Estimating the sensitivity of passive surveillance for HPAI H5N1 in Bayelsa state, Nigeria.

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Highlights

- We modeled the probability of detecting HPAI H5N1 in commercial and backyard poultry holdings.
- We generated data on the characteristics of poultry farming in Bayelsa state and identified farming practices that can affect the probability of detecting an outbreak of HPAI
- The relative risk of HPAI between commercial and backyard chicken farms was estimated via expert opinion elicitation
- We developed a scenario tree model to evaluate the sensitivity of passive surveillance for HPAI H5N1.
- The sensitivity of passive surveillance for HPAI H5N1 decreases at low levels of disease prevalence.
- Backyard chicken keepers' ability to recognize and report the disease has the most impact on the sensitivity of the passive surveillance.

Abstract

This study identified characteristics of poultry farming with a focus on practices that affect the detection of HPAI; and estimated the system sensitivity of passive surveillance for HPAI H5N1 in commercial and backyard chicken farms in Bayelsa-State, Nigeria. Field studies were carried out in Yenegoa and Ogbia local government areas in Bayelsa state. Willingness to report HPAI was highest in commercial poultry farms (13/13) than in Backyard farms (8/13). Poor means of dead bird disposal was common to both commercial and backyard farms. Administering some form of treatment to sick birds without prior consultation with a professional was higher in backyard farms (8/13) than in commercial farms (4/13). Consumption of sick birds was reported in 4/13 backyard farms and sale of dead birds was recorded in one commercial farm. The sensitivity of passive surveillance for HPAI was assessed using scenario tree modelling. A scenario tree model was developed and applied to estimate the sensitivity, i.e. the probability of detecting one or more infected chicken farms in Bayelsa state at different levels of disease prevalence. The model showed a median sensitivity of 100%, 67% and 23% for detecting HPAI by passive surveillance at a disease prevalence of 0.1%, a minimum of 10 and 3 infected poultry farms respectively. Passive surveillance system sensitivity at a design prevalence of 10 infected farms is increasable up to 86% when the disease detection in backyard chicken farms is enhanced.

Keywords: Scenario tree modelling; Passive surveillance; Backyard poultry; HPAI; Nigeria

Introduction

Outbreaks of Highly Pathogenic Avian Influenza (HPAI) are of notable concern because of its adverse impacts on public health, the poultry industry as well as the economy of affected nations. A total of 784 confirmed human cases of HPAI H5N1 with 429 deaths have been reported worldwide, most of which are linked with exposure to sick or dead poultry (WHO, 2015). HPAI outbreaks do not only devastate the poultry industry through the high mortality and morbidity of the disease or depopulation to control the outbreaks, but also cause a drop in demand for poultry and poultry products through negative market reactions. A typical case point in Africa is the outbreak of HPAI H5N1 in Nigeria which reduced the demand and consumption of poultry products and led to a loss of jobs for poultry farmers (Anon, 2006; Obayelu 2007).

The first case of HPAI H5N1 in Nigeria was detected on a commercial poultry farm in Kaduna state, on the 26 of January 2006 (Joannis et al, 2006; De Benedictis et al, 2007). The disease spread across 25 of the 36 states in the country between January 2006 and July 2008 (Fusaro et al, 2009), affecting both commercial and backyard poultry (Fasina et al, 2011). By January 2007 the first and only human case of HPAI was confirmed in Lagos state (WHO, 2015).

An estimated 1.3 million birds died or were culled in an attempt to control the outbreak in Nigeria (Fasina et al, 2011). Eighty percent reduction in the consumption of poultry in households and restaurants was reported during the outbreak in 2006 (Anon, 2006; Obayelu, 2007). Surveys conducted across poultry farms showed that over 45% of workers across HPAI infected farms lost their jobs due to lower revenue during HPAI outbreak (Anon, 2006; Obayelu, 2007)

Efforts were made by the Federal Government of Nigeria (FGN) in collaboration with several international bodies including the Food and Agricultural Organisation of the United Nations (FAO), the World Bank, the World Organisation for Animal health (OIE) and others to intensify surveillance and control the outbreak (Joannis et al, 2008). Control measures included; active surveillance in farms and Live Bird Markets (LBM), restriction of bird movements throughout the country, enlightenment of poultry farmers on the significance of bio-security, thorough decontamination of infected premises and rapid stamping out of all laboratory confirmed cases (Ekong et al, 2012). Confirmation of a farm positive for HPAI H5N1 within a village led to all birds within that village being culled (Henning et al., 2012).

Passive surveillance or the reporting of suspected cases of AI to the veterinary authorities was set up in 2006 with the aim to optimize rapid detection of the disease. Early detection can elicit a rapid response by the Nigerian government and is critical if disease eradication must be achieved (Salman et al., 2003). It is therefore essential that the performance of the passive surveillance system for HPAI be assessed especially as support from international organizations and agencies have been suspended (World Bank, 2011)

Surveillance system sensitivity (SSe) is the probability that at least one bird infected with HPAI will be detected by the system, provided the disease is present in the reference population at or above a specified level of prevalence (Martin et al, 2007). Passive surveillance for HPAI relies not only on the probability of infected birds showing clinical signs but also on the disease awareness of farmers and their willingness to report (Hardon and Stärk, 2008).

Bayelsa state is located in southern Nigeria (see Fig 1). Due to the presence of inland water bodies, its poultry density (122 poultry/Km^2), human population density (182 people/Km^2) and market access, the state has been considered a high risk area for the occurrence of HPAI (BSG, 2012; Uzochukwu-Obi et al, 2008). This study therefore aims to:

i. Describe the characteristics of commercial and backyard poultry farming in Bayelsa state with a focus on practices that can affect the detection of HPAI; and
ii. Estimate the system sensitivity of passive surveillance for HPAI in Bayelsa state using scenario tree modelling described by Martin et al, (2007).

Materials and Methods

2.1. Reference population

Bayelsa state is located in southern Nigeria, within Latitude 4^0 15’ North, 5^0 23’ South and longitude 5^0 22’ West and 6^0 45’ East. The state is divided into eight Local Government Areas (LGAs). According to the National Bureau of Statistics, in 2007, there were 265,189 households in the state and a total of 1,147,432 poultry - almost all of which are chickens. The structure of poultry production systems is similar to those in most developing countries; small number of large scale commercial poultry farms and countless numbers of small scale backyard poultry farms. Data on the number of backyard poultry was based on Uzochukwu-Obi et al., (2008) report which stated that an estimated 64.42% of households in the region keep backyard poultry. With this estimate and the total number of households in the state, it would give a total of 170,835 households having backyard chickens assuming there has been no significant change in the number of households in the state (Uzochukwu-Obi et al, 2008; NBS 2007). Based on a 2006 census, there were 64 registered commercial poultry farms in Bayelsa of which 59 were exclusive chicken flocks (92%), four keep a mixture of chickens and turkeys (6%) and one duck farm (2%). As chickens constitute the greatest percentage (>80%) of the poultry industry in Nigeria (Adene and Oguntade, 2008), this study assesses the system sensitivity of the passive surveillance in the chicken population only.

2.2. Field Study area

Field studies were conducted in Yenegoa and Ogbia LGAs of Bayelsa state. These two LGAs were purposively selected based on accessibility and available funds. Surveys were conducted on commercial and backyard poultry farms. Oral consent was obtained from the commercial poultry farm owners and household heads prior to their participation in the survey. Participants were also guaranteed that any published results would not mention information at the individual level. We started by surveying poultry famers and then moved towards people who they reported to. In this process we developed an information pathway.

2.2.1. Poultry farmers/ farm workers Interviews

Meetings were held in April 2012 with representatives of the state veterinary service and the state avian influenza control team. This was done to establish a list of poultry farms known to the government. This resulted in a list of 64 registered commercial poultry farms. No data on backyard poultry farms were available. Sampling of poultry farms was done using snowball sampling. Commercial chicken farms first visited were based on the list provided by the state veterinary service. Other poultry farms were then found through referral by the previous poultry farmers visited and distributors of poultry feed. 26 poultry farmers (13 commercial chicken farmers and 13 backyard chicken farmers) participated. Each survey involved discussion sessions with poultry farmers and collection of data on flock type, production systems, demographics, health practices, bio-security, feeding, and knowledge of poultry disease, drug use, and reporting practices.

2.2.2. Interview of Private vet doctors and "Informal poultry health advisors"

It became apparent that poultry farmers report to three categories of people:

i. Private veterinarian;

ii. Informal poultry health advisor; and

iii. State veterinary service.

An informal poultry health advisor is one who knows about poultry and poultry disease, has years of experience in the field, may be called a doctor but is actually not. He or she provides advice to poultry farmers on matters of bird health and may be skilled to carry out post mortem examinations on birds. His or her service is usually cheaper compared to private veterinarians. Discussions were held with two private veterinary doctors and two informal poultry health advisers in order to understand the process of detection of an infected flock, diagnostic capability and communication channels with the state veterinary service.

2.2.3. Data collection and analysis

Data on the characteristics of commercial and backyard poultry farming were obtained via discussion sessions with farmers. The response of farmers to specific topics discussed were immediately recorded in a notebook and translated afterwards into Microsoft excel 2010.

2.3. Surveillance System Components (SSC) based on passive surveillance

Passive surveillance is the reporting of HPAI by poultry farmers to the National Animal Disease Information and Surveillance through their respective state veterinary services. Each State in Nigeria has avian influenza desk officers strategically located in every LGA. These desk officers are key personnel of the National Avian Influenza Control Project (NAICP). They are in charge of HPAI surveillance and response activities in the state. Reporting of suspected cases of AI is directed to the desk officer in charge of the LGA where the suspicious bird(s) is (are) found. Upon suspicion, the following samples are collected and sent to the National Veterinary Research Institute (NVRI) by the government veterinarian: swabs of tracheal and cloacal contents taken aseptically, brain, trachea, spleen and intestinal contents. Specimens are taken from at least six birds preferably with an equal number of dead birds and those showing signs of acute disease (FDLPCS, 2006). These samples are pooled and tested using Rt-PCR. Positive samples are then subject to Virus isolation.

Nevertheless, in Nigeria not all poultry farmers are equally predisposed to report HPAI suspicion as a result of;

i. Poverty which can affect their ability to communicate suspicion due to lack of funds;
ii. Location in remote villages which can affect their ability to access veterinary services;
iii. Lack of mobile phone network in remote areas which hinges on communication; and
iv. He/she is just unwilling to report

Seventy percent of Nigerians live below the poverty line and poverty is present mostly in the rural areas where social services and infrastructure are limited (IFAD 2013). This will affect the total population under passive surveillance. Taking these facts into consideration, we assumed that the proportion of backyard poultry farmers that can partake in the passive surveillance programme for HPAI would range from 50% to 80%. This was input in the model using a pert distribution in @RISK. The Scenario Tree Model (STM) was populated based on data gained from interviews with poultry farmers, expert opinion, literature search and data from the NVRI.

2.4. Expert Opinion elicitation

A number of parameters in the model were estimated by expert opinion due to a lack of published data. Five experts agreed to take part. Two were drawn from the NAICP, one from the University of Nigeria and two from the National HPAI Reference Laboratory, NVIR. The median years of experience of the experts were 18 and the average was 17.7. Experts were asked to respond giving a minimum, most likely and maximum value to all scenarios presented. Individual responses were then combined by taking a simple average of their opinions to provide single distributions for each parameter and incorporated as inputs of the pert distribution in the model. Table 1 shows the details of the expert opinion elicitation process.

2.5. Scenario Tree Model

A STM was developed to estimate the probability that passive surveillance for HPAI H5N1 in Bayelsa would detect at least one diseased chicken farm if present in the chicken population at or above a stipulated design prevalence. The STM considers the key factors that influence the probability of a positive surveillance outcome (Martin et al, 2007). It displays a sequence of steps in the passive surveillance which is classified into category nodes, infection nodes and detection nodes. The risk category node splits the scenario tree into branches for which the risk of being infected differs. The infection node reflects the level of design prevalence chosen for the analysis. Detection nodes reflect the events that precede detection by the passive surveillance.

2.5.1. Risk Category Nodes

Based on farm type, one risk category node is considered in the STM. The branches are commercial and backyard chicken farms. The relative risk (*RR*) of infection between commercial and backyard chicken flocks was derived from expert opinion.

2.5.2. Infection nodes

The disease prevalence is assigned at the between-flock level. Three between-flock level prevalence (P^*_H) was considered in the analysis. 0.1%; 10 infected poultry farms and 3 infected poultry farms.

2.5.3. Detection nodes

A case of HPAI is defined as:

i. Over 50% mortality rate in poultry in two days;
ii. Death in other bird species on the farm (turkeys, geese, ducks etc.);

iii. Wild birds found dead in the neighbourhood over the past week;

iv. Dead chickens have been vaccinated for Newcastle disease within the last six months;

v. Other cases of mortality in the village over the past week; and

vi. HPAI has already been declared in the state (FDLPCS 2006)

The process of detection depends on the probability that an infected bird will show clinical signs (CS) and the ability of the poultry farmer to recognize the clinical manifestations of HPAI (RG). Given that most commercial poultry farms are characterized by large flock sizes, and closer monitoring of birds, we assumed a high probability of detection. For backyard chicken farms, where flock sizes are usually small, birds are less monitored, and in most cases are allowed to roam, confined only at night, there is a possibility of the disease going undetected (Henning et al., 2008). We therefore generated a pert distribution using @Risk for this parameter to account for uncertainty.

The poultry farmer's action (FA) following suspicion of HPAI is crucial and may be influenced by factors such as:

i. The farmer wants to avoid veterinary control;

ii. The farmer may be unable to contact the veterinarian to make a report as a result of very poorly developed road network and lack of means of communication; or

iii. The absence of compensation payment for culled birds.

This parameter was assigned values based on our field survey.

All private veterinarians are obligated to report (VR) suspicion to the State veterinary service (FDLPCS, 2006) however the probability that an informal poultry health adviser would report (QR) is unknown. This is mainly because there are no formal government records to prove their existence; and these poultry health advisers may not be well known by the state veterinary service. Data on the probability of QR was assigned by the author based on discussions with informal poultry advisers.

The detection process further depends on the probability that the government veterinarian will take samples at the suspected poultry farm (VS) and the probability that the national reference laboratory will perform the test for HPAI (LT). The value assigned to these parameters may be influenced by economic factors such as the availability of funding. Financial support provided by international organisations for HPAI H5N1 surveillance has been suspended (World Bank 2011). Hence, expert opinion elicitation was used to estimate the probability of the vet taking samples. The probability that submitted samples will be tested by the national reference laboratory was assigned based on data gotten from the NVRI, on the number of suspicion reports received/ submitted and subsequently tested from 2006 - 2015. This is shown in Table 2. On the average, 97% of HPAI suspicion reports submitted to the NVRI are tested. We therefore estimated the probability about this node using a pert distribution. The final steps are the probability of an infected farm testing positive to the diagnostic tests being used which are; Real-time RT-PCR (Se_{PCR}) and Virus isolation (Se_{VI}). These parameters were populated based on literature search and expert opinion (Alba et al, 2010). The structure of the scenario tree, the nodes and branches developed as a result of this study are shown in Figure 2. Table 3 shows the details of the probability distributions and proportions chosen for the STM.

2.6. Model output

A scenario tree model of HPAI passive surveillance was simulated using @Risk Version 5.7 (Palisade Corporation) with Microsoft excel 2010. The model was run at 10,000 iterations. Taking into consideration uncertainty and variability, probability distributions were used for some model parameters.

2.6.1. Estimating the sensitivity of passive SSC

Adjusted risk

The relative risk of infection between backyard and commercial chicken farms were adjusted to retain relativeness while ensuring that the weighted risk for the population is equal to one (1) (Martin et al 2007)

(1) $\boldsymbol{AR_i} = \sum_{i=1}^{nI} (\boldsymbol{RRi} \times \boldsymbol{PrPi}) = 1$

ARi represents the adjusted relative risk and *RRi* represents the relative risk for the *i*th branch of the node. PrP_i is the proportion of the reference population for each branch and *I*is the number of branches.

Calculating the Effective Probability of Infection (EPIH)

The adjusted risk was used to calculate the EPIH for commercial and backyard chicken farms using the following formula;

(2) $\boldsymbol{EPIH_i} = \boldsymbol{AR_i} \times \boldsymbol{P_H^*}$

P^*_H represents the disease prevalence at the between farm level

The system sensitivity of passive surveillance if HPAI were present at disease prevalence P^*_H, was estimated using the following equation;

(3) $\boldsymbol{SSe_{pass}} = 1 - (1 - \boldsymbol{EPIH_i} \times \mathbf{Se_i})^{\mathbf{n}}$

n is the number of flocks in the subpopulation of i; Se_i is the probability of an infected chicken farm being detected by the passive surveillance. *Se* is estimated by multiplying all detection nodes across the respective branches of the scenario tree as follows:

(4) $\boldsymbol{Se_i} = \mathbf{CS} \times \mathbf{RG} \times ((\mathbf{PCpV} \times \mathbf{PvR}) + (\mathbf{FCQ} \times \mathbf{QR}) + \mathbf{FCG}) \times \mathbf{VS} \times \mathbf{LT} \times \mathbf{SE_{PCR}} \times \mathbf{SE_{IV}}$

2.6.2. Sensitivity analysis

A sensitivity analysis was carried out using @Risk advanced sensitivity analysis, to assess the impact of input parameters on the system sensitivity of passive surveillance (SSe). Since some of our input parameters were estimated based on a field survey with a considerably small sample size, a sensitivity analysis was conducted on all detection nodes. Inputs with the most impact on the median SSe were displayed on a tornado graph which shows the minimum and maximum values of the median SSe when input values vary between the 10^{th} percentile and 90^{th} percentile.

Results

3.1. Survey of poultry farmers

Our field study generated data on farmers' action following suspicion of HPAI; means of dead bird disposal; treatment and consumption of sick birds. The result of our field study is shown in table 4.

Among backyard poultry farmers surveyed 3/13 would report their suspicions to a private vet, 2/13 to the state veterinary service, 3/13 to an informal animal health adviser and 5/13 would report to no one. Among commercial poultry farms surveyed, 6/13 would report to a private vet, 5/13 to the state veterinary service and 2/13 to an informal animal health adviser. Higher probability of reporting suspected cases of HPAI was significantly ($p = 0.003$) correlated with commercial poultry farms, $r = 0.54$, which can be considered a large effect. Higher numbers of birds in a farm was also correlated with higher probability of reporting suspected cases, $r = 0.30$, which can be considered a medium effect.

Among backyard poultry farmers surveyed, 3/13 disposed dead birds by burying them, 6/13 disposed dead birds at a nearby refuse dumpsite, 3/13 disposed in a nearby bush and 1/13 disposed into a nearby river. Among commercial poultry farms surveyed, 4/13 disposed dead birds by burying, 5/13 disposed by feeding them to other animals on the farm, 3/13 disposed them in a nearby dumpsite/bush and 1/13 sold them.

Treatment of sick birds with medication without prior consultation with a professional was practiced by 8/13 and 4/13 backyard and commercial poultry farmers surveyed respectively. While consumption of sick birds was not recorded in commercial poultry farms, 4 of 13 backyard poultry farmers would consume their birds that appeared to be ill.

3.2. Sensitivity of passive surveillance

The system sensitivity of passive surveillance was estimated at three levels of disease prevalence; 0.1%, 10 infected poultry farms (0.00585%) and 3 infected poultry farms (0.0018%). The median, 5 and 95 percentiles of the distribution of the system sensitivity of detection is displayed in table 5.

The results showed a 100% probability of detecting at least one HPAI infected farm assuming the disease is present at a prevalence of 0.1%. However, the estimated median probability of detecting HPAI was reduced to 67%, and 23% when reducing P^*_H to 10 and 3 infected farms respectively.

3.3. Sensitivity analysis

In the tornado plots we see that backyard farmers have an impact on the system sensitivity of the passive surveillance (figure 3). The capability of backyard poultry farmers to recognise HPAI has the strongest impact on the system sensitivity of passive surveillance. The median sensitivity of passive surveillance (P^H = 0.01%) for HPAI ranged between 21% and 87% when varying the values of the distribution of backyard chicken farmers' ability to recognise HPAI from 10th percentile to the 90th percentiles.

Discussion

4.1. Survey of commercial and backyard poultry farmers

Our survey generated information that can be used to inform surveillance and disease control activities. One of our objectives was to identify the characteristics of commercial and backyard poultry farming with a focus on practices that affect the detection of HPAI. This was achieved however limited by the small sample size used in this study.

While all commercial poultry farmers surveyed were willing to report suspicion of HPAI, none reporting of HPAI suspicion was common to backyard poultry farmers (5/13). This can be attributed to a low level of HPAI awareness common to poor rural households were access to print and electronic media may be limited. Low awareness of AI among backyard poultry farmers has been previously reported by Gugong et al., 2012 where 54% of 240 household poultry farmers survey in Kaduna state, Nigeria, were unaware of HPAI. We were able to identify three reporting channels available to poultry farmers in Bayelsa state. Among commercial and backyard poultry farmers surveyed, 5/26 reported to consulting an informal poultry health adviser and not the private or public veterinary service when they have problems with their birds. The reasons for this appear to be the cost of bringing a highly trained person to their flock versus a less qualified person. These individuals play an important role in providing informal animal health care in rural areas and to people of low economic status.

The majority of backyard poultry farmers (8/13) and some commercial poultry farmers (4/13) attempted some kind of treatment as a means of handling sick birds without prior consultation from a poultry health professional. This practice was reported in 19.8% of household poultry farmers surveyed in Mali (Molia *et al*., 2015). Personal communications with veterinary doctors revealed that animal health professionals are contacted in situations where poultry farmers could not manage on their own or when a large proportion of birds die. Self-medicating birds can delay the timeliness of detecting infectious disease by passive surveillance and should be discouraged.

The consumption of sick birds by poultry farmers in Nigeria is a practice that has been observed by several authors (Akinwumi et al, 2010; Otte et al, 2008; Uzochukwu-Obi et al, 2008) and was reported only among backyard poultry farmers in our study (4/13). Perhaps the economic status of the farmer may encourage such practices. Consumption of sick birds may limit the spread of the disease amongst poultry;

it may mask the true size of an outbreak, but has serious potential public health implications (Van Kerkhove *et al.*, 2011). Further study is needed to estimate the factors that encourage this behavior and effective measures to prevent it.

Improper disposal of dead bird carcases is quite common in Nigeria and has been reported previously (Gugong et al., 2012). While disposal of dead birds in open dumpsites and bushes can facilitate the dissemination of viruses (Musa et al., 2013; Spradbrow, 1993), feeding infected carcases to dogs may result in HPAI infection (Henning et al., 2011; Oluwayelu et al., 2011). Disposal of dead birds into water bodies can serve as sources of infection to humans particularly in rural communities where access to pipe borne water is limited. Though the sale of sick birds was not recorded among backyard poultry farms during our survey one commercial poultry farm sold dead bird carcases which he believed was used to process dog food.

4.2. Quantitative assessment of the sensitivity of passive surveillance.

Animal health surveillance systems are crucial for reporting, evaluating and managing the risks and impacts of animal diseases upon animal production as well as public health (OIE, 2014). This paper presents the first quantitative assessment of the system sensitivity of passive surveillance for HPAI in Nigeria since it was implemented. In this study, the STM based on passive surveillance for HPAI in Nigeria allows the estimation of the probability of HPAI H5N1 detection and evaluation of the disease detection process.

Our results estimate that the probability of detecting HPAI by the passive surveillance is high at a design prevalence of 0.1%. This high sensitivity can be influenced by the extremely large reference population size (Martin et al, 2007; Hadorn and Stark, 2008) which in this study falls between 84,000 and 130,000 poultry farms. However, passive surveillance has a moderate (67%) and low (23%) sensitivity to detect the disease in the early stages of infection when only ten or three farms are infected respectively. This result is fairly consistent with previous outbreaks of HPAI in Nigeria that have been characterized by widespread across over 50% of Nigerian states before the disease was detected and/or efficiently controlled (Monne *et al*., 2008; WAHID, 2015). This results in serious economic losses to farmers as well as the Federal Government of Nigeria in terms of the cost of control and compensation payment for culled birds which runs into millions of dollars (Fasina et al., 2008).

Passive surveillance for HPAI can serve as an early warning system (Goutard et al., 2012), which can limit an impending outbreak and avert the cost of fire-brigade control measures. An efficient passive surveillance is one in which the disease detection process is optimized from the poultry farm level to the laboratory where proper diagnosis takes place. Backyard and semi-commercial poultry make up over 74% of the Nigerian poultry population (Ortiz et al, 2007). Optimizing detection of the disease at the backyard farm level is crucial. Our sensitivity analysis reflects the importance of backyard poultry farmers as they have the greatest impact on the system sensitivity of passive surveillance. The probability that a backyard poultry farmer will recognizing and reporting an outbreak has a very high impact on the sensitivity of passive surveillance. This result is quite consistent with a similar study done in backyard and free range poultry in Thailand (Goutard *et al*., 2012).

Backyard poultry farmers' ability to recognize HPAI was modelled with a median value of 50%. Though this probability of detection is low relative to that in another study (Alba et al., 2010), it is expected to reflect the difficulty in identifying HPAI in Nigeria given:

a. The prevalence of other endemic diseases such as Newcastle disease which presents with the same clinical manifestations as HPAI (CSFPH, 2008; Saidu & Abdu 2008; Ezeribe *et al*., 2015). The poultry farmer may ignore the signs, and assume it is caused by other endemic.
b. The typical small size of backyard poultry flocks. In a situation of farms with eight birds or less, four to one dead birds may not trigger a farmer's awareness as they may perceive the bird to have died of natural cause. Differentiating accepted level of mortality from death due to HPAI becomes difficult.

The STM estimates that 80% of the population under surveillance would report suspicion of HPAI to either a private vet, the state veterinary service or an informal health provider. Though our estimates may be biased by our small sample size, it is fairly consistent with another study in Nigeria where willingness to report HPAI was estimated at 90% (Musa et al., 2016).

4.3. Limitations and assumptions.

Data of poultry population used here were extrapolated from several sources including the National Bureau of Statistics (NBS) 2007 estimates, Adene and Oguntade (2008) and FAO (2009). Estimates of the system sensitivity of the surveillance are influenced by the value of the relative risk. Due to lack of up-to-date poultry census (population at risk) and lack of complete data of disease outbreaks available, expert opinion was used in estimating the relative risk of HPAI used in the model. There was some level of uncertainty in the results obtained. In order to reduce uncertainty, experts with over 15 years' experience and from relevant fields were selected for the survey. Also some input values used in model parameters were derived from a field study which consisted of interviewing 26 farmers, two veterinarians, and two informal poultry health advisers. Due to lack of up-to-date registered list of poultry farms and list of veterinarians, it is difficult to conduct a random-based survey to obtain representative data. Nevertheless, the STM developed here can be updated when new information becomes available.

Conclusion

This study has identified characteristics of commercial and backyard poultry farming in Nigeria, with a focus on practices that affect the detection of HPAI; and estimated the sensitivity of passive surveillance for HPAI H5N1 among chicken farms in Bayelsa state. Our survey is the first to identify the disease reporting channels available to poultry farmers and provide empirical data on the proportions of the population that utilize these channels. Our estimates of the system sensitivity of passive surveillance for HPAI at a design prevalence of 0.1% is high. Though the present passive surveillance is limited in its ability to detect HPAI at the early stages.

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Figure caption

Figure 1 Map of Nigeria: The study area is Bayelsa state in the South-South region of Nigeria (Ekong et al, 2012)

Figure 2 STM describing the process of detection of HPAI by the passive surveillance. Only the branch of commercial chicken is represented suggesting that the other categories follow the same process. The same is the case for the nodes after the reporting to government.

Figure 3 Sensitivity tornado showing the minimum and maximum values that the median surveillance system sensitivity (SSe) acquires in the scenario tree model as the values of the different inputs vary.

Table 1. Expert opinion elicitation results on the relative risk of infection between commercial and backyard poultry farms, the probability that the vet will take samples and the sensitivity of Virus Isolation (minimum, most likely, maximum)

Node	Expert I	Expert II	Expert III	Expert IV	Average
Vet takes samples	(0.5,0.7,0.9)	(0.8,1.0,1.0)	(0.8,0.8,1.0)	(0.95,0.95,1.0)	**(0.8, 0.86, 0.97)**
Sensitivity of Virus Isolation	(0.95,0.97,1)	(0.95,0.98,1)	(0.95,0.98,1	(0.95,1,1)	**(0.9,0.97,0.99)**

RR of infection between commercial &backyard poultry farms	(3, 6, 10)	(4, 5, 8)	(5, 5, 8)	(5, 5, 6)	**(4.25, 5.25, 8)**

Table 2. Number of HPAI suspicion reports tested from 2006 – 2015.

Year	No of HPAI suspicion reports received	Number of HPAI suspicion reports investigated	Number of confirmed cases of HPAI H5N1
2006	890	850	140
2007	970	955	160
2008	450	440	Nil (2 cases via Active surveillance)
2009 - 2014	NA	NA	NA
2015	1050	1020	500

Source: National Veterinary Research Institute, Vom, Nigeria.

Table 3. A description of the STM, showing the nodes, selected branches, input name, input values/probability distributions and range of values used and their respective data sources.

Nodes	Type	Branches	Input name	Input value	Data source
Reference population		Commercial		64 (100%)	Authors

		chicken Backyard chicken		170,899 Pert (50%, 70%, 85%)	
Flock type	Risk category	Commercial chicken Backyard chicken	RR_{CC} RR_{BC}	1 Pert (4.25, 5.25, 8.0)	Expert opinion
Flock status	Infection	Infected Not infected	P^{*}_{H}	0.1%; 10 farms; 3 farms	Authors
Clinical signs	Detection	Displaying Not displaying	CS	0.9	Authors
Recognition of clinical signs	Detection	Recognized Not recognized	RG	0.8 (Commercial farms) Pert (0.0, 0.5, 1.0) Backyard farms	Authors
Farmer consults private vet	Detection	Yes No	FCpV	0.46- Commercial farms 0.23 - Backyard farms	Field study; Interviews
Farmer consults an informal poultry health advisor	Detection	Yes No	FCQ	0.15 - Commercial farms 0.23 - Backyard farms	Field study; Interviews
Farmer reports to government	Detection	Yes No	FCG	0.38 - Commercial farms 0.15 - Backyard farms	Field study; Interviews
Farmer consults no one	Detection			0.38, -Backyard farms 0.0 - Commercial farms	Field study; Interviews
Private Vet reports to government vet	Detection	Yes No	pVR	1	FDLPCS, 2006
Informal poultry health adviser report to government vet	Detection	Yes No	QR	Pert (0.5, 0.6, 1.0)	Field study interviews
Vet takes samples	Detection	Yes No	VS	Pert (0.8, 0.86, 0.97)	Expert opinion
Lab performs test for AI	Detection	Tested Not tested	LT	Pert (0.90, 0.95, 0,98)	Data from the NVRI
RT-PCR test	Detection	Positive Negative	Se_{PCR}	Pert (0.80, 0.85, 0.95)	Alba et al. (2010)

Virus isolation	Detection	Positive Negative	Se_{VI}	Pert (0.95, 0.99, 1.0)	Expert Opinion:

Table 4. Results of field study interviews with poultry farmers and farm workers

	Backyard Chicken farms (total 13 farms)	***Proportion (%)***	**Commercial chicken farms (total 13 farms)**	***Proportion (%)***
Farmers action				
1. Call private vet	3	*23.07*	6	*46.15*
2. Call government	2	*15.38*	5	*38.46*
3. Call informal animal health provider	3	*23.07*	2	*15.38*
4. Call no one	5	*38.46*	0	0
Disposal of dead birds				
1. Bury	3	*23.07*	4	*30.77*
2. Dispose at nearby refuse dumpsite	6	*46.15*	2	*15.38*
3. Dispose into the nearby bush	3	*23.07*	1	*7.69*
4. Dispose into nearby river	1	*7.69*	0	*0*
5. Fed to fish	0		2	*15.38*
6. Fed to dogs	0		3	*23.07*
7. sold			1	*7.69*
Treatment for sick birds				
1. Administer antibiotics and /or paracetamol without prior consultation with a professional	8	*61.54*	4	*30.77*
2. Administer drugs as advised by a professional	4	*30.77*	9	*69.23*
3. Does not treat	1	*7.69*	0	0
Consumption of sick birds				
1. Yes	4	*30.77*	0	0
2. No	9	*69.23*	0	0

Table 5. Median sensitivity of passive surveillance for HPAI (P^*_H = 0.1%, 10 infected and 3 infected poultry farms)

Design Prevalence P^*_H	**Median, 5 and 95 percentiles *Se* HPAI**
P^*_H = 0.1%	1.00 (0.99 – 1.00)
P^*_H = 10 infected farms	0.67 (0.34 – 0.85)
P^*_H = 3 infected farms	0.23 (0.10 – 0.37)