Chapter 19

Explorative study on avian influenza risk factors in the EU-27: literature study and expert opinion

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Abstract

European Union (EU) legislation requires that avian influenza (AI) measures should be largely based on a risk assessment of the local epidemiological situation. In this explorative study, we identified relevant risk factors for AI introduction and spread at regional level based on literature research and by elicitation of expert opinion using the Delphi methodology. Risk factors related to live animal movements and trade, human contacts and high farm densities were selected by the expert panel as main determinants of AI introduction and spread. Moreover, a strong emphasis on risk factors related to introduction pathways by wild birds (e.g. wetlands, free-range farming) was laid. Based on this information data collection can be focused and ultimately AI risk maps, a useful tool to facilitate risk based decision making, will be developed.

1. Introduction

In the last decade, the European Union (EU) has experienced several avian influenza (AI) outbreaks in domesticated poultry. Italy and The Netherlands were struck by two major highly pathogenic avian influenza (HPAI) epidemics in 1999-2000 and 2003 (Capua and Marangon, 2000; Stegeman et al., 2004). These epidemics occurred in densely populated poultry areas and had serious socio-economical consequences (Capua et al., 2002; Tacken et al., 2003). Since the onset of the H5N1 epidemic in Asia, the 27 member states of the European Union (EU-27) have reported 1027 AI events; 289 outbreaks in poultry and 738 cases in wild birds (EU outbreak reports). Growing concerns on the unprecedented number of outbreaks of HPAI H5N1 in Asia, its spread to other continents and human casualties has urged decision makers worldwide to evaluate and adapt existing AI prevention, monitoring and control strategies. Also in the EU, AI legislation has been updated several times. One of the key points in the current EU legislation is that EU measures are flexible and largely based on risk assessment of the local epidemiological situation (Pittman and Laddomada, 2008).

A risk based approach is crucial, since large differences in poultry densities, biosecurity, contacts, etc. may exist between the EU-27 regions. As a consequence some regions may have a relatively higher risk for the occurrence of AI outbreaks than others. This should be taken into account when region specific strategies are developed and the limited resources for prevention, monitoring and control are allocated. Prerequisites to identify regions with a relatively higher risk are identification of the main risk factors for AI and determination of their spatial distribution. Ultimately this information can be visualized in regional AI risk maps, on which the European regions are coloured according to their risk for the AI introduction and transmission. Accordingly, these maps present a useful tool to facilitate risk based decision making.

The aim of this study is to collect available information from the literature and to elicit expert knowledge on the main determinants of AI introduction and AI spread. Expert knowledge will be elicited by the Delphi methodology. This methodology was developed in the field of science and technology forecasting (Sackman, 1974). It is a technique to obtain consensus on

the opinions of experts through a series of structured questionnaires. After each round, an anonymous summary of the experts' answers from the previous round is given, which encourages participants to revise their earlier answers in light of the replies of other members of the panel. During this process the range of answers may converge towards consensus; the mean scores of the final round determine the results.
The set up of the paper will be as follows. First an overview about the definitions and conditions for the inclusion of risk factors used in the study will be shown, followed by a summary of the AI pathways and risk factors obtained from a literature analysis. Next the set up and results of the Delphi study will be described. Finally the findings are discussed in the light of risk based decision making on regionally adapted strategies.

2. Avian influenza pathways and risk factors

2.1. Definitions and conditions of inclusion

The epidemiology of avian influenza virus (AIV) is very complex as the virus has many potential hosts (wild birds, poultry, cats, people, pigs, etc.) and it has several possible pathways of introduction and spread. In this paper, we will focus on AI introduction in domesticated poultry and spread among domesticated poultry. Moreover, AIV has various H_xN_y subtypes. Virus strains that cause infection in poultry belong to the notifiable AIV subtypes H5 and H7 (NAIV) and thus we will focus on these subtypes. Also two pathotypes exist of which the low pathogenic type (LPAI) may mutate into HPAI (Capua & Alexander, 2004; WHO, 2004; Globig, 2007). Because of this complexity, clear definitions of the risk events that will be investigated in this study are needed. Since this study is performed to ultimately give decision makers more insight into risk of AI at the regional level, the definitions used in our study are directly linked to the way in which decision makers in animal disease control consider these events in terms of strategies for control, prevention and monitoring.
In the epidemiology of an infectious disease two distinct processes can be distinguished: the primary introduction and secondary spread. When deciding on allocation of resources for AI prevention and monitoring, decision makers mainly have to deal with risk of introduction in domesticated poultry. Although resources have to be spent on routine surveillance of the wild bird population, this is mainly done as an early warning system of possible introductions in poultry flocks. Hence in this study, the risk event of introduction is the incursion of NAIV into domesticated poultry flocks. For spread the definition of the risk event is less clear. Although one could define it as the risk of NAIV spread to at least one other premises, this does not reflect the perception of the decision maker who is mainly interested in extensive spread of the virus as this will have a severe impact on resources for control. Therefore we define the risk event of spread as the risk of extensive spread of the virus, i.e. the risk of a major outbreak. In this paper we will (partly) follow the definitions of De Vos et al. (2003), which are based on EU council directive 82/894/EEC:

- Primary introduction: the incursion of NAIV into the domesticated poultry of a region free of NAIV in domesticated poultry, causing a primary outbreak.
- Secondary spread: Extensive dissemination of NAIV from the primary outbreak to other holdings within the affected region, resulting in a major outbreak.

Using these definitions, an event is regarded as introduction when the virus comes in from another region (i.e. the virus travels over a relatively large distance) and it is regarded as spread when it originates from other flocks within the same region (i.e. it travels relatively small distances). The pathways for introduction and spread therefore largely overlap, but for introduction the emphasis will be more on mechanisms that enable the virus to bridge longer distances (import, migratory birds) and on alternative sources of origin, e.g. wildlife. Using the above mentioned definitions, the characterization of a region determines which events are regarded as introduction or as spread. In animal disease control, no exact definition of 'region' exists. Countries are divided into several regions, named compartments, of which the actual size may vary from country to country and can be adapted depending on the severity of the outbreak (see also EU Council Directive 64/432/EEC). In this paper, a region is assumed to be part of a member state or the whole member state in case of smaller countries like Luxembourg and Malta.

In the literature, many hypothetical routes of AI introduction and spread are mentioned (e.g. Utterback, 1984, Alexander, 1995). Despite all tracing efforts made during and after epidemics, many of the actual pathways are never elucidated (e.g. Capua et al., 1999, Nishiguchi et al., 2005). Instead risk factors can be studied in a risk factor analysis of data collected during and after epidemics (e.g. Manelli et al., 2005; Thomas et al., 2005). Regional risk factors are quantitative derivatives related to either the susceptibility and infectiousness of the farms (e.g. poultry species, biosecurity, farm size) or to the contact structure between source of infection and farms (e.g. live poultry movements, wetlands, poultry and farm density) (Stegeman et al., 1997). To make an inventory of risk factors, we performed a literature study on analyses and descriptions of former LPAI and HPAI outbreaks, reviews and reports to find quantitative as well as qualitative information about (potential) risk factors. We did not distinguish between LPAI and HPAI risk factors since several HPAI epidemics started after LPAI was introduced into a poultry flock and mutated into HPAI (e.g. Bowes et al., 2004) and pathways found in the literature did not seem to differ greatly.

Not all risk factors mentioned in the literature are relevant for a regional risk assessment. The following conditions for inclusion were used:

- Spatial component and non-dynamic (e.g. excluding 'season', 'age of the birds')
- Relevant for the EU-27 (e.g. excluding 'cockfighting')
- Related to the HRP only (e.g. excluding risk factors related to depopulation practices)
- Not only locally valid (e.g. excluding reported 'presence of wild animals')

Finally, from the collected information, lists of pathways and relevant risk factors were made.

2.2. Summary of avian influenza pathways and risk factors

A short summary of pathways mentioned in the literature is given in Table 1. Neighbourhood spread is mentioned as an important pathway of spread in the literature (Henzler et al., 2003, Marangon and Capua, 2005). Neighbourhood spread is spread over short distances of which the exact mechanisms are unknown. Most likely it is a combination of local contacts like people, vehicles, sharing machinery, vermin, dust particles, etc.

Table 1. Summary of pathways mentioned in the literature and their references

AI pathways	References
• Wild birds	Capua and Alexander (2004); EFSA (2005a,b); Kilpatrick et al. (2006); Evans et al. (2006); Mettenleiter (2007b)
• Trade in poultry/poultry products or other birds/bird products	Utterback (1984); Capucci et al. (1985); Manvell (2000); Starick and Werner (2003); Swayne and Beck (2004); Senne (2004); EFSA (2005a,b); Normile (2005); Van Borm (2005); Kilpatrick et al. (2006); Mettenleiter (2007b)
• Illegal trade poultry/poultry products or other birds/bird products	EFSA (2005a,b); Marshall (2006); Mettenleiter (2007a,b); Serratosa et al. (2007)
• People (clothing, shoes)	Utterback (1984); Fitchner (1987); EFSA (2005b)
• Transport vehicles, machinery	Utterback (1984), EFSA (2005b), Kuney (2006)
• Materials (crates, egg packing material, etc.)	Utterback (1984), EFSA (2005b)
• Air (dust particles spread by ventilation)	McQuiston et al. (2005); Alexander (2006)
• Water/feed/litter	Utterback (1984)
• Manure	EFSA (2005b)
• Other animals (birds, cats, rodents, etc.)	EFSA (2005a), Alexander (2006); Freise (2006a,b); Marshall (2007); Laves (2007)
• Neighbourhood spread	Henzler et al. (2003) ; Marangon and Capua (2005)

In Table 2, (potential) risk factors indicated in the literature and their references are given. Risk factors related to biosecurity level/breaches in biosecurity mentioned in the literature were e.g. poultry housing not wild bird proof (Cross, 1987), use of untreated surface water as drinking water (EFSA 2005a, Alexander 2006), or incomplete hygiene measures of farm visitors (Nishiguchi et al., 2007).

Table 2. Summary of avian influenza risk factors mentioned in the literature and their references

AI risk factors	**References**
Proximity to waterfowl sites	Cross (1987); Alexander (1995); Selleck et al. (2003); Elbers et al. (2004) ; Tiensin et al. (2004)
Number of wintering *Anseriformes*	Guberti and Scremin (personal communication)
Wetland size and connection with other wetlands	Guberti and Scremin (personal communication)
Free-range housing	Alexander (1995); EFSA report (2005b); Evans et al. (2006); Koch and Elbers (2006); Woolford (2006)
Backyard farming	Tiensin et al.(2004); Terregino et al. (2005); EFSA (2006)
Poultry (farm) density	Henzler et al.(2003); Capua & Alexander (2004); Stegeman et al. (2004); Power (2005); Oyana et al. (2006); Velkers et al. (2006); Zanardi et al. (2006); Boender et al. (2007); Kung et al. (2007)
Farm (or flock) size	Mannelli et al (2005); Thomas et al. (2004); Kung et al. (2007)
Poultry species (turkey, duck, finisher layers)	Lang (1982); Pomeroy (1982); Alexander (1995); Westbury et al. (1998); Tumpey et al. (2004); Senne et al. (?); Thomas et al. (2005)
Mixed farming (mixed poultry, poultry and pigs)	Capua et al. (1999); Tiensin et al. (2004); Bankowski et al. (1983); Olsen et al. (2000)
Live-bird markets	Garnett (1987); Panigrahy et al. (2002); Henzler et al. (2003); EFSA (2005a,b); Pelzel et al. (2006)
Biosecurity level/Breaches in biosecurity	EFSA (2005a,b); Marangon and Capua (2005); Power (2005); EFSA (2006); Alexander (2006); Kung et al. (2007); Nishiguchi et al. (2007); Thompson et al., 2008
Number of human contacts (employees)	Wells (1963); Homme (1970); Glass (1981); Fitchner (1987); Thomas et al. (2004); EFSA (2005b); Marangon and Capua (2005); Alexander (2006); Kuney (2006, 2007); Woo and Park, 2008

3. Delphi study

3.1. Materials and methods

This Delphi study consisted of three rounds. In each round, the expert panel received a questionnaire by email. For the primary objective of the study, the experts' opinion on the importance of several risk factors related to introduction and extensive spread of Avian influenza at regional level was asked. In addition, expert opinion was elicited to obtain information for two secondary research objectives within the project. To evaluate farm level data collected in Germany, Austria and The Netherlands (see Grabkowsky et al., this report), the experts were asked to rate the likelihood of AI introduction for contact pattern characteristics as well as the relative importance of different biosecurity and disease prevention measures in a high risk period. Expert opinion on the likelihood of transmission of several AI pathways between farms was elicited to obtain input for a stochastic spatial simulation model to simulate HPAI outbreaks in The Netherlands (see Longworth et al., this report. After each round, an anonymous summary of the experts' answers from the previous round was given. Below a description of the expert panel selection, the procedure of rounds 1-3, and the analysis of the results is given.

<u>3.1.1 Expert panel</u>

The experts were selected based on their experience in livestock disease management, research or policy making with specific emphasis on AI and poultry health. It was strived for to involve people from different European countries and from different stakeholder groups (academia, government, industry, etc.). In total, 32 people were approached; they were either invited directly or were referred to by other experts. Together with the invitation, a short document to explain the Delphi procedure and targeted timetable was sent. The experts received a document with technical details and definitions along with the questionnaire of round 1. Since the study started during the summer period in which many people were absent, the expert panel was given 28 days to return the questionnaire of the first round and 10-12 days to return the questionnaires of round 2 and 3.

The expert panel members were working either for international organizations (OIE, FAO) or at national institutes, organizations or universities based in the following countries: Austria, Belgium, Denmark, Germany, Italy, Serbia, Spain, The Netherlands and the United Kingdom. The initial responses to the invitation, return rates of the questionnaires, and the composition of the expert panel by stakeholder group are shown in Tables 3, 4 and 5, respectively.

Table 3. Initial responses to the invitation

Number of people approached	32
Invitation accepted	23 (72%)
Invitation rejected	7 (16%)
No response	4 (13%)

Table 4. Return rates of the questionnaires, rounds 1-3

	Round 1	Round 2	Round 3
Number of questionnaires sent	27	25	22
Number of questionnaires returned	17 (63%)	19 (76%)	21 (95%)

Table 5. Composition of the expert panel by stakeholder group, rounds 1-3

	Round 1	Round 2	Round 3
Academic research	3	4	4
AI reference institute	5	4	5
Product board/Poultry industry	3	4	4
Government/Food safety authority	1	3	3
International policy	3	3	3
Veterinary services	2	1	2
Total	17	19	21

3.1.2 Rounds 1-3

Primary objective

For the primary objective of the study, the experts' opinion on the importance of several risk factors related to introduction and extensive spread of AI at regional level was asked. The risk factors included in the questionnaire were obtained from the literature study, but were first transformed into risk factors that are characteristics of a region. For example, 'layer farming' was transformed into 'the number of layer farms in a region'. The risk factors were organized in classes related to: 1) Routes of introduction, 2) Routes of spread, and 3) Poultry demographics. The lists of risk factors related to introduction and spread routes were relatively long and the factors were difficult to compare among each other. Therefore, these risk factors were organized in several categories, e.g. wild birds, illegal import, etc.

In the first round, the experts were asked to rate the risk factors and categories as 'important', 'moderate' or 'negligible'. Factors for which more than 75% of the experts stated 'negligible' were excluded from the questionnaires of round 2 and 3. The experts were given the opportunity to add any relevant factors to the lists. For each category the experts indicated their familiarity on a scale from 1 ('highly competent') to 5 ('not familiar with subject'). In rounds 2 and 3, the expert panel rated the risk factors and their related risk categories according to their relative importance by dividing 100 points over each table of risk factors or categories. The questionnaires of rounds 2 and 3 included the results of rounds 1 and 2, respectively.

Besides routes and demographics, the regional biosecurity level is likely to affect the risk on AI introduction and spread as well. Since the authors did not find any information on determinants for regional biosecurity, the expert panel was asked to choose the best classification measure to determine the overall level of biosecurity in a region from three given options: 1) composing a measure from a combination of aggregated risk factors at farm level, 2) using a health standard classification system (e.g. QS in Germany, IKB in the Netherlands, etc.) or 3) using the poultry production sector classification system of the FAO. The experts were encouraged to substantiate their choice and to suggest other possible classification measures.

Secondary objectives

For the secondary objectives of the study, the experts' opinion on biosecurity and production related risk factors at farm-level, contact structure characteristics, as well as on between farm pathways was asked. For the biosecurity and production related risk factors the same rating scheme was used as described above. In round 2 and 3, seven statements on contact pattern characteristics at farm level were phrased. The experts were asked whether they agreed with the statements and if yes, to rate the likelihood of AI introduction for each of the contact pattern characteristics described on a scale from ++ (‘very important’) to −− (‘negligible’). The likelihood of transmission of the between farm pathways were rated on a scale from ++ (‘very high’) to −− (‘negligible’) in round 1 and 2. For five selected pathways a quantitative estimate of the minimum, most likely and maximum number of infections that would occur out of 100 average contacts between an infectious and a susceptible farm was asked for in round 3.

3.1.3 Analysis

Categories and risk factors

Mean weights, minimum and maximum values, and standard deviation (SD) were calculated with SPSS 12.0.1. To test whether the mean weights were significantly higher than the value according to the uniform distribution, a two-sided t-test was performed with $\alpha=0.05$ (SPSS 12.0.1). Risk factors for AI introduction and spread routes and demographics were ranked based on their overall mean weight in round 3. For introduction and spread routes, the overall mean weight was calculated by: $\frac{\text{mean weight category} \cdot \text{mean weight risk factor}}{100}$.

Delphi study characteristics: Convergence, dispersion & change of opinion

Delphi studies aim to reduce the range of answers/estimates resulting in convergence towards consensus. To investigate whether convergence occurred in the present study, the interquartile range (IQR, the difference between the 25- and 75-percentile, calculated with SPSS 12.0.1) was examined for the categories and risk factors of introduction and spread routes and poultry demographics in round 2 and 3. In addition, the dispersion of values was investigated by looking at the standard deviations. During the Delphi process these characteristics are expected to decrease in successive rounds. Moreover, they will indicate factors that are uncertain and thus are candidates for sensitivity analysis.

To get a more detailed insight into the ‘change of opinion’ of individual experts, the weights given by each expert (n=19) in round 2 and 3 to categories and risk factors of introduction and spread routes and poultry demographics were compared. Particularly medium changes (> 10, but ≤ 20 points) or large changes (> 20 points) were of special interest. Within the Delphi procedure, medium and large changes from round 2 to 3 are expected to be closer to the group average of round 2.

3.2. Results

3.2.1 Ranking of risk factors: routes and demographics

Mean, minimum and maximum values, standard deviation and overall mean (‘routes’ only) of the weights given by the expert panel are shown in Tables 6 to 11.

3.2.2 Regional biosecurity level

The majority of the expert panel members had preference for either option 1 (‘composing a measure from a combination of aggregated risk factors at farm level’, 6 out of 17) or option 3 (‘using the poultry production sector classification system of the FAO’, 8 out of 17). Only one expert chose option 2 (using a health standard classification system) and 2 experts did not state a preference. No alternative classification measures were suggested. Considering option 1, Grabkowsky et al. (this report) present an approach to assess a poultry farms’ risk status using different risk factors at farm level.

3.2.3 AI introduction at farm level: biosecurity and production related factors

Results on the weights given by the expert panel to biosecurity measures and production related factors at farm level are shown in Table 12 and 13. The measure ‘prevention of birds entering the poultry houses’ was considered the most important biosecurity measure, pest control of rodents and insects were considered least important. A ‘free-range system mixed with a cage or barn system’, ‘sharing personnel, vehicles or equipment with other poultry farms’ and ‘combined farming of different poultry species at one farm’ were considered the most important production related factors that increase the risk of AI introduction on poultry farms.

Table 6. Categories of introduction routes, ordered by mean weight

	Category	Mean weight	Min	Max	SD
1	Migratory / wild birds[a]	41.0	12	90	19.7
6	Illegal import of poultry/poultry products from third countries	16.4	5	35	9.0
4	Illegal interregional trade within EU-27	11.0	5	20	4.4
5	Import of poultry and poultry products from third countries	10.7	0	30	7.2
7	Poultry services, poultry professionals	7.6	0	30	7.1
3	lnterregional trade within EU-27	5.6	0	10	3.2
2	Interregional trade within within European supply chains	5.6	0	10	3.6
8	Bioterrorism/Sabbotage	2.1	0	10	2.7

[a]Mean weight significantly higher than the value according to the uniform distribution (two-sided t-test, α=0.05)

Table 7. Categories of spread routes, ordered by mean weight

	Category	Mean weight	Min	Max	SD
3	Unregistered trade within region	25.6	5	70	14.5
5	Neighbourhood spread[a]	25.5	10	60	12.0
4	Poultry services, poultry professionals	21.8	5	50	10.5
2	Trade within region	15.8	0	50	10.3
1	Wild birds	10.6	0	30	9.1

[a]Mean weight significantly higher than the value according to the uniform distribution (two-sided t-test, α=0.05)

Table 8. Risk factors related to introduction routes, ordered by category and mean weight (continued on next page).

Category	Risk factor	Mean weight	Min	Max	SD	Overall mean weight	Rank
1	Number of wild birds wintering in proximity to domestic poultry farms[a]	24.2	10	50	8.2	9.93	1
1	Presence of open water bodies in a region[a]	22.0	10	35	7.2	9.03	2
1	Presence of important bird areas (IBAs) in a region[a]	21.5	10	35	6.5	8.80	3
1	Percentage of freerange holdings located under migratory flyways	20.7	0	35	9.5	8.48	4
1	Percentage of poultry holdings in total located under migratory flyways	9.8	0	20	4.8	4.00	5
1	Number of hunters in contact with wild birds	1.8	0	10	2.7	0.72	33
2	Number of traded live birds without fixed contracts[a]	46.7	30	100	14.6	2.63	12
2	Number of traded live birds within closed supply chain	23.8	0	40	10.5	1.34	19
2	Number of traded poultry products without fixed contracts	18.1	0	40	9.4	1.02	25
2	Number of traded poultry products within closed supply chain	11.4	0	20	5.0	0.64	34
3	Presence of live bird markets in a region that trade interregionally - legal[a]	42.5	20	100	19.5	2.40	13
3	Number of imported live poultry from EU-27 - legal	17.3	0	40	8.9	0.98	27
3	Amount of faeces & litter from poultry houses imported - legal	10.0	0	30	7.7	0.56	38
3	Number of returning livestock trucks from EU-27 - legal	8.6	0	30	7.1	0.48	39
3	Number of imported captive caged birds - legal	8.5	0	40	8.2	0.48	40
3	Number of imported wild birds (birds of prey etc.) from EU-27 - legal	8.5	0	20	5.3	0.48	41
3	Number of imported poultry products from EU-27 - legal	4.6	0	10	4.1	0.26	48
4	Presence of live bird markets in a region that trade interregionally - illegal[a]	34.0	20	80	14.1	3.73	6
4	Number of imported live poultry from EU-27 - illegal[a]	17.1	2	30	7.3	1.88	16
4	Number of imported wild birds (birds of prey etc.) from EU-27 - illegal	11.7	0	30	6.4	1.28	21
4	Number of imported captive caged birds - illegal	9.7	0	25	6.1	1.06	23
4	Amount of faeces & litter from poultry houses imported - illegal	9.7	0	20	5.8	1.06	24
4	Number of returning livestock trucks from EU-27 - illegal	6.8	0	15	5.3	0.74	32
4	Number of imported poultry products from EU-27 - illegal	3.9	0	15	4.0	0.43	43
4	Amount of imported fresh poultry meat from EU-27 - illegal	2.9	0	15	3.9	0.31	46
4	Amount of imported fresh frozen meat from EU-27 - illegal	1.7	0	10	2.6	0.18	49
4	Number of imported hatching eggs from EU-27 - illegal	1.6	0	5	2.1	0.17	50
4	Number of imported table eggs from EU-27 - illegal	1.0	0	5	1.5	0.10	51
5	Number of imported live poultry from EU-27 - legal[a]	25.5	0	50	13.3	2.74	11
5	Number of imported wild birds (birds of prey etc.) from outside EU-27 - legal[a]	18.3	0	40	9.3	1.97	15
5	Number of imported captive caged birds - legal[a]	17.1	5	35	8.5	1.84	17
5	Number of returning livestock trucks from outside EU-27 - legal	9.4	0	20	5.2	1.01	26
5	Amount of faeces & litter from poultry houses imported from outside EU-27 - legal	8.9	0	20	6.3	0.95	28
5	Number of imported poultry products from outside EU-27 - legal	5.6	0	10	4.3	0.60	35
5	Amount of imported fresh poultry meat from outside EU-27 - legal	5.3	0	15	4.8	0.57	36
5	Amount of imported fresh frozen meat from outside EU-27 - legal	4.2	0	10	4.0	0.46	42
5	Number of imported hatching eggs from outside EU-27 - legal	3.0	0	10	4.0	0.32	45
5	Number of imported table eggs from outside EU-27 - legal	2.6	0	10	3.7	0.28	47

[a]Mean weight significantly higher than the value according to the uniform distribution of the category (two-sided t-test, α=0.05)

Table 8. (continued)

Category	Risk factor	Mean weight	Min	Max	SD	Overall mean weight	Rank
6	Number of imported wild birds (birds of prey etc.) from outside EU-27 - illegal[a]	22.7	0	50	11.5	3.72	7
6	Number of imported live poultry from outside EU-27 - illegal[a]	21.7	0	40	10.4	3.55	9
6	Number of imported captive caged birds - illegal[a]	19.1	5	40	10.1	3.13	10
6	Amount of faeces & litter from poultry houses imported from outside EU-27 - illegal	8.0	0	20	5.3	1.31	20
6	Number of returning livestock trucks from outside EU-27 - illegal	7.6	0	20	4.7	1.25	22
6	Number of imported poultry products from outside EU-27 - illegal	5.3	0	15	4.5	0.86	29
6	Amount of imported fresh poultry meat from outside EU-27 - illegal	4.9	0	15	4.6	0.81	30
6	Amount of imported fresh frozen meat from outside EU-27 - illegal	4.7	0	10	4.1	0.77	31
6	Number of imported hatching eggs from outside EU-27 - illegal	3.5	0	15	4.4	0.57	37
6	Number of imported table eggs from outside EU-27 - illegal	2.5	0	15	4.0	0.42	44
7	Percentage of poultry workers who have poultry at the home[a]	48.9	15	80	14.3	3.70	8
7	Number of interregionally operating poultry workers living outside of EU-27	28.5	10	50	9.0	2.16	14
7	Number of interregionally operating poultry workers living in EU-27	22.6	10	50	9.2	1.71	18

[a] Mean weight significantly higher than the value according to the uniform distribution of the category (two-sided t-test, α=0.05)

Table 9. Risk factors related to spread routes, ordered by category and mean weight.

Category	Risk factor	Mean weight	Min	Max	SD	Overall mean weight	Rank
1	Number of wild birds wintering in proximity to domestic poultry farms	25.3	0	50	11.8	2.7	11
1	Percentage of freerange holdings located under migratory flyways	25.3	0	50	12.0	2.7	12
1	Presence of important bird areas (IBAs) in a region	19.6	0	35	6.9	2.1	15
1	Presence of open water bodies in a region	18.0	0	30	7.9	1.9	16
1	Percentage of poultry holdings in total located under migratory flyways	11.8	0	50	10.9	1.3	17
2	Presence of live bird markets in region - registered[a]	35.3	20	52.4	8.7	5.6	6
2	Number of live poultry movements/year within a region - registered[a]	29.6	20	50	8.0	4.7	7
2	Amount of faeces & litter from poultry houses - registered	15.7	4.8	30	6.6	2.5	13
2	Presence of bird shows in region - registered	15.0	10	20	4.2	2.4	14
2	Table egg production/year - registered	4.4	0	15	4.5	0.7	19
3	Presence of live bird markets in region - unregistered[a]	37.5	5	52.4	10.9	9.6	3
3	Number of live poultry movements/year within a region - unregistered[a]	29.7	10	60	11.9	7.6	4
3	Amount of faeces & litter from poultry houses - unregistered	14.4	4.8	35	8.3	3.7	9
3	Presence of bird shows in region - unregistered	14.2	5	30	5.9	3.6	10
3	Table egg production/year - unregistered	4.1	0	15	4.3	1.1	18
4	Number of regionally operating poultry workers[a]	49.0	30	60	9.2	10.7	2
4	Number of regionally operating poultry professionals	29.5	20	50	8.9	6.4	5
4	Number of farm visitors	21.4	10	40	8.5	4.7	8
5	Local farm density	-	-	-	-	25.5	1

[a] Mean weight significantly higher than the value according to the uniform distribution of the category (two-sided t-test, α=0.05)

Table 10. Demographical risk factors related to introduction, ordered by mean weight

Risk factor	Mean weight	Min	Max	SD
Percentage of commercial poultry farms with free-range housing[a]	25.5	10	50	9.7
Number of birds (poultry) kept in freerange[a]	17.3	5	30	7.1
Number of commercial duck farms	12.6	0	30	7.4
Number of non-commercial flocks (farms with < 300 birds)	9.8	5	20	4.6
Number of commercial poultry farms	9.6	2	20	3.6
Number of commercial turkey farms	9.1	2	15	3.5
Number of farms with pedigree poultry (hobby)	6.9	0	15	3.7
Number of layer farms	4.8	0	10	3.1
Number of large-scale poultry farms	4.5	0	10	3.8

[a]Mean weight significantly higher than the value according to the uniform distribution (two-sided t-test, α=0.05)

Table 11. Demographical risk factors related to spread, ordered by mean weight

Risk factor	Mean weight	Min	Max	SD
Number of commercial poultry farms[a]	23.6	5	55	13.6
Percentage of commercial poultry farms with free-range housing	12.5	0	30	6.5
Number of large-scale poultry farms	12.3	0	30	8.6
Number of commercial turkey farms	10.8	0	40	8.3
Number of commercial duck farms	10.6	0	30	7.6
Number of birds (poultry) kept in freerange	9.9	0	20	5.7
Number of layer farms	8.0	0	30	8.1
Number of non-commercial flocks (farms with < 300 birds)	7.2	0	20	5.2
Number of farms with pedigree poultry (hobby)	5.2	0	10	3.8

[a]Mean weight significantly higher than the value according to the uniform distribution (two-sided t-test, α=0.05)

Table 12. Biosecurity measures to prevent AI introduction at farm level, ordered by mean weight.

Biosecurity measures to prevent AI introduction at farm level	Mean weight	Min	Max	SD
Prevention of birds entering the poultry houses[a]	16.3	5	30	5.9
Disinfection of footwear before entering the poultry house[a]	8.8	0	20	4.3
Treatment of open water before using as source for poultry drinking water	8.3	0	20	4.7
Changing of clothes before entering the poultry house	8.0	0	20	4.5
Prevention of birds entering the storage of feed and litter	7.3	0	10	2.9
Provision of information about AI to employees	6.9	0	15	4.1
Using single-use egg trays or cleansing/disinfection of reusable egg trays	6.5	2	20	4.4
Disinfection of farm equipment before use in the poultry house	6.4	0	15	3.2
Disinfection of shared farm machinery before use	6.2	0	10	2.8
Disinfection of farm vehicles before driving onto the farm	5.1	0	10	2.8
Training of farm owners and personnel in implementing biosecurity measures	4.6	0	10	2.5
Hand washing before entering the poultry house	4.5	0	20	4.3
Using a 1:1 feed delivery system	4.3	0	10	3.0
Regulated access restriction of visitors	3.2	0	5	1.8
Pest control - rodents	2.1	0	5	2.0
Pest control - insects	1.5	0	5	1.9

[a]Mean weight significantly higher than the value according to the uniform distribution (two-sided t-test, α=0.05)

Table 13. Production related factors that affect AI introduction at farm level, ordered by mean weight.

Production factor that increases risk on AI introduction	Mean weight	Min	Max	SD
Usage of a freerange system mixed with a cage or barn system[a]	26.9	10	50	11.9
Sharing personnel, vehicles or equipment with other poultry farms[a]	18.8	5	35	7.4
Housing different species of poultry at one farm[a]	16.2	0	30	7.4
High amount of business contacts on the farm	13.3	5	45	8.6
Usage of a mixed age system	8.6	0	25	6.2
Using non-family personnel in poultry houses	6.5	0	15	4.1
Not using a system with controlled movement of poultry	6.3	0	20	5.2
Combining poultry farming with pig farming	3.4	0	15	4.5

[a]Mean weight significantly higher than the value according to the uniform distribution (two-sided t-test, α=0.05)

3.2.4 AI introduction at farm level: contact structure

All experts agreed that the likelihood of an AI introduction on farms increases with ‘the number of visitors with access to the poultry house’, ‘the number of poultry professionals with access to the poultry house’, and ‘the number of contacts that the visitors had with other poultry farms on the same day’. The latter contact structure characteristic received the highest rating (16++ and 5+). These results are used to assess the farms contact structure in the paper by Grabkowsky et al. (this report).

3.2.5 Between-farm spread

For the pathways assessed, the standard of hygiene and cleaning and disinfection practices were found to be of considerable importance to the likelihood of transmission from an infected to a susceptible farm. Assuming a good standard of hygiene and cleaning and disinfection to be present, the pathways were ordered based on their average rankings in round 2, see Fig. 2.

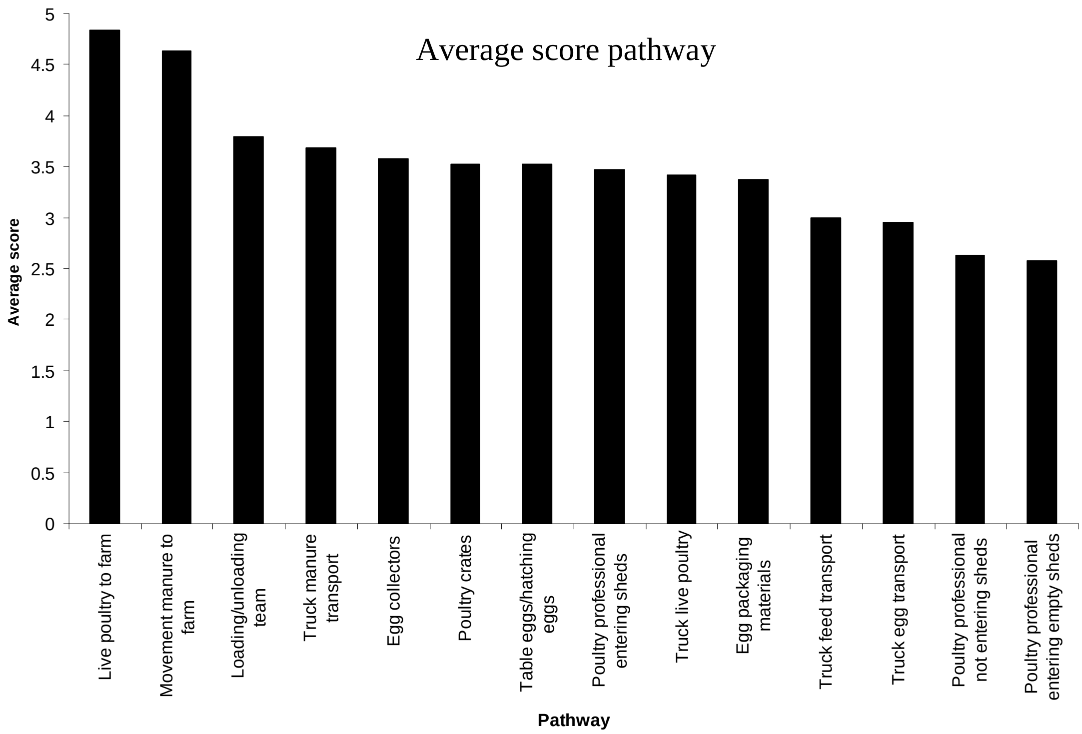

Figure 2. Average scores for the likelihood of transmission of pathways. For pathways in which distinction in hygiene level was made, a good standard of hygiene (cleaning and disinfection) was assumed.

‘Transport of live poultry’ and ‘the movement of manure from an infected to a susceptible farm’ were considered to have the highest likelihood of transmission per contact. ‘Poultry professionals not entering the sheds’ or ‘entering the sheds when they are empty’ were considered to have the lowest likelihood of transmission per contact. A number of experts indicated that the next step, quantification of the likelihood of transmission for five selected pathways, was a rather difficult task. The results ranged from an average of 77 infections out of 100 for ‘live poultry’ to 17 infections for ‘poultry professionals not entering the poultry sheds’.

3.2.6 Convergence, dispersion and change of opinion

In the majority of cases convergence occurred: the IQR decreased in 67% of the risk factors/categories with an average of 4.9 points (18% of the IQR remained the same size, 15% increased). The standard deviations decreased in 76% of the risk factors/categories. In total 106 medium (6%) and 25 large (1%) changes of opinion were observed. The 13 large changes within the risk factors for introduction all considered legal and illegal trade of birds (captive cage birds, imported wild birds and live bird markets). For the majority of the medium (63%)

and large changes (64%), the weights given in round 3 were closer to the group average of round 2 than the weights given in the second round.

4. Discussion and conclusions

In this explorative study, we investigated which factors are the main determinants for the risk of introduction and the risk of spread of notifiable avian influenza virus (NAIV) in domesticated poultry at regional level. We performed a literature study followed by a three-stage Delphi study to elicit the expert opinion of 21 international AI experts. Overall it can be concluded that the expert panel involved was highly motivated resulting in high response and return rates. The median values of self-rated expertise of the experts over all categories were between 1 (highly competent) and 3 (familiar). Although self-rated, this indicates that there was sufficient competence in the expert panel on all subjects in the questionnaire. The typical Delphi characteristic of convergence towards consensus by participants revising their earlier answers in light of the replies of other members of the panel seems to have been present.
The categories of introduction routes that obtained the highest ratings were by far migratory/wild birds followed by illegal import from third countries. Within the categories for introduction routes, particularly risk factors dealing with movements/trade of live birds (legal and illegal) were considered to be of major importance for AIV introduction. Free-range farming was considered to be the major demographical risk factor for AIV introduction. For spread the categories that obtained the highest ratings were unregistered trade within a region and neighbourhood spread. Similar to introduction, risk factors dealing with movements/trade of live birds (registered and unregistered) obtained the highest weights, but also poultry workers (e.g. catching crews and other service teams) were believed to be important for AIV spread. The number of commercial farms in a region was given the highest ratings among the demographical risk factors for spread.
The results presented are in accordance with the general view that live animal movements, human contacts and high farm densities play an important role in the dissemination of infectious animal diseases (e.g. Stegeman et al., 1997; Huirne, 2003; Capua and Alexander, 2004). Furthermore, a strong emphasis is laid on possible introductions by wild birds as can be seen from the high weights given to the wild bird category and to risk factors related to free-range farming, which is in accordance with e.g. Alexander (1995) and Koch and Elbers (2006). However, for some factors, the wild bird category in particular, a relatively high dispersion of values was observed among the experts. Due to a lot of debate about some issues among stakeholders and scarcity of data this is not surprising (EFSA, 2005; EFSA, 2008).
This explorative study is a first step in a qualitative GIS-based regional risk assessment that is ultimately aimed to develop AI risk maps of the EU-27. The identified risk factors will be used to focus data collection and the ratings by the expert panel will be used to weight the risk factors against each other. Risk maps are a comprehensive way of visualizing regions with a relatively higher risk for AIV introduction or extensive spread (e.g. Ehlers et al., 2003; Boenders et al., 2007). They can be used as a tool to facilitate risk based decision making, e.g. by identifying regions at risk for which a higher alertness, more stringent prevention measures or other or more extensive control measures are needed (e.g. ring culling and extended surveillance zones). With the intended EU-27 risk maps, it will also be possible to identify adjacent regions at risk situated in two or more member states. Hence, risk maps are promising tools for the future development of regionally adapted AI strategies in the EU-27.

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