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# A retrospective study and predictive modelling of Newcastle Disease trends among rural poultry of eastern Zambia

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ABSTRACT

Newcastle Disease (ND) is a highly infectious disease of poultry that seriously impacts on food security and livelihoods of livestock farmers and communities in tropical regions of the world. ND is a constant problem in the eastern province of Zambia which has more than 740 000 rural poultry. Very few studies give a situational analysis of the disease that can be used for disease control planning in the region. With this background in mind, a retrospective epidemiological study was conducted using Newcastle Disease data submitted to the eastern province headquarters for the period from 1989 to 2014. The study found that Newcastle Disease cases in eastern Zambia followed a seasonal and cyclic pattern with peaks in the hot dry season (Overall Seasonal Index 1.1) as well as cycles every three years with an estimated provincial incidence range of 0.16 to 1.7% per year. Annual trends were compared with major intervention policies implemented by the Zambian government, which often received donor support from the international community during the study period. Aid delivered through government programmes appeared to have no major impact on ND trends between 1989 and 2014 and reasons for this are discussed. There were apparent spatial shifts in districts with outbreaks over time which could be as a result of veterinary interventions chasing outbreaks rather than implementing uniform control. Data was also fitted to a predictive time series model for ND which could be used to plan for future ND control. Time series modelling showed an increasing trend in ND annual incidence over 25 years if existing interventions continue. A different approach to controlling the disease is needed if this trend is to be halted. Conversely, the positive trend may be a function of improved reporting by farmers as a result of more awareness of the disease.



## 1. Introduction

Poultry provides an important protein and revenue source for communities in tropical regions of the world. Most rural households in Africa own some scavenging chickens or other domesticated wild birds such as guinea fowl (Nwanta et al., 2008b). Since rural households traditionally find it difficult to trade off their cattle and other larger livestock, chickens and other domestic birds (guinea fowl, ducks, and pigeons) act as a quick source of income for their daily needs, like school requirements for their children (Songolo and Katongo, 2000; Alders et al., 2009). Furthermore, domestic birds act as the most reliable and affordable source of protein for these communities (Songolo and Katongo, 2000; Alders et al., 2009; Copland and Alders, 2009). Because poultry in these areas are left to scavenge freely within and between villages (Otim et al., 2007), poultry diseases like Newcastle Disease (ND) pose a significant challenge to this sector. ND outbreaks mostly go unnoticed but in extreme cases can wipe out all flocks of rural poultry. Consequently, this impacts significantly on food security and the general welfare of households (Harrison and Alders, 2010).

ND is caused by Newcastle disease virus (NDV), a member of the genus *Avulavirus* from the family *Paramyxoviridae* (Alexander and Senne, 2008; Diel et al., 2012). Chickens are highly susceptible to virulent NDV, that is notifiable to the World Animal Health Organization (Dortmans et al., 2012). The incubation period varies with

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the strain of virus, and is generally 4–5 days (range 2–15 days). The disease is characterised by neurological symptoms (e.g. tremors, tonic/clonic spasms, wing/leg paresis or paralysis, torticollis, and aberrant circling behaviour), weak limbs, cyanosis of the wattle and comb, nasal and eye discharges, greenish diarrhoea, weight loss, loss of egg production and high mortalities (Cattoli et al., 2010; Rakibul Hasan et al., 2010; OIE, 2012). At post-mortem, the characteristic lesions may include haemorrhages in the trachea, brain and spleen. Petechial haemorrhages coupled with ulcers that have raised borders on the mucosa of the proventriculus, caecal tonsils and inflamed lungs are also consistent with the disease (Kahn, 2005; OIE, 2012). Since most of the signs and lesions described above are not pathognomonic for ND, differential diagnosis in the absence of laboratory confirmation should be considered.

The faecal-oral route has been described as the main mode of transmission for ND (Nwanta et al., 2008b). Indigenous chicken breeds are thought to be more resistant to ND than commercial broilers and layers (Alders et al., 2009). Young birds are more susceptible than older ones (Alexander, 2000) and vaccination prevents clinical disease. However, when immunized birds are infected with virulent NDV, they are still able to transmit the disease to other susceptible birds despite their failure to succumb to clinical ND (Nwanta et al., 2008b; Miller et al., 2009; Dortmans et al., 2012) This may complicate the epidemiology of the disease in rural flocks where there may be a mixture of vaccinated and unvaccinated flocks that frequently mix through free movements.

Conventional vaccination in commercial chickens is effective but the use of these vaccines in local village systems is limited by cost, dose format and lack of thermostability. As a result, rural scavenging chickens are rarely vaccinated, and flocks remain highly susceptible to ND with periodic outbreaks that almost completely destroy the flock (Adene, 1997; Nwanta et al., 2008a).

Zambia's Eastern Province is a typical tropical habitat where rural poultry is common. It has three seasons comprised of the rainy season (December to April), which is characterised by high humidity and high rainfall exceeding 800 mm and temperatures averaging 20 °C. The cool dry season (May to August) has a low humidity and temperatures averaging around 16 °C, and temperatures in the hot dry season (September to November) are as high as 45 °C (Our-Africa, 2015). Unfortunately, the region is challenged by ND on an almost annual basis despite attempts to control the disease through several development plans by the Government of Zambia (GRZ) (Government-of-Zambia, 1989, 2006, 2011).

Few studies that analyse the endemic status of ND in tropical regions of the world and in particular southern and central Africa have been conducted. Analysing the trends of the disease in eastern Zambia by utilising historic disease reports would help understand the cyclic nature of the disease in tropical environments within village poultry populations. It would also assist in evaluating disease control policies in controlling the disease in the region over a period of time.

With the above background in mind a retrospective epidemiological study of ND disease reports submitted to the Provincial Veterinary Office of the Eastern Province of Zambia between 1988 and 2014 was conducted. Information from this study was then used to develop a predictive model of ND annual incidence for the province in the next 25 years.

## 2. Materials and methods

### 2.1. Study design

The rural chicken population in the eastern province of Zambia was used as the population at risk. Morbidity/mortality annual and monthly reports of ND submitted to the Provincial Veterinary office by district state veterinarians in the period between 1989 and 2014 was used as the data base for the epidemiological study. Part of this data was stored in Damasyl® – a livestock disease data storage programme used from 1999 to 2005.

Demarcation of veterinary districts changed on three occasions as a result of changes in political delineation of the eastern province of Zambia. From 1989 to 2005, rural chicken disease data was collected from five veterinary districts (Fig. 4; Chadiza, Chipata, Lundazi, Katete and Petauke). Later in the period from 2006 to 2010 data came from eight veterinary districts (Fig. 5; Chadiza, Chipata, Lundazi, Katete, Petauke, Mambwe, Nyimba and Chama). Finally, from 2011 to date Chama district was excluded from the province, and the province was further demarcated into 9 districts (Fig. 6; Chadiza, Chipata, Lundazi, Katete, Petauke, Mambwe, Sinda, Nyimba and Vubwi districts). Consequently, data collection and analysis for this study followed a similar pattern.

The first step involved collection of demographic data that would be vital for estimations of incidence, mortality rates and case fatality rates as well as indicating the growth or decline of the chicken population over the period 1989–2014. Spatial patterns were determined by categorizing the province into districts and temporal patterns were determined according to the year and month for the period of study.

Missing provincial chicken disease data from 1995 to 1998 posed a challenge for analysing trends during the study period. Therefore, in order to reduce bias during interpretation of results, most analysis conducted was restricted to the period from 1999 to 2014. However, annual trends were presented and described from 1989 to 2014. This was done in order to highlight the aspect of missing data as a weakness that might exist in institutions with passive disease surveillance systems.

### 2.2. Study procedures

#### 2.2.1. Seasonal and annual ND trends

Annual and monthly records of ND in rural chickens from 1989 to 2014 (available up to district level) were obtained from the provincial veterinary office. This was followed by collection of census data from the 2002 and 2006 livestock census as well as from the rural chicken census data extracted from stock registers of 2014, which were segregated up to district level. In cases where data were missing at the provincial office, a follow-up to the district veterinary offices was done to obtain this data. Maps with Geographical Information System overlays were collected from the provincial office and used to conduct spatial analysis using Epi Map®.

Population models were developed using baseline population data obtained from previous census activities for chickens for 2002, 2006 and information from stock registers for 2014. This involved use of the principle of exponential growth and decay (Bernstein, 2003) and was required for the estimation of population size in years where census data were not available.

Population models for each district and the entire province were developed by calculating the village chicken population growth rates in two blocks-2002 to 2006 and, 2006 to 2014 using Eq. (1).

$$\mathrm{PGR} = \left(X_t/X_0\right)\frac{\hat{1}}{t} - 1 \quad (1)$$

where $X_t$ was the population after a number of years (t) and $X_0$ was the initial population.

An exponential model with four time blocks (A–D) was considered because of gaps in available census data (Table 1 and Fig. 1). Population growth in the four blocks were modelled as follows:

*2.2.1.1. Period A 1999–2002.* Respective growth rates for the period 2002–2006 were used for extrapolating populations for Chadiza, Lundazi and Katete while the provincial growth rate was used for