Title: Evaluation of the Sensitivity of Passive surveillance for HPAI in Bayelsa state (Southern Nigeria)

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Abstract

The study evaluated the performance of passive surveillance in commercial and backyard chickens for HPAI H5N1 in Bayelsa state, Nigeria, using scenario tree modelling. A scenario tree model for passive surveillance was developed and simulated to estimate the sensitivity, i.e. the probability of detecting one or more diseased chicken farms at different levels of disease prevalence. The model showed a median sensitivity of 100%, 50% and 19% for detecting HPAI by passive surveillance assuming the entire reference population was under surveillance at a design prevalence of 0.1%, a minimum of 10 and 3 infected poultry farms respectively. When 35% of the reference population was under surveillance, the sensitivity of passive surveillance was 98%, 22% and 7% at a design prevalence of 0.1%, a minimum of 10 and 3 infected poultry farms respectively. The probability of detecting HPAI changed drastically when the proportion of backyard poultry farmers who reported suspected cases to the government or a private veterinarian varied from 3% to 26%. Parameters with the most significant contribution to the sensitivity of the surveillance program are; the ability of backyard poultry farmers to recognise HPAI; and their willingness to report suspected cases of the disease. Increasing the proportion of the population involved in passive surveillance; encouraging the reporting of suspected cases through enlightenment campaigns; compensation payment to poultry farmers for culled birds; and improving the communication channels between all relevant stakeholders is crucial to the detection process.

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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 606 confirmed human cases of Avian Influenza (AI) infection with 357 deaths (WHO, 2012) have been reported, most of which are linked with exposure to sick or dead poultry (WHO, 2011). Outbreaks of AI do not only devastate the poultry industry through the high mortality and morbidity of the disease or depopulation for controlling 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 Highly Pathogenic Avian Influenza (HPAI) H5N1 in Nigeria which reduced the demand and consumption of poultry products and led to a loss of jobs for poultry farmers.

Prior to the HPAI H5N1 outbreak in Nigeria, the poultry population was estimated at 150 million birds, 25% produced commercially, 15% semi-commercially and 60% backyard poultry (Ortiz et al, 2007). Poultry production is an important economic activity in Nigeria and is a significant constituent of family income especially in poor rural communities (CBN, 2004). It employs two-third of the nation's labour force (Ugwu, 2009). Backyard poultry is kept extensively throughout the country (Uzochukwu-Obi et al, 2008) and serves as a source of quick cash, food security and ultimately forms part of the peoples' livelihood (Diao et al, 2009).

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, 2012).

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 80% of workers of affected farms and 45% of un-affected farms had 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 of optimizing rapid detection of the disease. A compensation payment scheme for culled birds was introduced and later revised to encourage poultry farmers report suspected cases (Akinwumi et al, 2010) and minimize consumption or sale of sick birds in order to ease direct losses due to the disease (Otte et al, 2008; Anon, 2006)

There have been no reported cases of HPAI in Nigeria since 2008 (OIE, 2012). The technical assistance and financial support from international organizations related to this issue ended in May 2011 (World Bank, 2012). Nevertheless the Nigerian government would still need to re-consider and modify its control and prevention strategies for HPAI. It needs an evaluation of surveillance systems in order to optimize its efficiency.

With regards to surveillance, sensitivity is the probability that at least one bird infected with HPAI will be detected by the surveillance system, provided the disease is present in the reference population at or above a specified level of prevalence (Martin et al, 2007). This study aims to evaluate the sensitivity of the passive surveillance for HPAI, using Bayelsa state in the southern region of Nigeria (See Fig 1) as a case study. Due to the presence of inland water bodies, its poultry density (122 poultry/Km^2 of land area), human population density (182 people/Km^2) and market access, the state has been considered a high risk area for the occurrence of HPAI (Uzochukwu-Obi et al, 2008).

The method used is scenario tree modelling described by Martin et al, (2007). The result obtained will serve as a guide to refining the surveillance system design and improve the likelihood of disease detection. The objectives of the study are:

- To quantitatively assess the sensitivity of passive surveillance for HPAI, H5N1 in Bayelsa state.
- To identify potential areas for improvement to the surveillance system.

Materials and Methods

A scenario tree model (STM) was developed to estimate the probability that passive surveillance for HPAI H5N1 in Bayelsa would detect at least one diseased animal if present in the chicken population at or above a stipulated design prevalence.

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 (8) 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. Due to lack of up-to-date census of poultry farms in the state, data on the number of backyard poultry was based on Uzochukwu-Obi et al's, (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 are exclusive chicken flocks (92%), four keep a mixture of chickens and turkeys (6.2%) and one duck farm (1.5%). As majority of poultry in the state is comprised of chickens and chickens constitute the greatest percentage (>80%) of the poultry industry in Nigeria (Adene and Oguntade, 2008), this study therefore assesses the sensitivity of the passive surveillance in the chicken population only. A surveillance unit for this analysis is poultry holding.

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

Passive surveillance is the voluntary reporting of HPAI by poultry farmers to the National Animal Disease Information and Surveillance through their respective state veterinary services. Every state of Nigeria has a Desk officer who heads the National Avian Influenza Control Project (NAICP). The desk officer is in charge of HPAI surveillance and response activities in the state. Reporting of suspected cases of AI is directed to him. 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.

2.3. Field study / Data sources

Of eight LGAs in Bayelsa state, two LGAs were purposively selected based on accessibility and available funds; Yenegoa LGA and Ogbia LGA. The field study was carried out with the aim of obtaining a holistic understanding of the characteristics of poultry farming in the state and peoples' behaviour in terms of disease reporting. We started by interviewing poultry famers and then moved towards people who they reported to. In this process we developed an information pathway and subsequently drew the Scenario tree. The STM was populated based on data gained from questionnaire, expert opinion and literature search.

2.3.1. Poultry farmers/ farm workers Interviews

Sampling of poultry farms was done using snowball sampling. Commercial and Backyard chicken flocks first visited were based on the state veterinary services' knowledge. Other poultry farmers were then found through referral by the previous poultry farmers visited and distributors of poultry feed. This sampling method was used due to lack of up-to-date official registration of poultry farms in Nigeria. 26 poultry farmers (13 commercial chicken farmers and 13 backyard chicken farmers) were interviewed within the time available for the study. The interview gathered information on flock type, production systems, demographics, husbandry practices, bio-security, feeding, and knowledge of poultry disease, drug use, and reporting practices. The answers obtained from these interviews were incorporated in the model. Table 2 shows the details of the probability distributions and proportions chosen for the scenario tree model.

2.3.2. Interview of Private Vet Doctors and "Informal poultry health advisors"

Three categories of people who poultry farmers report to were identified;

i. A private veterinarian;

ii. An informal poultry health advisor; and

iii. The 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. Two private veterinary doctors and two informal poultry health advisers were interviewed. Interviews were done to understand the process of detection of an infected flock, diagnostic capability and communication channels with the state veterinary service.

2.3.3. Expert Opinion

A number of parameters in the scenario tree model were estimated by expert opinion due to a lack of published data. Four experts agreed to take part, experts selected possessed relatively equal levels of expertise. Two were drawn from the NAICP, one from the University of Nigeria and one 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 3 shows the details of the expert opinion elicitation process.

2.4. Scenario tree model (STM)

The structure of the scenario tree, the nodes and branches developed as a result of this study are shown in Figure 2. The STM evaluates the performance of the disease detection process. It considers the key factors that influence the probability of a positive surveillance outcome (Martin et al, 2007). The STM 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.

2.4.1. 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.

2.4.2. Infection nodes

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

2.4.3. Detection nodes

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 infection (RG). Because HPAI H5N1 is associated with high mortality and morbidity in chickens, we estimated a high probability of detection by most commercial farmers. The chicken owner may not precisely identify the disease but can clearly recognize a problem. For backyard chicken farms, where birds are less monitored, and in most cases are allowed to roam and 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.

The poultry farmer's action (FA) after the disease is recognised is crucial and may be influenced by certain important factors such as;

i. The farmer wants to avoid veterinary control for certain reasons;
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 proportions based on the responses of backyard and commercial poultry farmers interviewed. Farmers' actions were characterized into four possible outcomes as follows;

i. Farmer consults a private veterinarian (FCpV);

ii. Farmer reports to the state veterinary service/government (FCG);

iii. Farmer consults a “informal poultry health advisor” (FCQ), and

iv. Farmer consults no one.

Table 4 shows data used to populate these outcomes.

All 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 uncertain. This is mainly because there are no formal government records to prove their existence; and these poultry health advisers are not usually well known by the state veterinary service. Data on the probability of QR was assigned by the author based on field study interviews 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 process was used to estimate the probability of the vet taking samples and the probability that submitted samples will be tested by the national reference laboratory. The final steps are the probability of a diseased animal 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)

2.5. Model output

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

2.6. Estimating the sensitivity of passive SSC

2.6.1. 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)

$$\boldsymbol{AR}_{\mathbf{i}} = \sum_{i=1}^{nI} (\boldsymbol{RRi} \times \boldsymbol{PrPi}) = \mathbf{1} \quad (1)$$

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.

2.6.2. 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;

$$\boldsymbol{EPIH_i} = \boldsymbol{AR_i} \times \boldsymbol{P^*_H} \quad (2)$$

P^*_{H} represents the disease prevalence at the among-farm level

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

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

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:

$$\boldsymbol{Se_i = CS \times RG \times ((FCpV \times PvR) + (FCQ \times QR) + FCG) \times VS \times LT \times Se_{PCR} \times Se_{VI}} \quad (4)$$

Results

3.1. Sensitivity of passive surveillance

The 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 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 50%, and 19% when reducing P^*_H to 10 and 3 infected farms respectively.

Table 6 shows the sensitivity of passive surveillance assuming only 35% of the reference population was subject to passive surveillance, at a design prevalence of 0.1%, 10 and 3 infected holdings. These results show how the sensitivity of surveillance systems can be affected by the size of the reference population. The probability of detection assuming 10 farms were infected reduced by over 50%

3.4. Important input parameters to the sensitivity of passive surveillance for HPAI

Results for the poultry farmers' action following the recognition of clinical signs is shown in table 4. It was common that suspected cases were not reported among backyard poultry farmers found in rural settlements. Among the 26 poultry farms visited, 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.

r = (correlation coefficient)

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Sensitivity analysis of the effect of input parameters on the value of the output shows that the capability of backyard poultry farmers to recognise and report the clinical signs of HPAI has a considerable impact on the sensitivity of HPAI H5N1 passive surveillance. During the field study, 23% of poultry farmers interviewed - all of which were backyard poultry farmers, would not report their suspicion to anyone. Assuming this section of individuals did report to either the state veterinary service or a private veterinarian, the sensitivity of the surveillance system would increase by 50% as shown in Table 7.

Discussion

HPAI is a highly lethal disease in chickens. Infected birds develop clinical signs and die within two to three days (ESWI, 2012). With recognizable clinical signs shown in infected birds and a short incubation period, early detection and reporting of suspected HPAI cases by poultry owners is likely to be the most cost-effective means of surveillance. Passive surveillance has been reported to be more sensitive at detecting HPAI than active surveillance (Honhold, 2007; Hadorn and Stärk, 2008; Alba et al, 2010).

4.1. Quantitative assessment of the sensitivity of passive surveillance.

At a design prevalence of 0.1% the model assumes 100% sensitivity. This high sensitivity can be influenced by several factors one of which is the extremely large reference population size (Martin et al, 2007; Hadorn and Stark, 2008) which in this study is 170,899 poultry farms. The model assumes that the entire chicken population is under surveillance, this is logical as we are dealing with passive surveillance where voluntary reporting can be made by the entire population. However, regardless of a farmer's ability to recognise HPAI and his/her willingness to report, in Nigeria not all farmers are equally predisposed to report as a result of;

i. Poverty which affects their ability to communicate suspicion due to lack of funds;
ii. Location in remote villages which affects their ability to access veterinary services; and
iii. Lack of mobile phone network in remote areas which hinges on communication

According to IFAD (2013), 70% of Nigerians live below the poverty line and poverty is present mostly in the rural areas where social services and infrastructure are limited. This in reality will affect the total population under passive surveillance. Figure 3 shows how the sensitivity of passive surveillance varies when 100% and 35% of the reference population is subject to surveillance. This shows the difference between the ideal and the real sensitivity of passive surveillance for HPAI in Nigeria.

The sensitivity analysis indicates that backyard chicken farmers' capability to recognise and report HPAI is crucial in the detection process. Several factors were identified to have considerable impact on farmers' ability to recognise the disease. These factors include firstly, farmers' knowledge of the clinical manifestation of the disease. Secondly, the poultry size was considered very important especially in backyard poultry farms. Backyard poultry farms visited had a range of 300 – 6 chickens. In the situation of poultry farms with eight birds or less, one or two dead birds may not trigger a farmer's awareness of HPAI as they may perceive the bird to have died of any other disease or of natural cause. Differentiating accepted level of mortality from death due to HPAI becomes difficult. Lastly, taking into consideration that the majority of backyard poultry in the state are allowed to scavenge for food and are confined mostly at night, food and water intake may not readily be monitored. Though backyard poultry farmers have the opportunity for day by day observation of their individual birds, there is a need for further studies to establish how efficiently backyard poultry farmers are to detect HPAI H5N1 in a free range or scavenging system.

Backyard poultry farmers' willingness to report suspected cases is crucial. This is determined by how enlightened they are about the disease, its seriousness – economic and public health implications - and the level of compensation paid for culled birds (Hadorn and Stark, 2008). Of 13 backyard poultry farmers interviewed, six would sell-off and/or consume any of their birds they suspected to be sick. This practice is dangerous and could lead to the emergence and spread of human cases of HPAI or other zoonotic diseases. Further study is needed to estimate the factors that encourage this behaviour and effective measures to stop it. The revising of the compensation payment scheme for culled birds to a more acceptable amount by the Federal Government of Nigeria (FGN) significantly improved the number of cases reported in commercial poultry farms during the outbreak between 2006 and 2008 (Akinwumi et al, 2010). In the absence of financial support for the compensation of culled birds by the World Bank, it is necessary that the FGN maintains this scheme in order to motivate poultry farmers to report HPAI.

4.2. Potential areas for improvement to the surveillance system.

The current case definition for HPAI as stated by the Federal Department of Livestock and Pest Control Services (FDLPCS) is directed towards veterinarians, stating under what conditions HPAI should be suspected (FDLPCS, 2006). There are no such guidelines stating the conditions under which poultry farmers should report to or consult a veterinarian. Farmers need to know what to report and this should be appropriately and accurately communicated to them. For instance, education campaigns aimed at improving small scale poultry farmers' knowledge in Indonesia was used to improve their ability to recognise HPAI (FAO, 2009). There is need to tailor the case definition to suit small farms in order to optimize early detection in backyard farms.

The field manual that guides government veterinarians in the collection of specimen states that samples should be collected from six birds with an equal number of dead and sick birds. However there are some backyard poultry farms with less than six birds. Under such circumstance the government should revise the collection of specimen to be taken from across other backyard farms in close proximity and with possible contact to the suspected farm within a given locality.

Six out of 26 poultry farmers interviewed reported to consulting an informal poultry health adviser and not either 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 local, less highly qualified person. Governments need to think how to identify these informal animal health providers and incorporate them into the system of surveillance rather than getting everyone to report to qualified vets.

The result of the STM emphasizes the importance of backyard poultry farms in the HPAI passive surveillance because of their extensive farming throughout the country. Backyard farming practises are vulnerable to HPAI infection (Biswas et al, 2009) and pose a risk of HPAI transmission to humans through contact with infected birds (Bridges et al, 2002; Dinh et al, 2006; Mounts et al, 1999). However, during the 2006 – 2008 HPAI H5N1outbreaks in Nigeria the federal government has been criticized for concentrating compensation payment to large scale commercial poultry farmers, disregarding backyard poultry farmers to experience losses with no financial support (Akinwumi, 2010; IRIN, 2010, Uzochukwu-Obi et al, 2008). This lack of compensation could greatly discourage them from reporting and ultimately decrease the surveillance system sensitivity.

The consumption and selling of sick birds by bird owners in Nigeria is a practice that has been reported by several authors and was also observed during our field study (Uzochukwu-Obi et al, 2008; Otte et al, 2008; Akinwumi et al, 2010). Consumption of sick birds may limit the spread of the disease and mask the true size of an outbreak but it has serious potential health implications. Selling sick birds is very important in the spread of the disease. The government should take these aspects into consideration for developing a HPAI control strategy.

Some backyard poultry farmers interviewed confirmed that they had given drugs, mainly antibiotics (tetracycline) and paracetamol to their sick birds. Veterinary doctors interviewed mentioned that most poultry farmers would consult them for help in situations where they could not manage on their own or when a large amount of birds die. This practise of self-medicating birds delays the timeliness of detecting a case in the passive surveillance and should therefore be discouraged in order to improve the overall efficiency of the system.

Overall, the larger the percentage of the population involved in passive surveillance, the more sensitive the system will be. Creating better access roads; providing efficient mobile communication channels; and improving the general standard of living are issues that should be prioritized by the government. These have benefits not only for disease surveillance but also in matters of health, security, social and economic development.

4.3. Limitations and assumptions.

The time gap between infection and detection may cause disease spreading to other locations. Bird movements to and from LBM have been reported as important places in the spread and circulation of HPAI H5N1 (Kung et al, 2007; Sims, L. 2007).The model does not take into account the time elapsed between infection or the manifestation of clinical signs and reporting to the concerned authorities. This window period is crucial for the spreading of the infection in a system where free range backyard poultry rearing thrives.

At the time of this research there was no up-to-date census on Nigerian poultry. 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, (2008). Estimates of the 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 evaluated the sensitivity of passive surveillance for HPAI among chicken farms in Bayelsa State using scenario tree methodology described by Martin et al, (2007). The model estimated a high sensitivity of passive surveillance to detect the disease at low disease prevalence (0.1%). Its sensitivity reduced to 50% assuming a minimum of ten infected farms were present in the state. The probability of detecting HPAI can be improved by educating backyard poultry farmers on how to identify the disease and encouraging them to report suspected cases. Other responsive participants such as informal poultry health advisors should be more accountable in ensuring HPAI detection as they act passively with farmers. It is perceived that the FGN reviews its compensation strategy to include enhanced remuneration for backyard poultry farmers to encourage the disclosure of affected birds.

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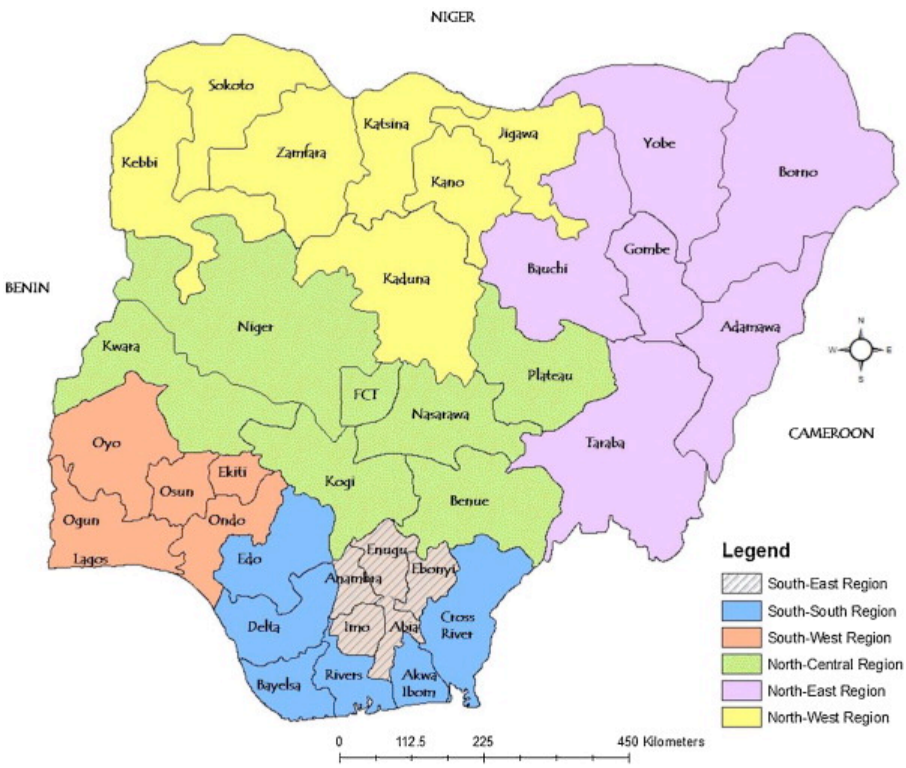

Figure 1; Map of Nigeria showing the six geopolitical zones (Ekong et al, 2012)

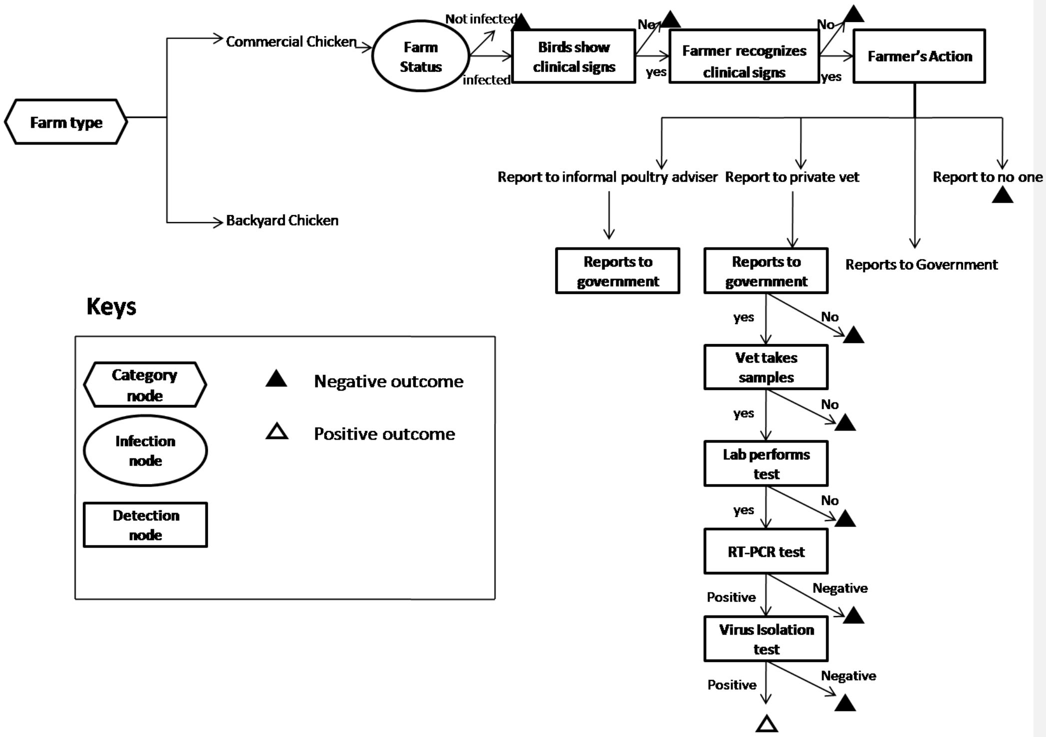

Figure 2.STM describing the process of detection of HPAI by the passive surveillance. Only the branch of backyard chicken is represented suggesting that the other category follows the same process. The same is the case for the detection category nodes

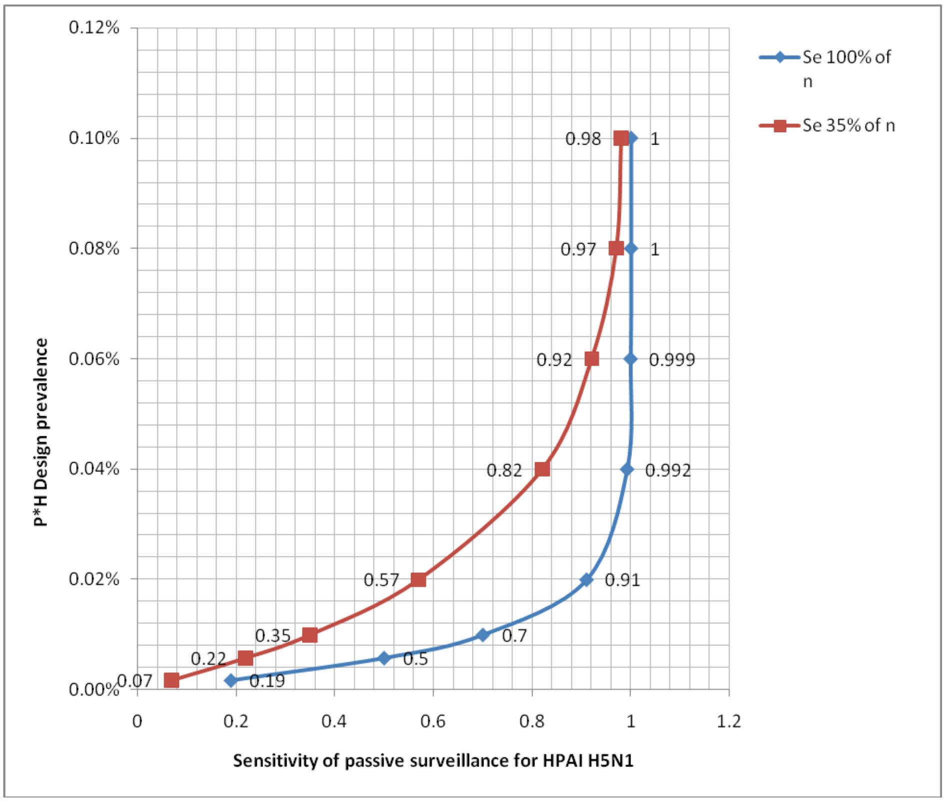

Figure 3. Chart showing the changes in sensitivity of passive surveillance for HPAI when 100% and 35% of the reference population is under surveillance.

Table 1. Interview questions to farmers and veterinarians to define parameters associated with detection by the passive surveillance.

Interview questions addressed to poultry keepers

- What type of birds do you currently have on your premises and what is their total number?
- For how long have you been keeping poultry?
- What do you feed your birds
- What are the common signs of illness in your poultry?
- What poultry disease are you most concerned about?
- Do you administer any form of drugs to your birds?
- When you notice a sick bird, what do you do?
- Who do you contact if a considerable amount of your birds were to fall ill
- What is your acceptable level of mortality?
- Who do you contact if a large amount of your birds were to die within a relatively short period?
- At what point would you seek veterinary advice?

Interview questions addressed to private veterinarians

- For how long have you been practicing in Bayelsa state?
- What are the most common poultry diseases you have encountered throughout your stay in the state?
- What poultry disease have you never come across
- At what point do you think poultry keepers would consult a Veterinarian for help concerning their birds?
- What diagnostic tools are available to you?
- Under what conditions would you suspect HPAI in a poultry flock?
- What do you do upon suspicion?
- At what point would the state veterinary service be notified?

Table 2. 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
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	Author
Clinical signs	Detection	Displaying Not displaying	CS	0.9	Author
Recognition of clinical signs	Detection	Recognized Not recognized	RG	0.8 (Commercial flocks) Pert (0.1, 0.5, 1.0) Backyard flocks	Author
Farmer consults private vet	Detection	Yes No	FCpV	0.231 - Commercial flock 0.0385- Backyard flocks	Field study; Interviews
Farmer consults an informal poultry health advisor	Detection	Yes No	FCQ	0.0385 - Commercial flocks 0.192- Backyard flocks	Field study; Interviews
Farmer reports to government	Detection	Yes No	FCG	0.231 - Commercial flocks 0.0385- Backyard flocks	Field study; Interviews
Farmer consults no one	Detection			0.231-Backyard flocks 0.0- Commercial flocks	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 (0.89, 0.93, 0,99)	Expert opinion
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 3 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 laboratory will perform tests (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)**
NVRI Lab Performs tests	(1.0,1.0,1.0)	(0.8,1.0,1.0)	(0.8 0.81.0)	(0.95,0.95,0.95)	**(0.89,0.93,0.99)**
Sensitivity of Virus Isolation	(0.95, 0.97, 1)	(0.95, 0.98, 1)	(0.95, 0,99, 1)	(0.95, 1.0, 1.0)	**(0.95, 0.99, 1.0)**
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 4 Response to questions on farmers' action following the recognition of clinical signs for HPAI H5N1

Farm Type	**Number interviewed**	**Farmer's action**	**Numbers responding**	**Proportion of total interviewed**
Backyard chicken	13	Call private vet	1	0.0385
		Call government vet	1	0.0385
		Call a informal poultry health advisor	5	0.192
		Call no one	6	0.231
Commercial chicken	13	Call private vet	6	0.231
		Call government vet	6	0.231
		Call a informal poultry health advisor	1	0.0385
		Call no one	0	0
Total	26		26	1
Total	**26**		**26**	**1**

Table 5 Median sensitivity of passive surveillance for HPAI in chickens assuming the entire chicken population is under surveillance (P^*_H = 0.5%, 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 (1.00 – 1.00)
***P^*_H* = 10 infected farms**	0.50 (0.28 – 0.67)
***P^*_H* = 3 infected farms**	0.19 (0.09 – 0.29)

Table 6 Median sensitivity of passive surveillance for HPAI in chickens assuming 35% of the reference population is under surveillance (P^*_H = 0.5%, 0.1%, 10 infected and 3 infected poultry farms)

Design Prevalence P^*_H	**Median, 5 and 95 percentiles *Se* HPAI**
P^*_H = 0.1%	0.98 (0.86 – 1.00)
P^*_H = 10 infected farms	0.22 (0.11 – 0.32)
P^*_H = 3 infected farms	0.07 (0.04 – 0.11)

Table 7 Median sensitivity of passive surveillance for HPAI in chickens assuming 23% of backyard farmers who do not report their suspicion report to either a private vet or the state veterinary service (P^*_H = 0.5%, 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 (1.00 – 1.00)
P^*_H = 10 infected farms	0.78 (0.51 – 0.91)
P^*_H = 3 infected farms	0.36(0.19 – 0.51)