S4 farm staff who are likely to stop visiting other poultry farms if they suspect a contagious disease outbreak on their farms;
- proportion of S4 farm staff who are likely to stop visiting other poultry farms if they suspect a contagious disease in other poultry farms;
- proportion of S4 farms that are visited at least once per week by people having contact with poultry, poultry feeds or equipment.

5.1.3.1 Probability that contaminated staff or visitors from an infected S4 farm will access a susceptible S4 farm

Description of information available

Based on expert opinion, 46% of S4 farm workers visit an average of 7 other similar farms per week. Less than 7% of these workers are likely to stop such visits when there is an outbreak of infectious diseases in their area. S4 farms also receive many other visitors that might come into direct or indirect contact with poultry such as veterinarians, traders, or even neighbors. Given that 94% of S4 farms do not enforce standard decontamination protocols such as change of shoes and clothing on entry and exit of the farms, a majority of visitors would be able to introduce disease agents if contaminated. Commercially available disinfectants such as soaps and detergents, when used properly, can inactivate HPAI virus (e.g. Songserm et al. 2006; Shahid et al. 2009).

Interpretation

The above information shows that movements of staff and visitors between S4 farms are frequent. In addition, due to low biosecurity levels in such farms, it is likely that staff or visitors contaminated with HPAI virus would expose a susceptible farm to H5N1 infection.

Conclusion

The risk of contaminated staff from an infected S4 farms visiting a susceptible S4 farm is high.

5.1.3.2 Probability that visitors of a susceptible S4 farm such as veterinarians and traders have direct or indirect contact with poultry, feed and equipment on the farm and that this contact will lead to infection in poultry

Description of information available

According to expert opinion, 55% of S4 farms receive visitors who would have direct contact with poultry. In addition, 28-30% of such farms would not restrict their visitors from accessing poultry feeds and equipment. Local veterinarians, who often respond to disease outbreaks, are considered to have the highest chance of coming into direct or indirect contact with poultry. The likelihood of such visitors contaminating feed, equipment and water is high since very few of them would stop visiting other farms when there is a disease outbreak.

Interpretation

Most visitors of S4 farms come into direct or indirect contact with poultry, feeds or farm equipment. It is therefore very likely that direct or indirect contact between staff or visitors contaminated with infectious material containing H5N1 virus and poultry will be able to lead to infection in poultry on a farm.

Conclusion

There is a high risk of visitors or staff of susceptible S4 farms coming into direct or indirect contact with poultry. Such visitors or staff would introduce the disease into the farm if they are contaminated with HPAI virus.

5.1.3.3 Overall risk of exposure for pathway 3

The overall risk of HPAI infection on an S4 farm following exposure to contaminated staff or visitors is high with high uncertainty. A summary of the exposure assessment is outlined in Table 15.

Table 15. Risk of exposure of a susceptible S4 farm to H5N1 virus via farm staff or visitors originating from an infected S4 farm

Step of pathway	Source	Risk Category	Uncertainty
Probability that contaminated staff / visitor comes into contact with a susceptible S4 farm	Expert opinion	High	High
Probability of contact between contaminated visitors (traders, veterinarians) and poultry, poultry feeds and equipment in a susceptible farm	Expert opinion	High	High
Probability that contact between contaminated visitors / staff and poultry in a susceptible farm results in an infection	Expert opinion	Very High	High

5.1.4 Pathway 4: Risk of transmission of HPAI from an infected S4 farm to a susceptible S4 farm via farm-bridge species

The likelihood of farm-bridge species introducing HPAI into an S4 farm depends on the level of contact between farm-bridge species and poultry, the frequency and duration of each contact and the infectiousness of contaminated or infected farm-bridge species.

Information required:

- proportion of S4 farms on which farm-bridge species are observed;
- proportion of S4 farms on which farm-bridge species come into close contact with poultry;
- proportion of S4 farms that allow farm-bridge species to enter and interact freely with poultry;
- proportion of S4 farms that are treated against vermin;
- proportion of live-bird markets where farm-bridge species are observed.

5.1.4.1 Probability that farm-bridge species, infected or contaminated with H5N1 virus in an infected S4 farm, will come into contact with poultry in a susceptible S4 farm

Description of information available

The expert opinion survey estimated that wild birds would be observed in close contact with poultry and poultry feed in 92% of S4 farms. Scavenging wild birds, including vultures and birds of prey, are also often seen in markets or dump sites. The survey further indicated that 63% of S4 farms would keep dogs. Most small-scale farmers along Lake Victoria practice mixed poultry farming, with dogs, cats, pigs, ducks and other waterfowl on the same farm. Some S4 farms also keep both domestic and wild birds in the same premises (Okuthe and Munyua 2008; Nyagah 2007).

Interpretation

Poultry and farm-bridge species closely interact in S4 farms.

Conclusion

The probability that infected farm-bridge species will come into direct or indirect contact with poultry in a susceptible S4 farm is very high.

5.1.4.2 Probability that contact between contaminated or infected farm-bridge species and poultry of a susceptible S4 farm will result in an infection

Description of information available

Cats and birds such as vultures are able to excrete HPAI virus when infected; this suggests that these species can transmit the disease between farms (Beeler 2009; Marschall and Hartmann 2008; Burgos and Burgos 2007; Thiry et al. 2007). An analysis of HPAI H5N1 viruses from poultry and hooded vultures (*Necrosyrtes monachus*) in Burkina Faso indicated that some of the viruses were common to both of these birds; this observation further supports the fact that vultures can play a role in the transmission of the disease (Ducatez et al. 2007). Many wild bird species are migratory or cover an extensive territory. It has been suggested that these birds might have contributed to the spread of the virus within or between countries and between farms. Dogs are unlikely to play a substantial role in the transmission of the disease because they are poor shedders of the virus (Beeler 2009). Low biosecurity levels in S4 farms allow close interaction between farm-bridge species and poultry.

Interpretation

Contact between poultry and infected or contaminated farm-bridge species is likely to result in the infection of poultry.

Conclusion

The probability that poultry on a susceptible S4 farm will become infected following contact with infected or contaminated farm-bridge species is very high.

5.1.4.3 Overall risk of exposure for pathway 4

The overall risk of HPAI virus infection of a susceptible S4 farm following direct or indirect contact between contaminated or infected farm-bridge species and poultry is very high with high uncertainty.

A summary of the information presented in this section is given in Table 16.

Table 16. Risk of exposure of a susceptible S4 farm to H5N1 infection via farm-bridge species

Step of pathway	Source	Risk Category	Uncertainty
Probability that farm-bridge species will come into contact with contaminated material in markets	Expert opinion Okuthe and Munyua (2008)	Very High	High
Probability that farm-bridge species will come into contact with S4 poultry leading to infection	Expert opinion Okuthe and Munyua (2008)	Very High	High

5.2 Exposure assessment: Risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm (S4 – S3 transmission)

Three pathways involving fomites associated with live birds, staff or visitors, or farm-bridge species were considered.

5.2.1 Pathway 5: Risk of transmission of HPAI from an infected S4 to a susceptible S3 farm via fomites associated with live birds

Information required:

- proportion of S3 farms that exchange poultry equipment such as cages, trays, sacks and other farm equipment with S4 farms;
- probability that contact between contaminated fomites and poultry in an S3 farm will result in an infection.

5.2.1.1 Probability that HPAI is transmitted from an infected S4 farm to a susceptible S3 farm via fomites associated with live poultry or poultry products

Description of information available

Equipment used by S3 farms to supply live poultry or poultry products to S4 farms may get contaminated with HPAI virus in S4 farms if these farms have had the disease and have not disclosed their exposure status (Boone and Gerba 2007). Such equipment may introduce infectious material to S3 farms especially if they are not cleaned or disinfected before being taken back.

The potential of fomites and water for the transmission of HPAI H5N1 between farms has been discussed in section 4.1.2.2. In addition, according to a study investigating the role of feathers, water and faecal material in HPAI virus transmission (Yamamoto et al. 2010), H5N1 virus can remain viable for the longest period in feathers. Viral infectivity persisted in the feathers for 160 days at 4°C and for 15 days at 20°C. Feathers detached from domestic ducks infected with HPAI virus H5N1 are thus another source of environmental contamination and may function as fomites with high viral loads in the environment.

Interpretation

Given that S3 and S4 farms have low capacities to implement effective biosecurity measures, there is a high likelihood that contaminated equipment shared between these farms such as crates, cages or feed containers such as sacks would act as fomites. Contact between contaminated equipment and susceptible poultry would very likely lead to an infection.

Conclusion

The risk of equipment such as cages or trays and other fomites associated with live poultry introducing HPAI virus from an infected S4 farm to an uninfected S3 farm is high.

5.2.1.2 Overall risk of exposure for pathway 5

The probability of HPAI infection being introduced into an S3 farm from an infected S4 farm through contaminated equipment associated with the live birds was assessed as high, with high uncertainty.

5.2.2 Pathway 6: Risk of transmission of HPAI from an infected S4 to an S3 farm via movement of staff or visitors

Information required:

- proportion of people working in S4 farms that visit S3 farms at least once in a week;
- proportion of S3 farm staff owning backyard poultry;
- number of S3 farms visited by staff and other visitors from S4 farms on weekly basis;
- proportion of S4 farm staff that are likely to stop visiting S3 farms if they suspect an outbreak of a contagious disease in their farms;
- proportion of S4 farm staff that are likely to stop visiting other poultry farms if they suspect an outbreak of a contagious disease in other poultry farms of the area.

5.2.2.1 Probability that contaminated staff or visitors from an infected S4 farm visit susceptible S3 farm and that this visit will lead to an effective contact with poultry (in an S3 farm)

Description of information available

The expert opinion survey revealed that 32% of S4 producers are thought to work in S3 farms and that over 46% of them would visit up to 7 similar farms in a week. Only 5% of them would stop such visits when disease outbreaks are reported in their area. A large proportion (72%) of S3 farms were considered to allow visitors and their vehicles to access their farms without strict biosecurity requirements.

Interpretation

This information shows that frequency of staff movement between S4 and S3 farms is high. The likelihood of them transmitting diseases between farms, especially when there is an outbreak of an infectious disease in their area, is likely to be high.

Conclusion

The risk of staff or visitors from an infected S4 farm introducing HPAI infection into a susceptible S3 farm, based on expert opinion, is high with high uncertainty.

5.2.2.2 Overall risk of exposure for pathway 6

The overall risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm through contaminated staff or visitors is high with high uncertainty.

5.2.3 Pathway 7: Risk of transmission of HPAI from an infected S4 to a susceptible S3 farm via contaminated farm-bridge species

5.2.3.1 Probability that farm-bridge species infected or contaminated with HPAI virus in an S4 farm will come into an effective contact with poultry in a susceptible S3 farm

Description of information available

The expert opinion survey indicated that farm-bridge species and poultry are likely to come into close contact in 32% of S3 farms. Some of these interactions occur indirectly through sharing of feed, watering troughs and resting sites. A small proportion (24%) of these farms treats their premises against vermin while 59% of them keep dogs. Evidence provided for the exposure assessment of pathway No. 4 suggests that contact between poultry and farm-bridge species infected or contaminated with HPAI virus would lead to an infection in poultry.

Interpretation

Interaction between farm-bridge species and poultry in small-scale commercial (S3) and backyard (S4) farms is more intense in areas where S3 farms are surrounded by S4 farms. As there are no restrictions on the distance between S3 and S4 farms in Kenya, this situation is very common. Such interactions would allow for the transmission of infectious diseases between S4 and S3 farms. In other cases, farm-bridge species contaminated in other sites such as markets, dump sites or slaughter houses may be responsible for transmitting the disease between farms.

Conclusion

The probability that farm-bridge species exposed or contaminated with HPAI virus in an S4 farm will come into close contact with poultry in a susceptible S3 farm, leading to HPAI transmission, is high with high uncertainty.

5.2.3.2 Overall risk of exposure for pathway 7

The overall risk of transmission of HPAI from an infected S4 farm to a susceptible S3 farm via infected or contaminated farm-bridge species is high with high uncertainty.

5.3 Exposure assessment: Risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm (S3 – S4 transmission)

Transmission pathways considered include movement of (i) live poultry and (ii) fomites associated with live poultry.

5.3.1 Pathway 8: Risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm via live poultry

Information required:

- proportion of S3 farms that are likely to sell birds in the face of an outbreak;
- proportion of S3 farms that give out birds for breeding to S4 farms.

5.3.1.1 Probability that infected spent hens or cockerels are sold or given out by an infected S3 farm to a susceptible S4 farm

Description of information available

The expert opinion survey indicated that up to 23% and 60% of S4 producers are thought to purchase replacement stocks directly from live-bird markets or from traders, respectively. Thirty percent of the replacement stocks in these markets come from S3 producers while 29% of traders that supply replacement stock to S4 producers purchase these birds from S3 farms. A small proportion of S3 farms (9%) are also involved in the exchange of breeding birds such as cockerels and spent hens through traders or retailers. Some backyard poultry owners buy spent hens or broilers from S3 farms for home consumption.

Interpretation

There is a very high proportion of S4 farms involved in purchase of replacement stocks from S3 farms through traders or open markets.

Conclusion

The probability that S4 farms acquire breeding stock from S3 farms either from the markets or via traders is high. However, the probability that spent hens and cockerels are sold or exchanged directly between S3 and S4 producers is medium. The probability that infected spent hens or cockerels are sold or given out by an infected S3 farm to a susceptible S4 farm, either directly or indirectly, is high.

5.3.1.2 Probability that a contaminated or infected bird obtained from an infected S3 farm will be mixed with other poultry in a susceptible S4 farm without any quarantine measures

Description of information available

According to expert opinion, about 52% of S3 farms are likely to sell off live birds when they experience an outbreak of a contagious disease. This increases the risk of infected birds being sold in the markets or by traders. Generally, S4 producers mix newly acquired birds within their existing flock without any quarantine measures. This increases the risk of the resident birds catching an infection if the newly introduced birds have an infectious disease.

Interpretation

Due to inability of S4 producers to implement quarantine measures, purchase of a contaminated or infected bird would invariably lead to an outbreak of the disease in the farm.

Conclusion

The probability of birds infected or contaminated with HPAI virus from an S3 farm will be mixed directly with resident flocks on S4 farms is high.

5.3.1.3 Overall risk of exposure for pathway 8

The overall risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm via live birds is high.

5.3.2 Pathway 9: Risk of transmission of HPAI from an infected S3 farm to a susceptible S4 farm via fomites associated with live birds

Information required:

- practices regarding the exchange of live bird equipment such as cages and crates for transport as well as other production equipment;
- proportion of S3 farms that routinely clean and disinfect equipment;
- proportion of S3 and S4 farms that allow entry of vehicles into the farms.

5.3.2.1 Probability that infected S3 farms share farm equipment with susceptible S4 farms and that contact between contaminated equipment and poultry will lead to HPAI infection in the S4 farm

Description of information available

S3 farms that sell birds when they experience a disease outbreak in their area risk contaminating their cages, clothing and shoes or traders` or transporters` vehicles. A high proportion (72%) of these farms also allows free entry of visitors into their farms without proper biosecurity measures. Given that an estimated 21% of S3 farms exchange production or transport equipment with S4 farms, it is very likely that infection could be carried from S3 to S4 farms via fomites. Cages, crates or vehicles used to ferry birds between these farms and the markets are usually not disinfected.

S4 producers also often buy manure from S3 farms for use as cattle feed especially during the dry season, or as organic manure for their food crops. The manure is not normally composted before being sold or used; it therefore acts as a major source of HPAI risk to S4 farms that purchase it (Nyagah 2007).

Interpretation

The interactions between S3 and S4 farms described above act as major sources of risk of HPAI transmission especially from intensive S3 farms to backyard poultry farms.

Conclusion

The risk of transmission of HPAI from S3 to S4 farms via contaminated equipment is very high because the levels of biosecurity practised in these sectors are very low.

5.3.2.2 Overall risk of exposure for pathway 9

The overall risk estimate for the transmission of HPAI from an infected S3 farm to a susceptible S4 farm via fomites is very high with high uncertainty.

6 Overall summary and Recommendations

6.1 Summary

6.1.1 Risk estimation

The main findings of this assessment as outlined in Table 17 suggest that the risk of transmission of HPAI from an infected S4 farm is high, but when an infected S3 is considered as the source of infection, the risk of transmission is medium. This may be attributed to the fact that S4 farms lack capacity and incentives to implement bio-containment measures when a disease outbreak occurs. The risk of release of HPAI from S4 farms (in S4 – S4 and S4 – S3 transmission pathways) was always assessed very high while the risk of release from S3 farms (in S3 – S4 transmission) was always estimated as medium. In addition, there was no difference in the exposure risk levels by farm type – both S3 and S4 farms were allocated high or very high risks of exposure. A key assumption made in this assessment is that S3 and S4 farms would not substantially change their poultry production practices following HPAI outbreaks. Farms would therefore continue selling their birds, exchanging farm equipment or allowing visitors to come into direct or indirect contact with poultry.

Table 17. Summary of the results of the qualitative risk assessment of the transmission of HPAI by risk question and pathway

Pathways	Release		Exposure		Overall Risk	
	Risk	***Uncertainty***	**Risk**	***Uncertainty***	**Risk**	***Uncertainty***
Risk question 1- S4 – S4 transmission:						
1: live poultry	Very High	*High*	High	*High*	High	*High*
2: fomites	Very High	*High*	High	*High*	High	*High*
3: staff and visitors	Very High	*High*	High	*High*	High	*High*
4: farm-bridge species	Very High	*High*	Very High	*High*	Very High	*High*
Risk question 2: S4 – S3 transmission:						
5: fomites	Very High	*High*	High	*High*	High	*High*
6: staff and visitors	Very High	*High*	High	*High*	High	*High*
7: farm-bridge species	Very High	*High*	High	*High*	High	*High*
Risk question 3: S3 - S4 transmission						
8: live poultry	Medium	*High*	High	*High*	Medium	*High*
9: fomites	Medium	*High*	Very High	*High*	Medium	*High*

6.1.2 Main challenges encountered

Delayed implementation of value chain analysis

This analysis could have benefited greatly from a value chain analysis characterizing actors and type of market interactions involved in poultry trade. Risk analysis, when based on detailed understanding of value chains related with production, trade, marketing and consumption of products, enables the identification of critical points for disease control. In this project, value chain analysis was implemented much later because more time was needed for the development of the survey design and instruments and training of research assistants. As a result, the risk assessment relied on expert opinion only.

Scanty information on the poultry sector practices, the epidemiology of infectious diseases and the effectiveness of control measures in Kenya

Fifteen experts were contacted for the expert opinion elicitation survey, but only 7 were able to complete and return the questionnaires. Although the experts recruited for the survey were expected to utilize a range of information sources such as personal opinion, observation or existing data while answering the questions, many of them used personal opinion because they could not access relevant data or information. Data that are often kept by the DVS are not usually readily available, for example, through on-line (web) sources. Also, few experts could access peer-reviewed papers from on-line electronic databases. As a result, there was a huge variation in the answers obtained. Although potential sources of variability and uncertainty can be theoretically identified, it was difficult to tease out these indices in the analysis conducted. For example, the different opinions obtained may be due to differences in the areas or ecological zones where each expert operated from, but also in the levels of knowledge on the topics examined. Experts were asked to answer questions on HPAI transmission, yet most of them had never experienced HPAI outbreak. They therefore used their experiences with Newcastle disease to answer questions on HPAI transmission. Lack of data or experience on HPAI transmission is an important source of uncertainty in the present survey.

Rodgers and Petch (1999) have indicated that experts are often reluctant to provide probability distributions because they feel that this is more difficult than reporting a single point estimate. They also point out that asking the experts to quantify uncertainty may not be beneficial because uncertainty from the expert's perspective may be due to his/her inability to access information rather than actual lack of information on that outcome. In an attempt to limit this problem, the Risk Assessment Facilitator always availed himself for consultation on phone when the experts had questions to raise.

6.1.3 Impact on risk estimation

The estimates derived from the expert opinion elicitation are associated with a high level of uncertainty. This is due not only to the lack of data or experience with HPAI, but also to the difficulty in providing quantitative estimates. The results obtained for some answers suggest this may have resulted in an overestimation of the risks. For example, the proportion of S4 backyard producers working on S3 farms was estimated by experts as 32% on average, which seems very high. Also, it is possible that experts used their experience or observations in high poultry density settings to answer the questionnaire. This would explain, partially at least, why the estimates sometimes appear inflated.

Given the high uncertainty in quantitative estimates and the experts' risk perceptions, the results of this risk assessment should be considered as "worst case scenario" for high poultry density areas in Kenya.

6.2 Recommendations

Implementation of improved biosecurity practices

The results of the study indicate that S4 farms have a higher risk of releasing HPAI virus compared to S3 farms via fomites, farm staff and visitors or farm-bridge species. Although the capacity of these farms to implement improved biosecurity measures is low, there is a need to sensitize backyard chicken keepers on a few simple, low-cost bio-containment measures that they can implement to reduce the risk of release of the disease when they get exposed. These include proper disposal of carcasses and confinement of poultry only when there is an active disease outbreak in the village to prevent further exposure. The DVS should also enhance its surveillance and either attempt to identify and impose penalties on farms that sell off poultry in the face of an outbreak, or undertake targeted social marketing campaigns to raise awareness in affected communities to create peer pressure to discourage the practice.

The results show that S3 farms have a high risk of being exposed to the disease via farm staff and visitors, fomites and farm-bridge species. Fomites obtained from such farms also have a very high risk of exposing uninfected S4 farms to the disease. S3 farms also have relatively higher capacity to implement a range of biosecurity measures than S4 farms. These may include provision of protective clothing to their staff, limiting visitors from coming into contact with poultry through enclosing poultry within pens or houses, prompt disposal of contaminated material, cleaning and disinfection of farm tools and equipment before and after use and provision of disinfection baths.

Both S3 and S4 farms should be encouraged to quarantine new birds purchased or acquired before mixing with the existing ones. When possible (more so in S3 farms), separate workers should handle the different groups of birds. Otherwise, newly introduced birds should always be attended to last.

Disease reporting

Poultry farmers and market actors should be sensitized on the need to promptly give reports of infectious disease outbreaks to mitigation agents to allow timely implementation of interventions. This implies that producers, traders and other stakeholders should be involved in the development of HPAI contingency plans to ensure ownership and understanding of the roles of each actor. Disease surveillance systems should also be improved in order to cut down average response time (of 7 days) reported in this study.

Research gaps

Research is also needed in the following areas:

- Identifying risk factors for disease occurrence and persistence;
- Characterizing susceptibility of farm-bridge animals and bird species to HPAI so that their involvement in the transmission of the disease can be accurately determined;
- Evaluating effectiveness of the various biosecurity measures;

- Assessing potential for the use of risk analysis as a component of the early warning system in risk-based surveillance strategies.
- Exploring the potential for using risk analysis and value chain analysis to determine critical control points.

7 Conclusions

The likelihood of HPAI spreading from an infected S4 to susceptible S4 or S3 farms was assessed high while that from infected S3 to susceptible S4 was assessed as low or medium. Fomites moved from S3 farms was found the main pathway through which susceptible S4 farms can get infected from infected S3 farms. If infected, S4 farms were found at higher risk of releasing HPAI virus than S3 farms. This is mainly related to their lack of capacity to implement bio-containment biosecurity practices.

The present risk assessment relies on expert opinion and its results are associated with a high level of uncertainty. Rather than providing an absolute estimate of the risk of transmission from infected farms, the study indicates which pathways and practices are more likely to facilitate disease spread and should thus be targeted to reduce the risk of transmission of contagious diseases in the Kenyan poultry sector. The high degree of uncertainty surrounding many of the parameters underlying the assessment, however, highlights the need for further research to strengthen the analysis.

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