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Descriptive epidemiology of the outbreak of avian influenza in Nigeria: a retrospective review, 2015-2017

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Abstract

Introduction: *sporadic outbreak of avian influenza (AI) are still being reported in Nigeria. As of the first quarter of 2021, outbreaks of AI have been reported in 10 States. There was a paucity of information on the lessons learnt from the 2015-2017, AI control in Nigeria. The purpose of this study was to identify hotspots of AI in Nigeria, describe the epidemic pattern of AI outbreaks in Nigeria and determine the epidemic threshold of AI between 2015-2017 with a view to provide information necessary for public health actions.*

Methods: *we conducted a retrospective study by reviewing the AI line list, case reports of confirmed outbreaks of AI in Nigeria from the National animal disease information system (NADIS) databases of the Federal department of Veterinary and Pest control services between 2015-2017. We identified affected states, the number of AI cases, total number of poultry affected per state. We conducted a geospatial analysis using Arc Geographical information system (ArcGIS Online) software to describe Hotspots of AI outbreaks, classified as (major (high), minor (low)) based on disease burden in affected states. We described the epidemiological patterns of AI outbreaks with epidemic curves and calculated the epidemic threshold (EPT) of AI outbreaks based on cumulative sum, (CUSUM) statistics, (C1-C3) for the month of October 2015-2017.* ***Results:*** *in 2015, 513 confirmed cases of AI were reported in Nigeria. Kano State accounted for 187 (37%) of cases, Plateau State, 148 (29%), Rivers State, 43 (8%) major hotspots for AI, 18 states accounted for minor clusters of 25 cases. In 2016, 248 confirmed AI cases were reported in Nigeria. Kano State accounted for 99 (40%) of cases, Plateau State, 66 (27%), Federal Capital Territory (FCT) Abuja 16 (6.5%), had major clusters of AI cases, 24 states had minor clusters with 13 cases. In 2017, 50 confirmed AI cases were reported in Nigeria. Plateau state accounted for, 22 (44%) of cases, Bauchi State, 11 (22%), and Oyo State 8 (16%), were identified as major hotspots of AI, 10 other states had minor clusters, with 9 cases. The 2015-2017 outbreak was a propagated epidemic, with EPT, (20, 12 and 5) in 2015, 2016 and 2017 respectively.* ***Conclusion:*** *the 2015-17 outbreaks of AI in Nigeria were clustered within five geopolitical zones of Nigeria, in six states. North-central and North-western states of Nigeria accounted for the highest-burden of AI. The outbreak of AI in Lagos may be epidemiologically linked to the resurgence of AI in the Northwest and Northcentral states of Nigeria in 2015, through trade in poultry and poultry products with northern states of Kano, and Plateau. Three subtypes of AIVs, (two homologous (H5N8, H5N6), and one heterologous (H9N2) strain are co-circulating within LBMs in Nigeria. The propagated epidemic of 2015-17 is instructive of flock-to-flock transmission within farming units. The spread of infection between states and contiguous LGAs may be through vehicular transport of apparently healthy flocks. Delayed outbreak responses, and sole dependence of states on the federal government on AI control, containment equipment's, and inadequate manpower in some states of the federation, may be the bane of effective control of the outbreak of HPAI in Nigeria between 2015-2017.*

Introduction

Avian influenza (AI) is enzootic in poultry, caused by influenza A viruses of the family *Orthomyxoviridae* [1,2], wild birds are its natural reservoirs [3,4]. Migratory birds have been identified as asymptomatic carriers of avian influenza viruses (AIVs) they travel long distances along routes known as flyways to different continents of the world for breeding, wintering, and roasting [5]. These birds may come in contact with local poultry flocks at watering holes, feeding spots such as rice farms, where infection may occur. They may also be captured by local hunters, for their meat or sold to middlemen at the live bird market (LBM) [6]. There are 5 major classifications of migratory flyways: the Central pacific, American, West Africa-Eurasian, Central Asian and East/Asian Austral-Asian flyways, Nigeria is located within the West Africa-Eurasian flyways, the route of migration for migratory raptors, passerines, water and seabirds [7]. Zoonotic infections have been reported with AI Asian lineage H5N1, and H7N9 Chinese variants [1]. Influenza A viruses are classified into subtypes based on their surface proteins, hemagglutinin (HA) and neuraminidase (NA) [1,4]. At present, 16 HA (H1 to H16), and 9 NA (N1 to N9) have been isolated in birds [1]. Interspecies infection with avian influenza viruses (AIVs) has been reported in horses, believed to be the precursor of Equine influenza [8]. Influenza A virus is described as highly pathogenic (HPAI) when the intravenous pathogenic index (IVPI) is greater

than 1.2, and low pathogenic when IVPI is less than 1.2 [9].

Highly pathogenic avian influenza virus (HPAIV) H5N1 was first reported in Nigeria in 2006 [10], it persisted until 2008 [11], across 25 States in 97 local government areas (LGAs), one human fatality was reported in Lagos State in 2007 [1,12]. Over 1.2 million poultry was affected, estimated at 1.8 million dollars [11]. Nigeria was declared free of avian influenza in 2013 [6,13]. However, the Isolation of LPAI H5N2 in a pool of ducks at the live bird market, (LBM) in Oyo State Nigeria in 2014 [10], may have given credence to the assertions that AI may be endemic in Nigeria. In 2015, the resurgence of AI, H5N1 and the emergence of a reassortant AI strain H5N8 isolated from a backyard poultry farm in Kano State and LBM in Lagos State Nigeria, accounted for the loss of over 3.7 million poultry nationwide, estimated at over 7.2 million dollars in economic losses [3,4,6,11]. At present, three subtypes of AIVs, (two homologous (H5N8, H5N6), and one heterologous (H9N2) strain are co-circulating within LBMs in Nigeria [11,14]. The LBMs in Nigeria are unstructured with no clear demarcation between poultry businesses and other market activities [11], this may provide the milieu for mixing of different poultry species vis-à-vis contact of naïve flocks with reservoirs of AI (wild, domesticated) at the LBMs [6], this may have played a role in the emergence of reassortant AI H5N8 in Kano State Nigeria in 2016 [6]. To this end the LBMs was identified as an important epidemic unit for avian influenza surveillance in Nigeria, however, poor quality of surveillance data to access the attributes of the AI surveillance system in Nigeria may have brought to the fore the need for a comprehensive evaluation of the avian influenza surveillance system [15]. The purpose of this study was to conduct a geo-spatial analysis to identify, describe hotspots of AI outbreaks in Nigeria between 2015-17, describe the epidemiologic pattern of the outbreak of avian influenza outbreak in Nigeria, and ascertain the epidemic threshold for the outbreak of AI within the study period, with a view to provide information necessary for public health actions.

Methods

Study area: Nigeria is a country located in West Africa, bordered by the Republic of Niger to the North, Chad to the Northeast, Cameroon to the east and Republic of Benin to the west. There are 36 States in Nigeria with the Federal Capital Territory (FCT). Nigeria population is estimated at over 200m [16], with an estimated poultry population of over 180m [17], of these, 80 million poultry chicken are raised in an extensive system, 60 million in semi extensive system and 40 million in the intensive system [17]. The poultry industry in Nigeria is the most capitalized of the Agricultural subsector estimated at 22 billion dollars per annum [11].

Study design: we conducted a retrospective study by reviewing line-list, case reports of confirmed outbreaks of avian influenza in Nigeria based on data obtained from the Federal Ministry of Agriculture and Rural Development, (veterinary and pest control services) from 2015-2017. We identified affected states, determined the number of cases, the total number of poultry affected and conducted a Geospatial analysis using Arc Geographical information system (ArcGIS) software to describe avian influenza hotspots classified as (major, minor) based on the disease burden in affected states. We determined the epidemiological patterns of AI outbreak with epidemic curves and calculated the epidemic threshold (EPT) of AI outbreaks based on cumulative sum (CUSUM) statistics, (C1-C3) within the years under review. The epidemiological threshold was determined based on the formula: epidemic threshold = mean (α) + 3 standard deviations (δ) of seven past surveillance points of the year under consideration (October 2015-2017), skipping over the two most recent points. Incomplete epidemic data, date of confirmation and number of cases was harmonized with case

reports of the concerned outbreak obtained from the state epidemiological unit.

Results

In 2015, 513 confirmed cases of AI were reported in Nigeria with over 1.8 million poultry flocks affected in 509 farms, 12 LBMs, one zoological garden was affected across 21 States, in 87 local government areas (LGAs) (Table 1). Kano State, accounted for 187 (37%) of AI cases, Plateau State, 148 (29%), Rivers State, 43 (8%) was identified as major hotspots for AI (Figure 1), 18 States accounted for minor clusters of 25 cases. In 2016, 248 confirmed AI cases were reported with over 2.4 million poultry affected in 252 farms, across 27 States, in 27 LGAs. Kano State accounted for 99 (40%) of AI cases, Plateau State, 66 (27%), FCT Abuja 16 (6.5%), accounted for major clusters of cases (Figure 2), 24 states had minor clusters of 13 cases. In 2017, 50 confirmed AI cases were reported with over 566,000 poultry affected in 37 farms, one LBM, across 26 States in 13 LGAs. Plateau State accounted for, 22 (44%) of AI cases, Bauchi State, 11(22%), and Oyo State 8(16%), were identified as major hotspots of AI (Figure 3), 10 other states had minor clusters of 9 cases.

Epidemic patterns of avian influenza outbreaks in Nigeria from 2015-2017: the first confirmed case of HPAI was reported 1/1/2015 at (Eti-Osa) LGA of Lagos State through 01/06/2017 in (Dawakin Kudu) LGA of Kano State. The 2015 re-emergence of HPAI AI started with a sharp spike in the number of cases between weeks 3-4, by week 5-7, the honourable Minister of Agriculture and rural Development, (HMA) address the public and sensitised poultry stakeholders on the re-emerging zoonoses (Figure 4). By weeks 6-7, there was a sharp increase in the number of cases which peaked at 39 cases, then a gradual decline in cases between week 8-13, which dipped to about three cases by week 16, corresponding to the week for presidential election in Nigeria. By week 21-31 the Federal Ministry of Agriculture and Rural Development, (FMA&RD), and her partner agencies, the Food and Agricultural Organization (FAO), United States Agency for International Development (USAID), commenced distribution of disinfection and containment equipment's to all 36 States of Nigeria and the FCT. Following these measures, there was a lull in cases between weeks 21-48. However, week 48 recorded the last confirmed outbreak of AI in 2015. In 2016, despite various control strategies instituted by the FMA & RD, which saw a reduction in cases between the second and third quarter of 2015, the second wave of the outbreak of AI commenced with 9 cases reported between epi-week 1-2, then picked at 19 cases by week 3-4 (Figure 5), then dropped to 8 cases by week 6. This culminated in a spike in the number of cases which peaked at 18 cases between weeks 7-8. However, from weeks 12-17 the FMA&RD, commenced the second trench of distribution of containment equipment's to support states while building capacities of Federal and State Epidemiology officers. There were no reported cases of AI from week 19-51 of 2016. However, by week 52 of 2016, during a targeted surveillance an influenza A strain H5N8 was isolated from a pool of backyard poultry in Kano State Nigeria. This was the first time HPAI H5N8 would be reported in Nigeria since 2006.

Similarly, in 2017, the 3rd wave of AI was reported between week 2-3, which rose from one and picked at six cases by week 8 (Figure 6), then a slight decrease to about four cases by week 10, with a dip of one case by week 11. There were three spikes with 2-3 AI cases between week 13-19 of 2016, which dipped to one case by week 24, no new cases were reported until weeks 42-43 of 2017. The epidemiologic pattern of the 2015-2017 outbreak of AI in Nigeria was a propagated epidemic. Furthermore, the epidemiologic cycle of confirmed AI cases during these periods was more than one incubation period (maximum of 21 days) for avian influenza. Outbreak waned following distribution of AI containment equipment´s to support States between epidemic weeks 17-45 of 2015 and epidemic weeks 14-52 of 2016. We determine the epidemic threshold of avian influenza for the months of October from previous confirmed AI

cases between 2015-2017 (Table 2) based on cumulative sum statistic (CUSUM) of seven past epidemiological months before the month of October 2015-2017, the epidemic threshold was (20, 12 and 5) respectively.

Discussion

The hotspots for avian influenza outbreaks in Nigeria from 2015-2017 were clustered in six states and five geopolitical zones: North-west (Kano), North-central (Plateau, Abuja), Northeast (Bauchi), South-west (Oyo), and South-south (Rivers) State. Although the south-western states of Nigeria were often considered as its major poultry hub, the region accounted for 4.5% of disease burden, south-east 0.7%, Northcentral, Northeast and Northwest accounted for 94.8% losses within the period under review. Poultry business in Nigeria is such that there is a bi-directional movement of day-old chicks from the South to the North of Nigeria, while poultry raw material (maize, wheat, jute bags) are transported to the Southern States of Nigeria from the North [18]. These poultry trades may be epidemiologically linked to the outbreaks in the North/South-East and South-South region of Nigeria. Ineffective quarantine services, poor biosecurity measures by farming units during production, transport of poultry and its products, ensures that microbes follow trades routes to contiguous farms/LBMs, where they may be responsible for disease outbreaks. The first confirmed case of avian influenza in 2015 was reported in Lagos State, within the first epidemiological week, Kano State and Plateau State reported sporadic outbreaks by the 4th epidemiological week. The maximum incubation period of AI was 21 days it is plausible that sales of apparently healthy chickens transported from the South-west of Nigeria to the North may have played a role in the outbreak in Kano State. More so, Kano and Plateau State are the main distribution hub for poultry to the north-east and the Northwestern States of Nigeria, this may have contributed to the spread of AI to the contiguous Northern States. Similarly, the first confirmed cases of AI influenza in the Southern Nigeria; south-south (Edo State) and south-east (Anambra State) occurred in the 2nd and 14th epidemic weeks of 2015 respectively, the spread of infections from Lagos to Edo, and then Anambra State was plausible because outbreaks occurred 2 weeks, and 11 weeks apart. Avian influenza viruses are enzootic in the poultry subsector of Nigeria [10,14,19], the LBMs, free-range poultry system are foci for genetic reassortment of circulating influenza strain [4,10,19]. Sero-surveillance studies conducted in 18 LBMs across Nigeria in 2019 showed that 3 subtypes of AIVs (two homologous (H5N8, H5N6) and one heterologous (H9N2) strain are co-circulating within LBMs in Nigeria [11,14].

Avian influenza H9N2 was first identified in China in 1998, since then sporadic outbreak has been reported with more than 40 human cases between 1999-2012, at present human to human infection has not been documented [20], however, epidemiological and virological evidence has shown that H9N2 isolates from man had an avian origin [21]. H5N6 was first reported in Asia in 2013 and Africa (Nigeria) in 2019, this isolate belongs to the same genetic clade 2.3.4.4b with the 2017-18, European strain of H5N6, introduced into the African continent by migratory birds [19]. Thus, the isolation of AIV H5N8 in a pool of ducks at the LBM in Kano State in the 3rd quarter of 2016, may have occurred through independent introduction into the poultry subsector by mixing of local poultry with captured migratory birds at the LBMs [4,6], or reassortment of viral proteins between circulating influenza strains in wild and domestic poultry. It´s instructive to note that HPAI, H5N8 was responsible for the outbreak in Asia in 2007, United Kingdom, Canada in 2014 [22]. Studies have also shown that AI H5N8 spread to Africa was through the Afro-Eurasia flyways [23]. Furthermore, the 2014-2015 outbreak of HPAIV involving a different strain of H5N8 was shown to have spread during the seasonal migration of aquatic Palearctic dabbling ducks [24]. The epidemic pattern of 2015-2017 was a propagated epidemic; this may be instructive of the spread of infections between, and within farms,

LBMs and contiguous states, through the vehicular movement of apparently healthy flocks. However, flock to flock transmission within farms and LBM was the likely means of spread of diseases in farms.

The trade-in poultry and poultry products between Southern and Northern states in Nigeria may have played a role in the AI resurgence of 2015. However, Chieloka *et al.* [4] opined that the outbreak in the North (East, West, Central) of Nigeria may have occurred by independent introduction of HPAIV by migratory wild birds. He posited that the reduced inflow of water downstream to the Kano river which supplies the *Jama´are*river, a major tributary to the Yobe river and the Hadejia-Nguru Wetlands with an estimated migratory bird population of over 400,000 [4], due to the closure of the Tiga Dam in Kano State during farming seasons may encourage upstream migration of birds towards flood plains and irrigated wetland, rice paddies to feed, breed [4], consequently, migratory birds may come in contact with local poultry flocks, naïve to influenza viruses harboured by these wild reservoirs. These migratory patterns make them easy game for hunters who capture them and sell to middlemen at the live bird markets (LBMs). Subsequent mixing of these wild games with other poultry flocks at the LBMs may lead to an outbreak of AI, vis-a-vis the emergence of reassortant influenza strains with its attendant zoonotic risks. The reduction in the number of AI cases reported between epidemic weeks 17-45 of 2015 and epidemic weeks 14-52 of 2016 following distribution of containment, control equipment´s to support states may be indicative that early intervention in the control of the outbreaks by epidemiological units across Nigeria may have steamed the tides of AI and reduce the burden of losses. Consequently, continued dependence on the Federal government by states before implementation of major disease control strategies may be inimical to the control of future panzootic. The epidemic threshold of AI outbreak from 2015-2017 was (20, 12, and 5) respectively. The epidemic threshold was exceeded in weeks 4-5 of 2015, 3-4 of 2016 and 7-9 of 2017. Effective implementation of AI control strategies before these periods may have reduced the burden of losses due to the outbreak of AI in Nigeria between 2015-2017.

Conclusion

The 2015-17 outbreaks of AI in Nigeria were clustered in five geopolitical zones, across six states. North-central and North-western states of Nigeria accounted for the highest-burden of AI. The LBMs in Nigeria are unstructured with no clear separation of poultry businesses from other market activities as such mixing of different poultry species are rife. As a result, the LBMs have continued to play a major role in the outbreaks of AI vis-a-vis the emergence of reassortants influenza strains. The index case for the outbreak of AI in Nigeria, between 2015-17 was reported in Eti-osa LGA of Lagos State Nigeria. This outbreak may be epidemiologically linked to the resurgence of AI in the Northwest and Northcentral states of Nigeria through trade in poultry and poultry products with Kano, and Plateau States. The epidemic pattern of the 2015-17 outbreak in Nigeria was a propagated epidemic, instructive of flock-to-flock transmission within farming units and spread of infection between states and contiguous LGAs may be through vehicular transport of apparently healthy flocks. Delayed outbreak responses, sole dependence of states on the Federal government of Nigeria on AI control, containment equipment's, and inadequate manpower in some states of the federation was the bane of the effective control of the outbreak of HPAI in Nigeria between 2015-2017. We recommend routine sero-surveillance of farms, LBMs, migratory wild birds across the federation to determine circulating strains of avian influenza. Maintenance and enforcement of biosecurity measures, structures on the farms should be made a prerequisite before permission is given to farmers to establish poultry farms in Nigeria. The state government should construct a dedicated LBMs within the state to separate poultry businesses from other market activities. These should be complemented with the

reactivation of the control post, agricultural quarantine services, across the country, with a renewed vigour to enforce biosecurity and biosafety measures in the trade of poultry and poultry products across the country.

What is known about this topic

- *Avian influenza was first reported in Nigeria in 2006;*
- *Resurgence of avian influenza occurred in 2015;*
- *Avian influenza H5N1 was responsible for the 2006 outbreak.*

What this study adds

- *The hotspot for AI in Nigeria between 2015-17 is clustered within 5 geopolitical zones, in six states;*
- *Three subtypes of AIVs, (two homologous (H5N8, H5N6), and one heterologous (H9N2) strain are co-circulating within LBMs in Nigeria;*
- *The epidemic threshold for the 2015-2017 AI outbreak was exceeded in weeks 4-5 of 2015, 3-4 of 2016 and 7-9 of 2017.*

Competing interests

The author declares no competing interests.

Authors' contributions

Dr Okoli S.C wrote this manuscript. The author have read and agreed to the final manuscript.

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Tables and figures

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Table 2: epidemic threshold of AI October between 2015-2017

Figure 1: map of Nigeria showing hotspot of avian influenza in 2015

Figure 2: map of Nigeria showing hotspot of avian influenza in 2016

Figure 3: map of Nigeria showing hotspot of avian influenza in 2017

Figure 4: epidemic curve of confirmed cases of AI in Nigeria in 2015

Figure 5: epidemic curve of confirmed cases of AI in Nigeria in 2016

Figure 6: epidemic curve of confirmed cases of AI in Nigeria in 2017

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Table 1: distribution of the burden of avian influenza outbreak in Nigeria from 2015-2017

STATES	LGAs with AI 2015	No of cases 2015	No of poultry affected 2015	LGAs with AI 2016	No of cases 2016	No of poultry affected 2016	LGAs with AI 2017	No of cases 2017	No of poultry affected 2017
Kano	21	187	640,822	8	99	456727	0	1	53,000
Lagos	9	27	88,289	1	3	5885	0	0	165
Ogun	5	7	83441	0	0	0	1	1	10000
Rivers	3	43	103149	0	7	18619	0	0	0
Delta	6	8	10710	0	3	344927	2	0	0
Plateau	2	148	456204	2	66	205381	1	22	71,568
Edo	3	3	11360	3	8	25800	0	0	0
Gombe	2	2	8120	0	0	0	0	0	0
Imo	1	1	10000	0	0	0	0	0	0
Oyo	4	7	27603	0	1	1647	0	8	0
Jigawa	4	4	6580	2	2	21265	0	0	13,160
Kaduna	4	23	58311	3	13	603274	0	3	185,368
Bauchi	5	25	89784	0	6	81625	0	11	46,134
Zamfara	2	3	22587	1	3	29699	0	0	47,060
Katsina	4	12	123995	3	5	61003	0	1	3,198
Sokoto	4	4	8000	0	1	6000	0	0	0
Anambra	2	3	10,750	0	0	0	0	0	0
Nasarawa	1	2	12,500	1	3	138197	0	1	3,200
Enugu	1	1	2,493	2	3	125000	0	0	0
Abia	2	2	6,569	1	0	0	1	0	0
Abuja	1	0	0	2	16	295967	0	1	130,000
Bayelsa	1	1	22,800	0	1	3000	0	0	0
Ebonyi	0	0	0	0	3	3355	2	0	3,355
Adamawa	0	0	0	0	3	28900	4	1	200
Kebbi	0	0	0	0	1	1500	1	0	0
Benue	0	0	0	0	1	350	1	0	350
Total	87	513	1,804,067	27	248	2,458,121	13	50	566,758

Table 2: epidemic threshold of AI October between 2015-2017			
Epidemic months	**Confirmed AI cases 2015**	**Confirmed AI cases 2016**	**Confirmed AI cases 2017**
January	42	28	9
February	60	30	15
March	40	12	5
April	17	5	4
May	7	0	3
June	10	4	2
July	12	5	0
August	8	0	0
September	7	0	0
October	6	7	1
November	8	0	0
December	4	0	0
Mean(α) Standard deviation(δ)	27	12	5.4
EPT= α+3(δ) of 7 past Surveillance point	20	12	5.0

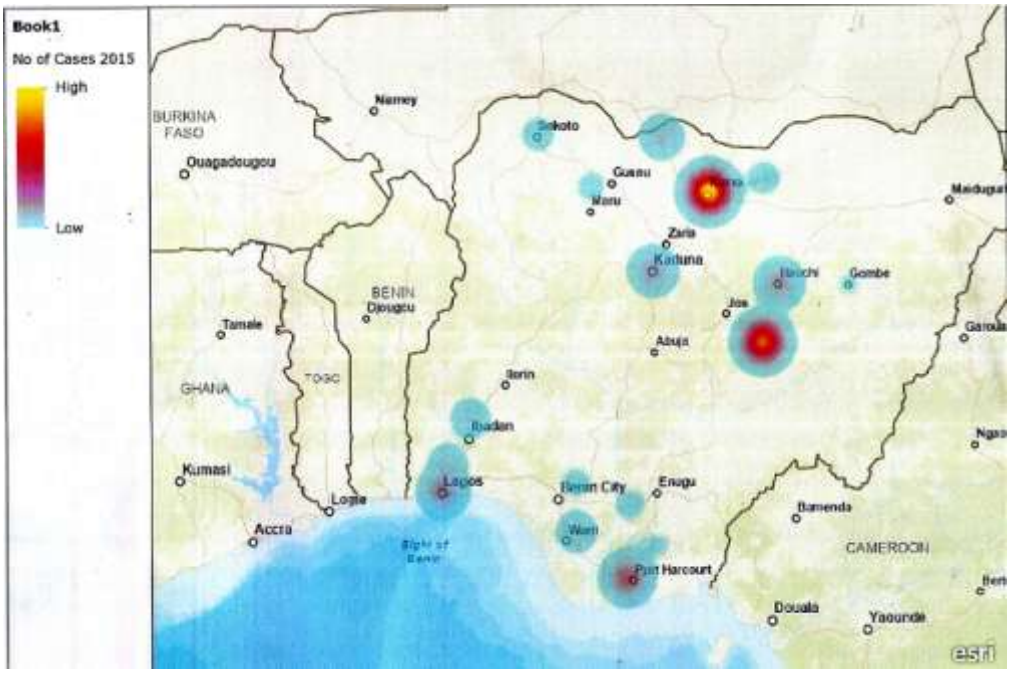

Figure 1: map of Nigeria showing hotspot of avian influenza in 2015

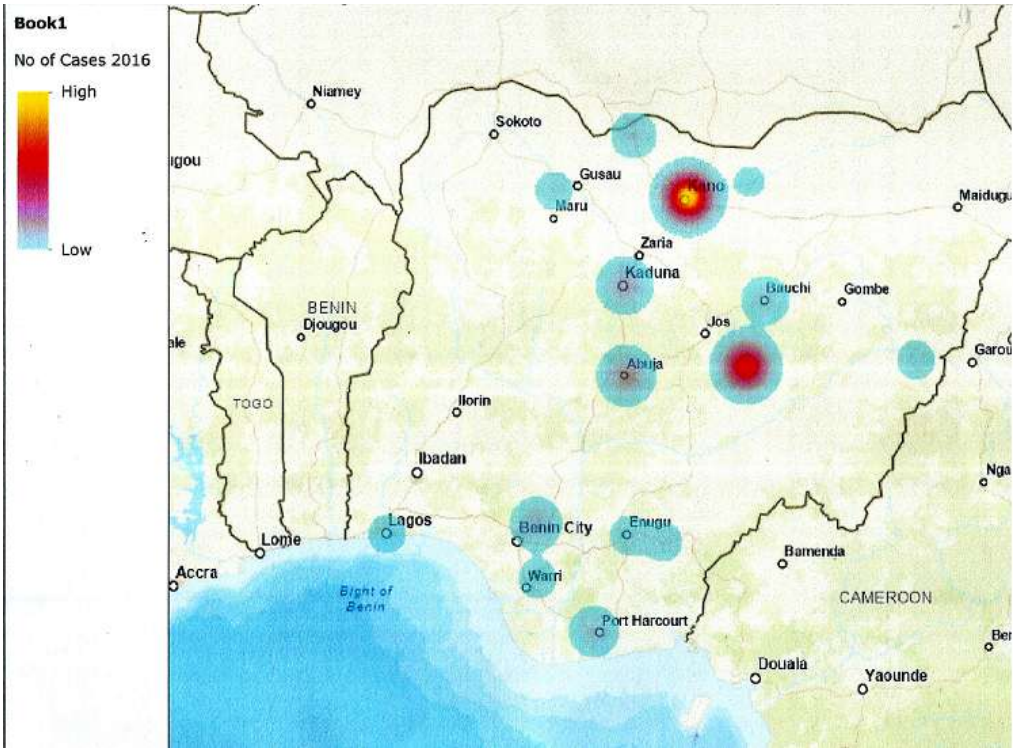

Figure 2: map of Nigeria showing hotspot of avian influenza in 2016

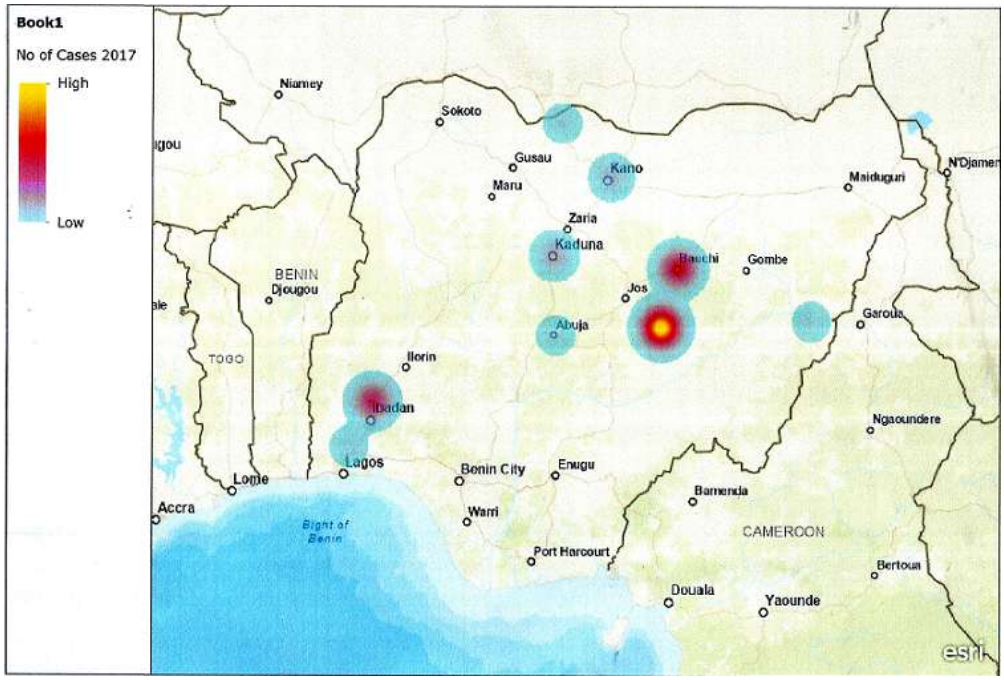

Figure 3: map of Nigeria showing hotspot of avian influenza in 2017

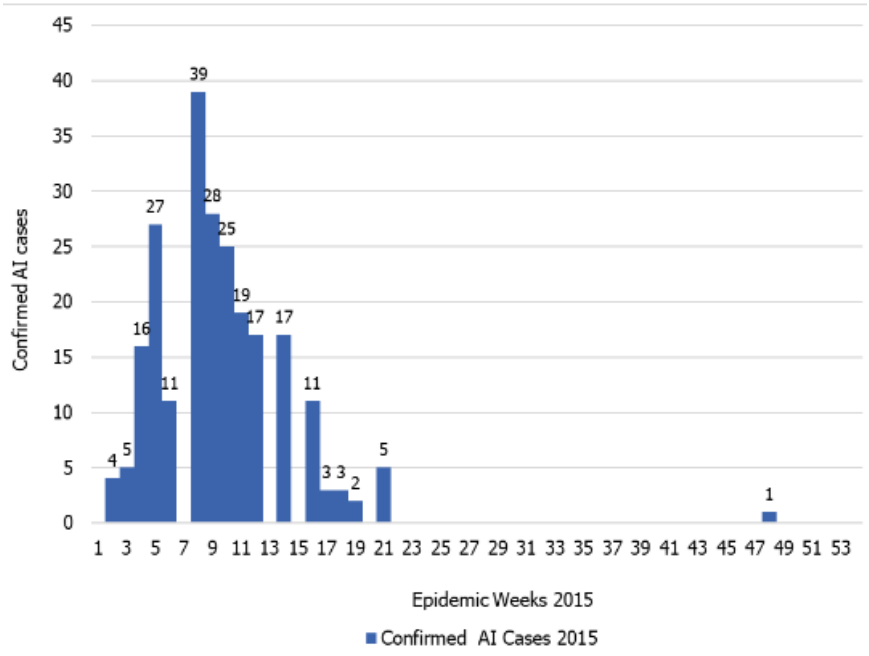

Figure 4: epidemic curve of confirmed cases of AI in Nigeria in 2015

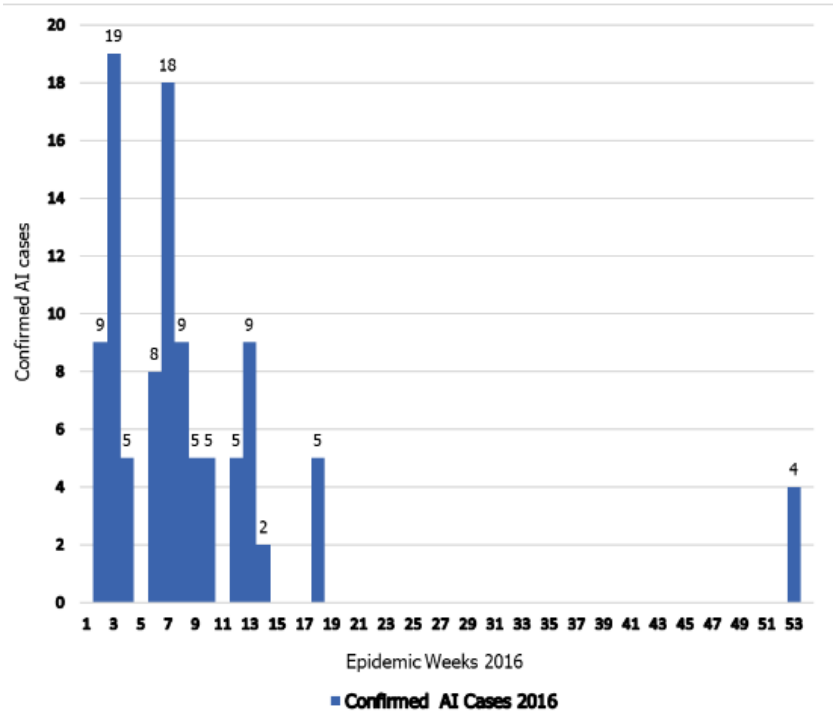

Figure 5: epidemic curve of confirmed cases of AI in Nigeria in 2016

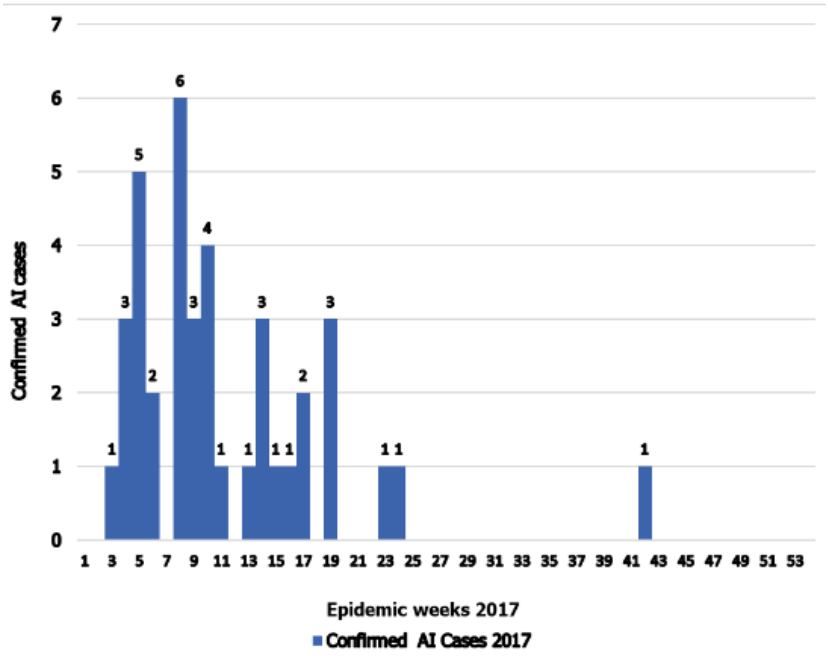

Figure 6: epidemic curve of confirmed cases of AI in Nigeria in 2017