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A PathWayDiagram for introduction and prevention of Avian Influenza: Application to the Dutch poultry sector

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ABSTRACT

The introduction of Highly Pathogenic Avian Influenza (HPAI) viruses is a continuing threat to the poultry sector. In times of increased risk of introduction (e.g. because of HPAI outbreaks in neighbouring countries or trade partners), decision-makers face the question whether they should intensify current preventive measures or establish new ones. To support this, a qualitative decision tool in the form of a PathWayDiagram (PWD) is presented. The PWD includes theoretically possible pathways for introduction of HPAI in the domestic commercial poultry population together with corresponding preventive measures. Hence, the PWD is a systematic checklist focused on (1) possibilities of (increased risk of) introduction and (2) possible preventive measures. It can be used in a high-alert situation, when decision-makers have to act in a relatively short time to decide on and implement a coherent set of preventive measures covering the high-risk pathways involved.

1. Introduction

Occurrence of Highly Pathogenic Avian Influenza (HPAI) in the domestic commercial poultry population can have a large impact in terms of the number of birds involved, the control costs of the disease and the social consequences (Capua and Alexander, 2004). Low Pathogenic Avian Influenza (LPAI) virus is endemic in migratory birds throughout the whole world, i.e. a permanent Avian Influenza Virus (AIV) reservoir (Alexander, 2007). This LPAI virus is able to mutate under field conditions into HPAI viruses, and is still present in some countries in Europe, Asia and the Middle East (Capua and Alexander, 2004). Therefore, the introduction of AIV is a continuing threat to the poultry sector in major poultry producing countries, such as The Netherlands.

Quite regularly, i.e. 2–4 times per year (Waelen, personal communication) officers working at disease control agencies in The Netherlands are confronted with situations of elevated alert with regard to introduction of HPAI due to outbreaks elsewhere. During these high-alert situations, decision-makers face the following questions under time pressure: (1) is there an increased risk of HPAI introduction?; and if so, (2) which introduction routes might be of concern and what is their relative importance?; and (3) what preventive measures can or should be established? Such decisions can be structured and supported by the use of a PathWayDiagram (PWD). A PWD shows the theoretically possible routes of exotic livestock disease introduction in a particular country (De Vos et al., 2003).

The aim of this paper is to present such a PWD for the introduction and prevention of HPAI with the focus on its qualitative use in high-alert situations, applied to The Netherlands.

2. Approach

The objective was to develop a PWD for decision support in high-alert situations. First, a general outline of the PWD was developed, including the various levels and sub-

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populations. Subsequently, a thorough literature search was carried out to identify the theoretical pathways leading to the introduction of HPAI, focused on peer-reviewed English articles and Dutch and English non-published literature (e.g. government reports). The databases Scopus, Web of Science, and the search engine Google Scholar were searched, using the key words *AI*; *HPAI*; *LPAI*; *risk*; *introduction*; *preventive measures*; and *pathways* for the years 1990–2010. Thirdly, this inventory of pathways and preventive measures was consolidated in a detailed PWD.

3. Description of the PathWayDiagram

3.1. The PathWayDiagram

In Fig. 1, a comprehensive PWD for introduction and prevention of AI is presented.

Transmission routes for virus introduction, so-called pathways, can be divided into direct and indirect, as well as endogenous and exogenous. *Direct pathways* are pathways resulting in an outbreak in the commercial domestic poultry population without passing through endogenous populations, i.e. endogenous migratory bird, non-commercial poultry (including birds other than poultry), human and mammal populations. *Indirect pathways* do pass through these endogenous populations. Pathways that originate from inside the region are called *endogenous*, whereas pathways from outside the region are called *exogenous*.

The PWD includes five levels, where a level (L) is defined as a horizontal layer in the PWD.

At L1 (*direct pathways for virus introduction into a region*), all individual routes of over 20 pathways are included. Starting from the upper-left of the PWD, the first nine exogenous pathways, including live birds, other animals and people, are presumed to constitute the highest risk for virus introduction as the virus is replicating in live animals and shed into the environment (Cardona et al., 2009). More to the right, eight pathways including animal products are shown. The last group of exogenous pathways includes miscellaneous routes of virus introduction. Some exogenous routes only contribute to virus introduction if they originate from a neighbouring area, e.g. air currents, rodents and arthropods. These routes carry the virus only over short distances and therefore, their presumed role in virus introduction is low (Davison et al., 2003; EFSA, 2008). At the upper-right of L1, one endogenous direct route for virus introduction is given, i.e. escape of AIV from a domestic AI laboratory.

At L2 (*infection or contamination with virus*), the logical units in which a pathway is usually measured are listed, e.g. one bird, a batch of animal products or a returning livestock truck.

In L3, *preventive measures* are listed, which can be taken to detect or inactivate the virus. The preventive measures described per pathway are derived from requirements of international bodies (European Union (EU), World Organisation for Animal Health, and Food and Agriculture Organization) and transposed from EU directives into national legislation (see e.g. Anonymous, 2007; World Organisation for Animal Health, 2007). *Routine measures* are in place in 'peace-time' situations. *Ad hoc measures* are actions which can be taken in high-alert situations, i.e. HPAI outbreaks in e.g. EU Member States or in the case of HPAI-affected wild birds in e.g. neighbouring countries. These measures can be intensification of routine measures or new actions. Also, the organisations, which are responsible for these preventive measures in The Netherlands, are listed.

In case preventive measures fail, the AIV can either go to (one of) the *endogenous populations* (L4) or directly to the *domestic commercial poultry population* (L5), causing an outbreak. The colored lines (ending in arrows) indicate the possible routes of the pathways to the endogenous populations (green, black, blue and purple circles, L4) and/or the domestic commercial poultry population (red circle, L5). For example, AIV via the pathway 'legal import of genetic material' (L1) can either infect or contaminate domestic non-commercial poultry (black line, L4), or infect/contaminate the domestic commercial poultry population (red line, L5). If virus transfer to (one of) the endogenous populations occurs, again there are possible routes spreading the disease to other endogenous populations (L4) and routes infecting the domestic commercial poultry population (L5). For the endogenous populations, it is presumed that no virus is present and therefore, only ad hoc measures are given.

The final event, an outbreak in the domestic commercial poultry population (L5), can occur by two ways, i.e. if at least the minimum infective dose is exceeded, or if exogenous infected live poultry is added to the domestic commercial poultry population (bold red arrow in Fig. 1). In the latter case, no infective dose is needed because the imported animals become part of the population.

Hence, the PWD describes for all pathways the relevant events and possible preventive measures between (1) a high-risk introduction route (L1) and (2) the outbreak of AI in commercial poultry (L5).

3.2. Example of a pathway: migratory birds

As an example for all pathways, the pathway for migratory birds is described in detail. In case the available information leading to the elevated alert-situation indicates that migratory birds might form an increased risk, the route through the PWD is as follow. Migratory birds (L1), serving as a natural reservoir of LPAI, primarily disseminate LPAI viruses as a result of migratory bird activity (Isoda et al., 2006). If at least one bird is infected/contaminated (L2) and preventive measures fail (L3), such as preventing direct or indirect exposure to potentially AIV-infected migratory birds, the LPAI viruses can either go directly (red line/arrow) to the domestic commercial poultry population (L5), or to the endogenous populations (L4), e.g. via direct contact of free ranging poultry with migratory birds or via indirect contact e.g. through surface water used for drinking water (Capua and Alexander, 2004).

At L4, the endogenous populations do not need to be infected, because they can transfer the virus mechanically in infective faeces to the domestic commercial poultry population (L5) if ad hoc measures fail, e.g. confinement of poultry (Stallknecht et al., 1990). At L5, after an infective